A Study on Mechanisms of Human Vision by Investigating Visual Illusions
--- Quantitative Measurements of Herman Grid Type Illusion ----

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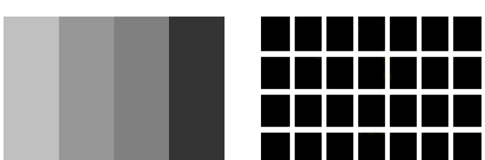
Abstract

Detailed mechanisms of human vision should be clarified against the background of the preparation of printed outputs for recognition via human vision. Our approach is to study visual illusions, which often uncover interesting aspects of visual mechanisms. The Herman Grid type illusion is studied to clarify the edge enhancement effect of human vision system; this type of illusion is considered to be associated with lateral vision inhibition. We quantitatively measure the effects of the Herman Grid Illusion. Measurements were carried out using a black and white pattern, as well as three primary color patterns to confirm the color dependency of human vision. The results of these quantitative measurements are expected to help to identify ideal imaging systems from the viewpoint of image recognition mechanisms.

1. Introduction

Recent digital image processing technologies can easily recover the detail of obscure images. However, such emphasis often triggers unexpected effects, for instance excessive edge enhancement. We note that human vision can also recover detail; one example is the Mach band effect (Fig.1 (a)). We hope to produce processed image with better visual quality by taking account of the characteristics of image processing in our brain. The image processing effects in our vision are often strongly displayed in visual illusions. Therefore, measurements and analysis of visual illusions are expected to be helpful in clarifying the image processing functions of human vision. [1] This study focuses on the Herman Grid illusion. Lateral inhibition [2] is generally considered to be one cause of the Herman Grid illusion (Figure 1(b): Illusional spots are usually seen at cross points); this study quantitatively measures these effects.



(a)Mach band (b)Herman grid

Figure 1. Typical patterns that cause striking visual effects

2. Outline of Experiments

Herman Grid illusion effects were quantitatively measured using not only a simple black and white pattern, but also other various patterns: proportion, gray level, and color.

First, we measured gray levels of illusion spots as a degree of the illusion using a simple black and white pattern (Experiment 1). Second, we measured the dependence of the illusion on proportions of the block pattern (Experiment 2). The third experiment measured the dependence of the illusion on gray levels of the solid area in a block pattern (Experiment 3). Fourth, we prepared various color patterns, in which pairs of the three primary colors were selected for the solid areas and the background; the color observed as the illusion spot patterns was recorded (Experiment 4).

From the results of these experiments, we quantitatively clarified the Herman Grid illusion with the goal of elucidating lateral inhibition. We defined the "degree of effect on Herman Grid illusion" as the gray level (0~255) of the illusional spot patterns observed; the level was taken as the ratio against that of the original block pattern. If the gray level of the observed spots equaled that of the block pattern, the ratio was 100 %; if no spot was observed, the ratio was 0 %.

Subjective measurements were carried out using images displayed on a computer screen in a soundproof chamber. Subjects were directed to watch the screen and to answer tasks on the screen using a keyboard (Figure 2). Common environmental conditions of the experiments are listed in Table 1. The correlation curve between input signal level (0 to 255) and display luminance is shown in Figure 3.

Table 1. Environmental Conditions

Display	Liquid crystal display (Back light type)
Size of display	12.1 inch (diagonal)
Number of pixels	800×600
Pitch of pixels	0.31 mm
Distance between screen and subject	40 cm
Evaluation space	Soundproof chamber

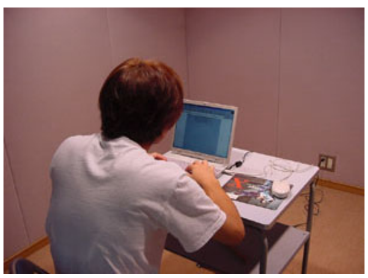


Figure 2. A typical test scene

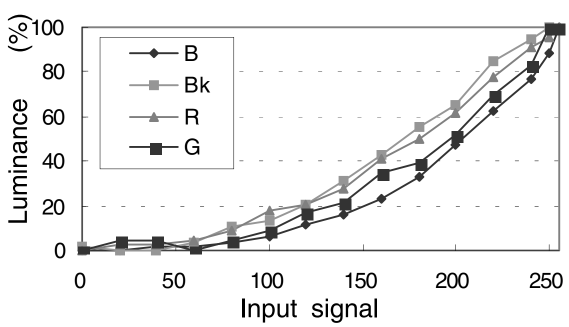


Figure 3. Correlation curve between input signal level (0 to 255) and luminance on the display

