# Displacement of Perceived Vanishing Point in a Corridor Scene

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**ABSTRACT**
The purpose of this study is to investigate the perception of vanishing points in 3-D space. In the first experiment, participants observed a corridor scene in a real space, where seemed a kind of one-point perspective. They judged perceived positions of vanishing point formed by 4 pairs of parallel lines and angles of boundary lines of walls. As a result, we found that the perceived vanishing points were observed at different location from the vanishing point of perspective images. Furthermore, the mechanism of perceived vanishing points might be different from that of angle perception of parallel lines in 3-D space. In the second experiment, we investigated the relationship between distance of a front wall in the scene and perceived vanishing points. Results seem that the mechanism of perceived vanishing point depends on the personal, and it may be divided into three types.

**Keywords**
Perspective image, vanishing points, visual impression, optical illusion

## INTRODUCTION

In recent years, some of computer generated images (CGI) are almost indistinguishable from photographs or live action videos, however, there are too many gaps between the CGIs and real scenes. One of the reasons is that there are differences between the geometric perception by the human vision system and perspective images. Computer graphics and images taken by a video camera are drawn by the perspective projection. Perspective images are represented based on basic optical theories, but our perceived scene isn't equal with those perspective images. Many researchers have reported differences between the impression on photographs and that formed at these real scenes [1-3]. Several researchers have proposed drawing methods to simulate our geometric perception [4, 5]. Our research group also ~~has~~ reported about perceived size [6]. They suggested that a function created from the result of psychological experiments was useful for representation of perceived size in images. In the research, they proposed a logistic function to predict the perceived size of objects in a scene. The size or distance of objects in images was determined using the function. As a result, the observers filled images generated by using the function with more reality than perspective images. This research had led to a development of image rendering technology for computer graphics [7].

On the other hand, in perspective projection, parallel lines in 3-D space converge at a point in the image, which is called as the vanishing point. Hokusai Katsushika who was a famous *ukiyoe* artist in *Edo* period described a drawing technique, *Mitsuwari no Hou*, in his book, and he taught how to control the vanishing points for landscapes drawing in *ukiyoe* prints [8]. Figure 1 shows this technique. We thought that changing the positions of vanishing points in images through our perception might be a key method for representation of perceived scene on CGIs. In this study, our purpose is to investigate the perception of vanishing points in a corridor scene. At first, we investigated the differences between perceived vanishing points and perceived angles of parallel lines in the real corridor scene. Second, we investigated the relationship between distance of a front wall in the scene and perceived vanishing points by using 3-D computer graphics and LCD shutter glasses.

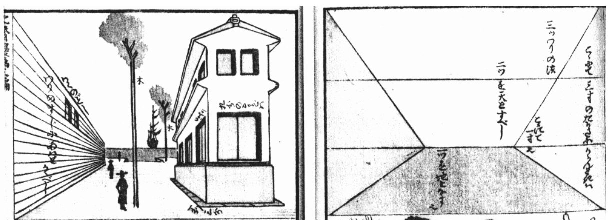


**Figure 1. Description of *Mitsuwari no Hou* by Hokusai Katsushika. The scene is similar to one-point perspective image, but there are two vanishing points [8].**

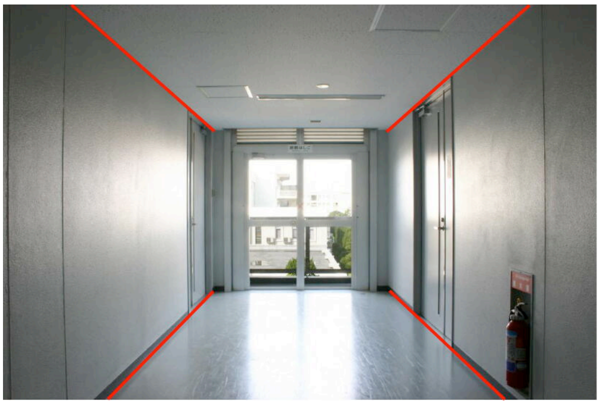
## EXPERIMENT 1 : PERCEPTION OF VANISHING POINTS AND ANGLES OF PALLAREL LINES IN A REAL SPACE

### Experimental method

*Stimulus*

We investigated perceived vanishing points when viewing a real corridor scene (Figure 1). We selected the location with four parallel lines, where seemed a kind of one-point perspective. This experiment was conducted at 6.8m away from the edge of the corridor. The level of observer's eyes was 1.2m above the floor.