3. Experiments

3.1 Experiment 1: Density Level of Illusional Gray Spot and Dependence on Distance of the Spot from Gazing Point

3.1.1 Experimental Method

The purpose of this experiment was to quantitatively measure the fundamental effects of the Herman Grid illusion. Ten subjects were ordered to choose the same gray levels from a sample patch pattern on the computer screen as the illusional spots they observed on the screen. The Herman Grid pattern was displayed as 10×10 mm on the screen, and the 25 blocks (5×5) were separated by 2mm: Sixteen target areas were chosen for the measurements as shown in Fig.4: (1) – (16). The subjects were ordered to gaze at point (6) regardless of which target area they were evaluating.[2]

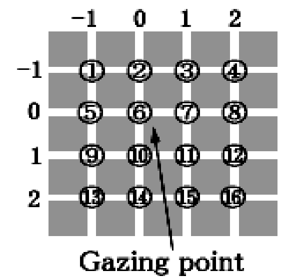


Figure 4. Sixteen target areas for evaluation in Experiment 1

3.2.2 Results and Discussions

Measured results for the 16 target areas are shown in Figure 5 as gray level ratios. Figure 6 shows a summary of the results showing the dependence on the distance from gazing point to target area expressed as viewing angle. Roughly flat rates are shown in Fig.5 and Fig.6 as observed gray levels on each target area except for the gazed area (6). These results indicate that lateral inhibition, considered to be the cause of the Herman Grid illusion, was constant over the viewing angle range of 0~5 degrees, except the gazing point.

It is also to be noted that an illusion spot of very slight gray level was observed even at the gazed area: it is conventionally believed that no illusion exists at the gazing spot.

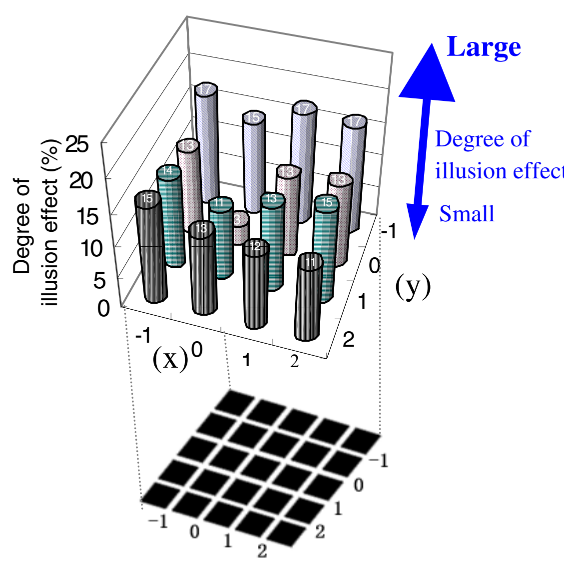


Figure 5. Measured effects of illusions in Experiment 1

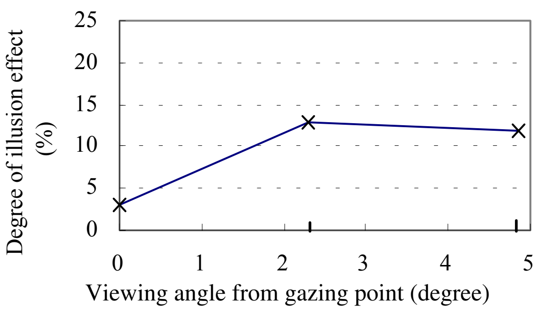


Figure 6. Dependence of illusion effect on the distance from gazing point measured in Experiment 1

3.2 Experiment 2: Evaluation of the Dependence on Aspect Ratio of Patterns

3.2.1 Experimental Method

The purpose of this experiment was to quantitatively measure the variation of the illusion effect when the aspect ratio of block patterns and gaps was varied. Gray levels of the illusional spots were measured, using four members of subjective, on various images with different aspect ratios (Figure 7). The ratio of "gap width"(a) to "total length of gap width and block width"(b) was varied from 2.4% to 48.4% in 20 increments of 2.4%: the total length (b) was always kept at 12.7 mm. Target area of measurement was position (3): to the above and right of the gazing point. Two trends, increasing and decreasing gap widths, were used; two subjects were used to examine each order.

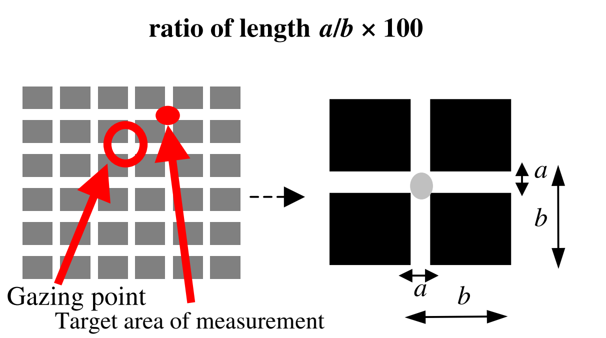


Figure 7. Target area(left) and proportion of block pattern(right) width(right)

3.2.2 Results and Discussions

Measured dependence on aspect ratio is plotted in Figure 8. The illusion effect peaks at the ratio of around 10%. The illusion diminishes rapid at ratios under 7%. This sudden drop can be explained as follows. At small ratios the subjects (according to their comments) failed to well distinguish the gap itself.