We provided two conditions at the location. The first is close-door condition. Figure 2 (a) shows the scene of this condition. The second is open-door condition. Figure 2 (b) shows the scene of this condition. Participants could see out of the door clearly.



(a) Close-door condition.

(b) Open-door condition.

**Figure 2. The photograph of the real scene used in Experiments 1. 4 boundaries (red lines) as parallel lines in 3-D space cross a vanishing point in the photograph (perspective image). Participants focused each pair of parallel lines in this scene, and estimated location of each vanishing point, and angle of each boundary line.**

*Procedure*

We paid our attention to 4 perceived vanishing points created by combination of 4 boundaries; the boundaries of left wall and ceiling, left wall and floor, right wall and ceiling, right wall and floor. Participants focused on each pair of the boundaries, and estimated location of each vanishing point by two ways; 1) drawing directly his/her perceived vanishing point in an answer sheet, 2) drawing perceived angles of focused two boundaries in an answer sheet. The answer sheet was drawn a rectangle of 14.8 by 21cm, that was the aspect ratio of the front wall of the corridor.

*Participants*

In the closed-door condition, 10 students took part in this experiment as observers (aged 20-23 years). Each participant had normal or corrected-to-normal vision.

In the open-door condition, 10 undergraduate and graduate students took part in this experiment as observers (aged 19-21 years). Each participant had normal or corrected-to-normal vision.

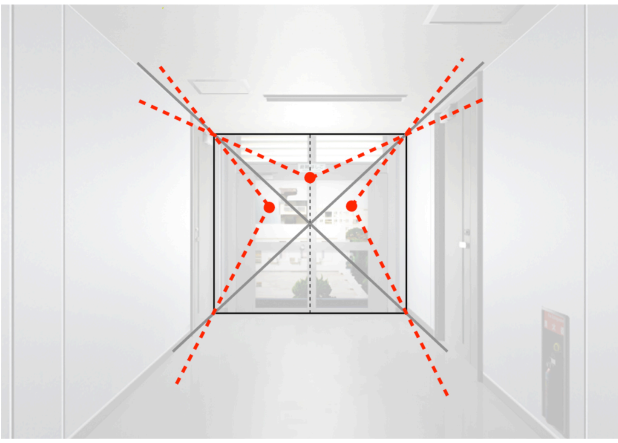
**Results and Discussion**

We measured displacements of the vanishing points. Figure 3 illustrates the mean value of the experimental results. Figure 3(a) shows mean locations of perceived vanishing points in the close-door condition. Figure 3 (b) shows mean perceived angles of boundaries between wall and wall. Figure 3 (c) (d) show comparisons between the results in the close-door condition and that in the open-door condition. The mean of perceived vanishing point when viewing the ceiling shifted up to 2.46 degree in visual angle from the vanishing point in the perspective image (the correct vanishing point). The mean of perceived vanishing point when viewing the floor shifted down to 0.53 degree. The mean of perceived vanishing point when viewing the right wall shifted up to 1.17 degree, and shifted to 2.23 degree right. The mean of perceived vanishing point when viewing the left wall shifted up to 1.07 degree, and shifted to 2.21 degree left. The mean of perceived angles of boundaries between the floor and the both wall were tilted 6.72 and 6.90 degree to the inside of the floor. The mean of perceived angles of boundaries between the ceiling and the both wall were tilted 21.66 and 21.74 degree to the inside of the floor.

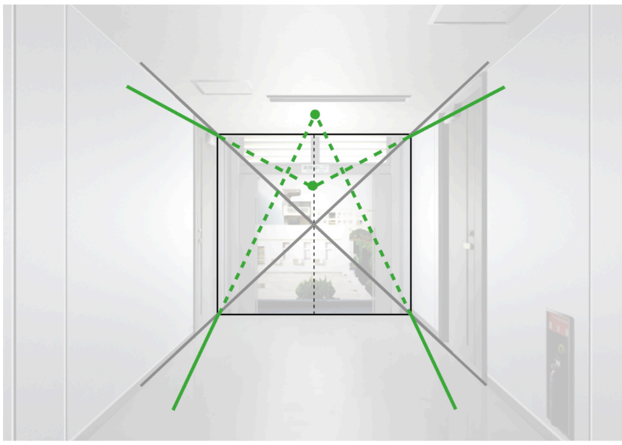
An analysis by using the 95% confidence limit revealed the following; 1) the perceived vanishing points in the ceiling, the right wall, and the left wall were differed from the correct point, 2) when viewing the floor, the perceived angles of the both boundaries between the floor and the both walls were tilted to the inside of the floor (figure 3(d)), 3) when viewing the ceiling the perceived angles of boundaries between the ceiling and the both walls were tilted to the inside of each wall. These results show that the perceived vanishing points and the perceived angles of boundaries in the real space are different from those in the perspective image.

Figure 3 (c) (d) show comparisons between the results in the close-door condition and that in the open-door condition. The followings are the results in the open-door condition. The mean of perceived vanishing point when viewing the ceiling shifted up to 1.65 degree in visual angle from the vanishing point in the perspective image. The mean of perceived vanishing point when viewing the floor shifted down to 0.66 degree. The mean of perceived vanishing point when viewing the right wall shifted up to 0.49 degree, and shifted to 1.60 degree right. The mean of perceived vanishing point when viewing the left wall shifted up to 0.30 degree, and shifted to 20.6 degree left. The mean of perceived angles of boundaries between the floor and the both wall were tilted 21.66 and 21.74 degree to the inside of the floor. The mean of perceived angles of boundaries between the ceiling and the both wall were tilted 0.30 and 0.60 degree to the inside of the floor.

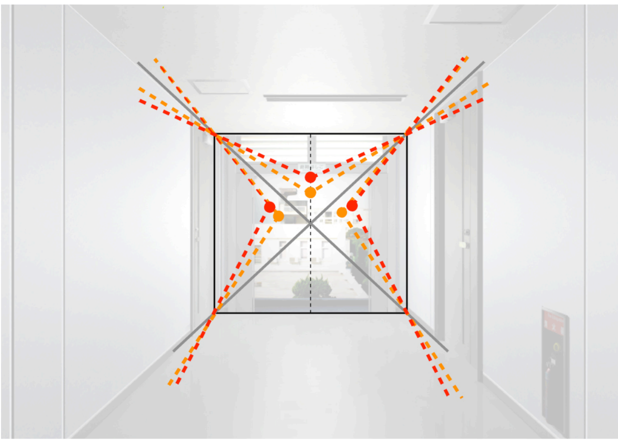
A *t*-test confirmed that the perceived vanishing point of the ceiling in the open-door condition was significantly different from that in the close-door condition [$t(18)=2.48$, $p<.05$]. Horizontal position of the perceived vanishing points of the right and left walls in the open-door condition were significantly different from those in the close-door condition [left wall: $t(18)=1.996$, $p<.10$, right wall: $t(18)=2.136$, $p<.05$]. When the door of the front wall was opened, the



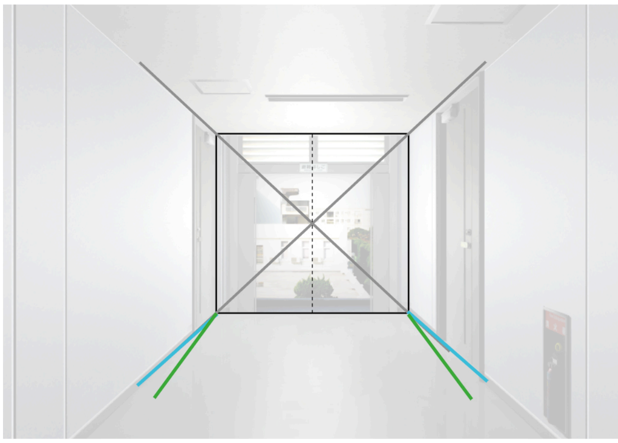
**(a) Mean locations of perceived vanishing points in the closed-door condition. The center dot: when viewing the ceiling, the left dot: when viewing the left wall, the right dot: when viewing the right wall. Dotted lines are boundaries that are inferred from those points.**



**(b) Mean angles of perceived boundaries in the closed-door condition. The upper lines: when viewing the ceiling, the lower lines: when viewing the floor. Dots are vanishing points that are inferred from those lines.**



**(c) Comparison of mean locations in perceived vanishing points between two conditions. Red dots: the closed-door condition, orange dots: the open-door condition.**



**(d) Comparison of mean angles in perceived boundaries between two conditions. Green lines: the closed-door condition, blue lines: the open-door condition.**

**Figure 3. Results of Experiment 1. 4 boundary lines of walls (parallel lines in 3-D space) cross at the vanishing point in perspective image (gray lines). There are significant differences among the above results.**

perceived vanishing points tended to close the correct position. The perceived angles of the lower boundaries in right and left walls in the open-door condition were significantly different from these in the close-door condition [left: $t(18)=3.223$, $p<.01$, right: $t(18)=3.117$, $p<.01$].

Above results show that the perceived vanishing points were influenced by open or close of the front door. In addition, it seems that the mechanism of perceived vanishing point is not based on an angle visual illusion in perspective scenes [9], because the vanishing points expected from the perceived angles of boundaries were different from the perceived vanishing point answered directly.

## EXPERIMENT 2: PERCEPTION OF VANISHING POINTS WHEN VARYING A DISTANCE FROM AN OBSERVATION POINT

### Experimental method

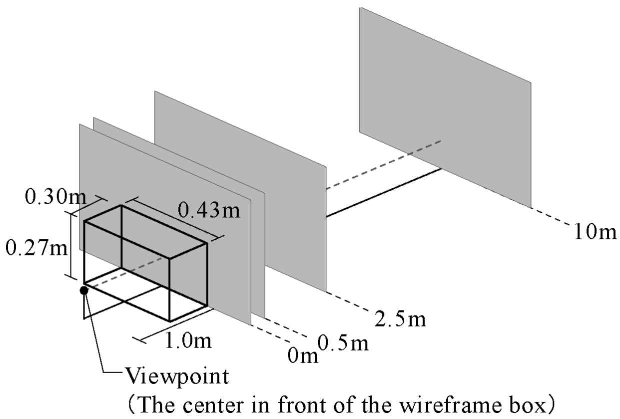
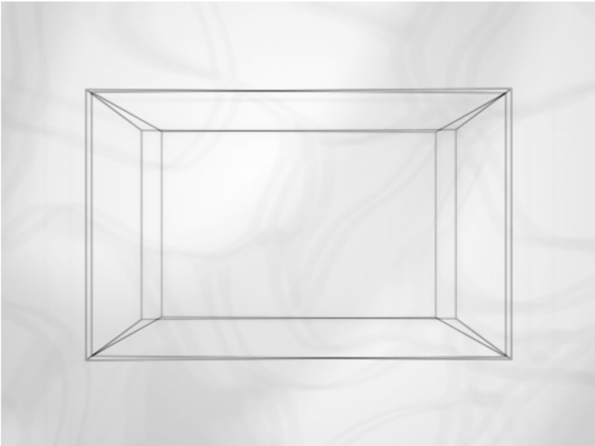
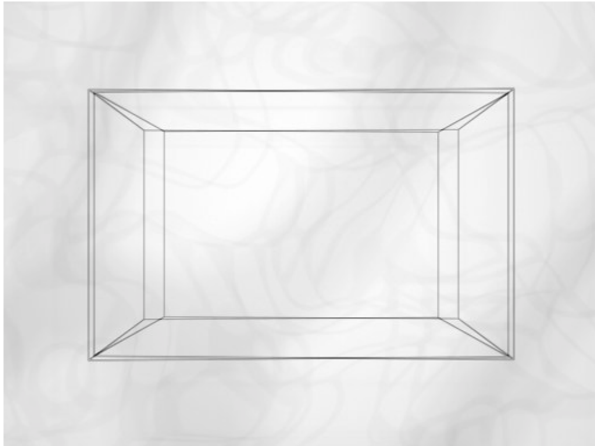


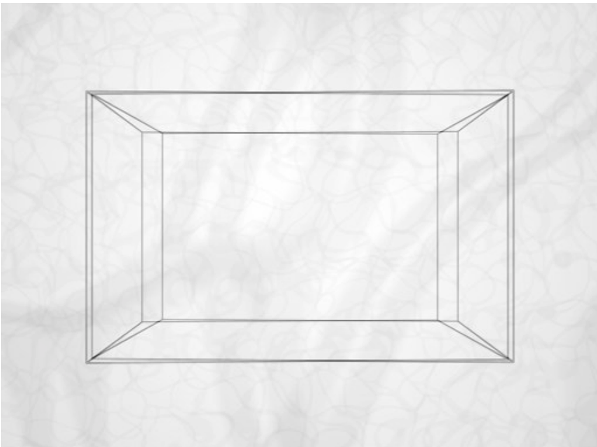

**Figure 4. CG setting for rendering stereo images.**



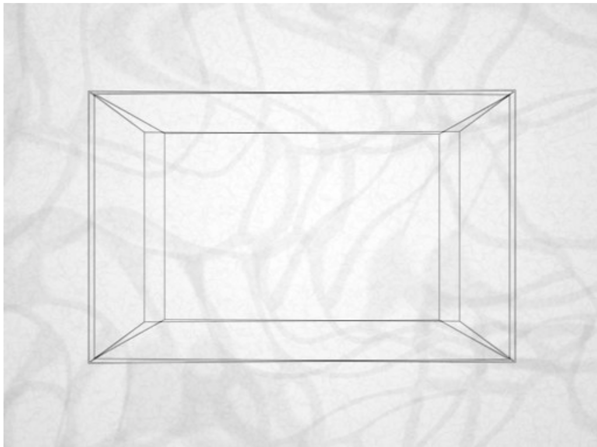
**(a) 0m distance.**



**(b) 0.5m distance.**



**(c) 2.5m distance.**



**(d) 10m distance.**

**Figure 5. Stereoscopic images for Experiment 2. 4 distances of the front wall (a)-(d) were presented by parallax. The distance of the wall is measured from the far rectangle in the wireframe box. When presenting the stimuli, an area of two thirds in the image was presented for avoiding easy estimation of the correct vanishing point.**

*Stimulus*

The results of Experiment 1 lead an assumption that the farther the front wall is located, the closer perceived vanishing points are estimated to the correct vanishing point. Thus we conducted Experiment 2 using 3-D computer graphics and LCD shutter glasses, and created stereoscopic image to control the distance of a front wall.

A wireframe box and a flat wall were drawn by CG software (Blender ver. 2.49a, Blender Foundation). The size of box (WHD) was 30 x 43 x 27 cm in the CG model. We used 4 positions of the front wall (0 m, 0.5 m, 2.5 m, and 10 m from the far rectangle in the box). The camera was equipped to two positions correspond to the right and left eyes (pupil distance: 60 mm, 100 cm from the front rectangle in the box). These optic axes crossed at the center of the front rectangle in the box. Images for left and right eyes were rendered, and those were converted to stereoscopic images with binocular parallax by using software (PLAY3DPC, I-O data). Rendered images of each wall position are shown in Figure 5.

The presented images were trimmed from those original images (Figure 5) for avoiding easy estimation of the correct vanishing point by using some pictorial cues, and we made four types as presented images for estimation of the ceiling, the floor, the right wall, and the left wall. For example, when the observer estimated a vanishing point of boundaries of the ceiling, we presented the area of upper two thirds in an image.

A CRT display (PCXAV-YZ 17inch SVGA MONITOR,

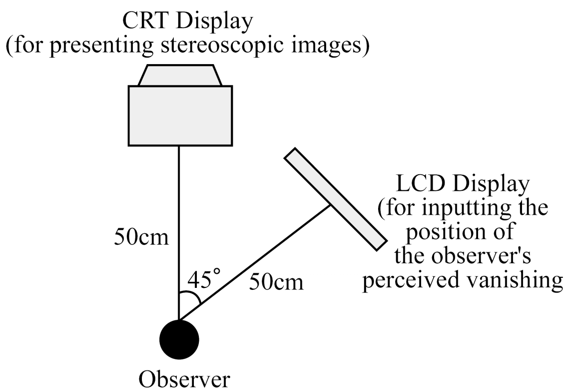
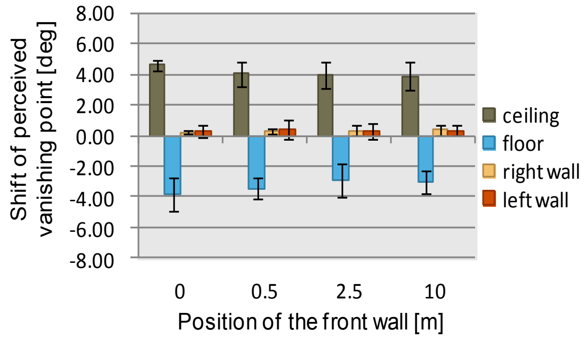
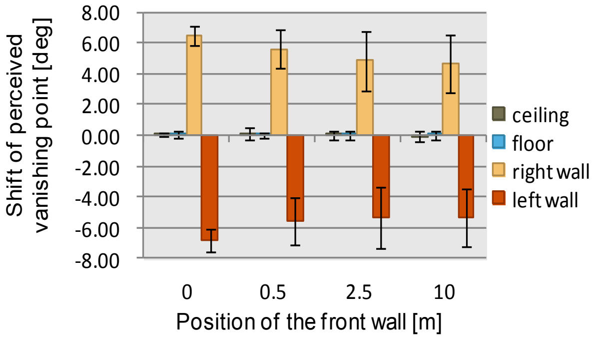


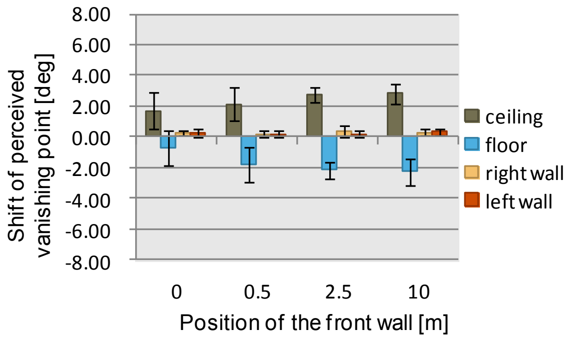

**Figure 6. Experimental environment.**



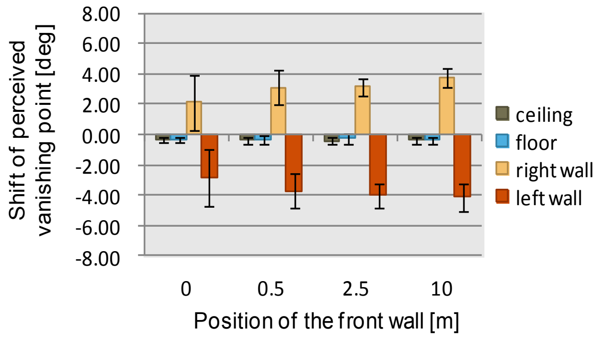

(a) **Group 1. Vertical shift.**



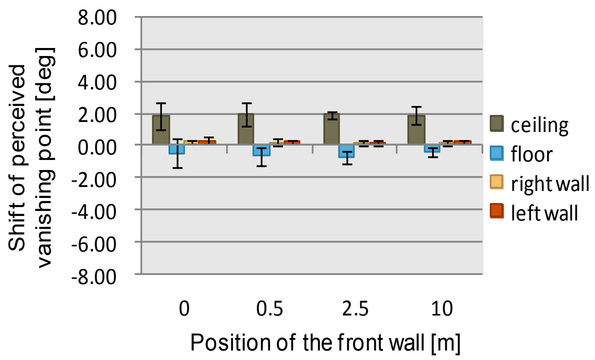

**(b) Group 2. Horizontal shift.**



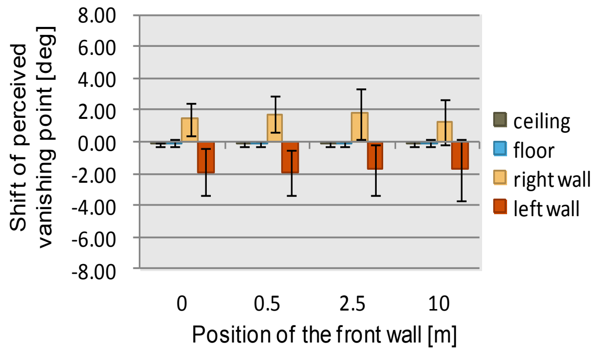

**(c) Group 2. Vertical shift.**




**(d) Group 2. Horizontal shift.**




**(e) Group 3.Vertical shift.**




**(f) Group 3. Horizontal shift.**

**Figure 6. Results of Experiment 2. Group 1 was participants whose perceived vanishing points were closer to the correct vanishing point when the front wall was located at the further position, (a) (b). Group 2 was participants whose perceived vanishing points were closer to the correct vanishing point when the front wall was located at the nearer position, (c) (d). Group 3 was participants whose perceived vanishing points were independent of the position of front wall, (e) (f). The vertical axis of graph is a shift angle of perceived vanishing point from the correct vanishing point, and the unit is visual angle (deg). The bar in each figure shows standard deviation.**

DEC) was placed in front of the observer for presenting the stimuli (Figure 6). The size of stimuli was 21.5 x 13.7cm.

*Procedure*

Participants were required to observe a stimulus with LCD shutter glasses (PLAY3DPC liquid crystal shutter glasses, I-O data), and input the perceived vanishing point in the right display (FLATSON L1942T 19inch, LG) by using a mouse device. The right display presented a rectangle of the same size with the far rectangle of the box in the stimuli. The right display was tilted to the right in 45 degrees.

Each of the 16 stimuli (4 positions of the wall x 4 attention locations) was presented once to each observer. The order of observation of the 16 stimuli was counter-balanced among the participants.

*Participants*

10 students took part in this experiment as observers (aged 19-23 years). Each participant had normal or corrected-to-normal vision.

**Results and Discussion**

Since the results depended on participants, we divided the participants into three groups. Figure 6 shows the result of experiment. Group 1 was three participants whose perceived vanishing points were closer to the correct vanishing point when the front wall was located at the further position. Group 2 was 4 participants whose perceived vanishing points were closer to the correct vanishing point when the front wall was located at the nearer position. Group 3 was three participants whose perceived vanishing points were independent of the position of front wall.

A one-way repeated measures ANOVA of position of front wall as the factor was conducted. In Group 1, the main effect was marginally significant or significant in perceived vanishing points of the following; the ceiling (vertical shift) [$F(3,6)=3.431$, $p<.10$], the floor (vertical shift) [$F(3,6)=3.624$, $p<.10$], the right wall (horizontal shift) [$F(3,6)=5.104$, $p<.05$], and the left wall (horizontal shift) [$F(3,6)=4.275$, $p<.10$]. In Group2, he main effect was significant in perceived vanishing points of the following; the ceiling (vertical shift) [$F(3,6)=4.192$, $p<.05$], the right wall (horizontal shift) [$F(3,6)=11.197$, $p<.005$], and the left wall (horizontal shift) [$F(3,6)=7.045$, $p<.01$]. In Group 3, the main effect was not significant in any perceived vanishing point.

This result shows a possibility that the mechanism of perceived vanishing point depends on observers, and the type of mechanism is divided into several groups. Two groups are influenced by the location of front wall, but those show opposite tendencies. The other group is not influenced by the location of front wall. The mechanism of perceived vanishing point is not simple.

## CONCLUSION

We investigated perceived vanishing points in 3-D space in this study. In Experiment 1 we confirmed that there was difference between perceived vanishing points in a real corridor scene and the correct vanishing point in its perspective image. Furthermore, the shift of perceived vanishing point depended on attention points.

In Experiment 2, we investigated the relationship between distance of a front wall in the scene and perceived vanishing points. Results showed that the mechanism of perceived vanishing point depended on observers, and it might be divided into three types. The results of Experiment 1 showed that the mechanism of perceived vanishing point was not based on an angle visual illusion in perspective scenes. However, the mechanism is not simple.

We are interested in representing perceived vanishing point in images. And we expect that it is possible to enhance the reality in images by introducing the perceived vanishing points. Future studies may reveal the mechanism of perceived vanishing points, and may bring better impression of images through the application of perceived vanishing points.

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