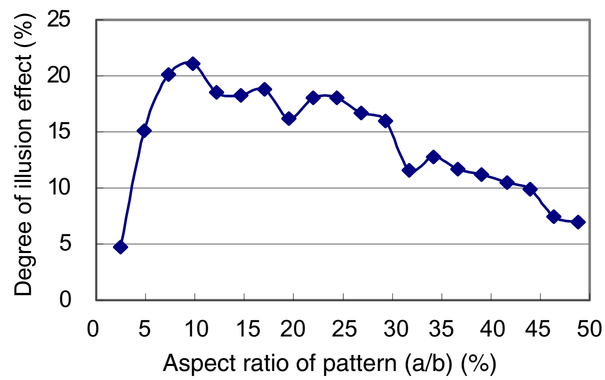


Figure 8. Correlation curve between input signal level (0 to 255) and luminance on the display

3.3 Experiment 3: Evaluation of Dependence on the Gray Level of Block Pattern

3.3.1 Experimental Method

The purpose of this experiment was to clarify the gray level dependence of illusional spots on the gray level of the block pattern. Gray level of block pattern was varied from full black to white in ten steps, see Figure 9. Five subjects were ordered to choose the sample spot, on a screen, that they felt to be the same as the illusional spot observed, in the same way as used in the previous experiments. Other conditions including gazing point, target area, and environments were the same as Experiment 2.

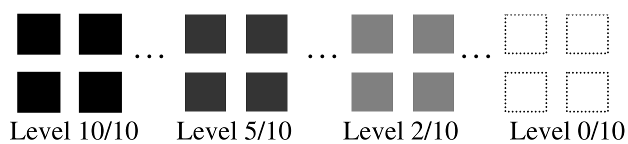


Figure 9. Typical gray level patterns used in Experiment 3

3.3.2 Results and Discussions

Gray levels of illusional spots are compared to block pattern levels in Figure 10. Figure 11 shows the ratio of gray level of observed spot compared to that of original block pattern. It is noted that the ratio is almost constant: the percentage of gray level observed is around 30%.

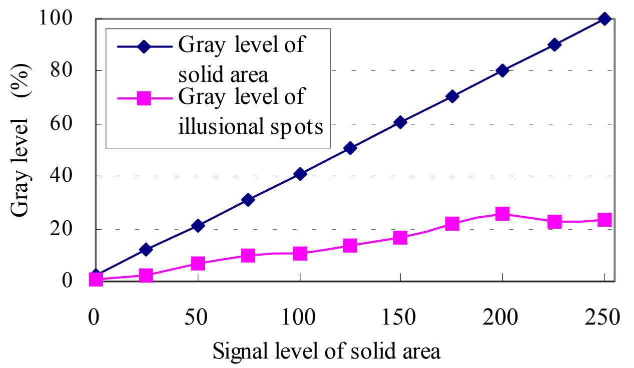


Figure 10. Measured relation between degree of the illusion effect and gray level of solid area

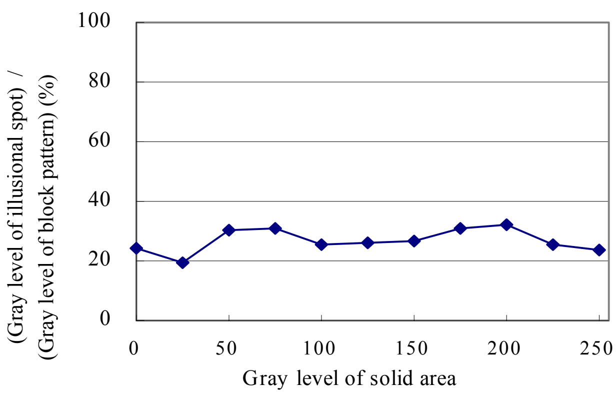


Figure 11. Ratio between the gray level of illusion spot to solid area

3.4 Experiment 4: Evaluation of Illusion Effects on Colored Herman Grid Patterns

3.4.1 Experimental Method

The final experiment used colored Herman Grid patterns. The block pattern and the background were colored using six color pairs, which were selected from among the three primary colors: R, G, and B. Evaluations were performed in order to determine the colors of the illusional spots. Five subjects were ordered to choose one of 40 color patches, displayed on the screen, whose color was most similar to the illusional spot observed. These forty color patches were selected from among the combinations of 4 levels (0, 85, 170, 255) of R, G, and B. Environmental conditions were the same as in the previous experiments. A total of 8 combinations of colors, including 2 sets of black and white patterns (Posi and Nega) were used as shown in Table 2 and Fig.12.

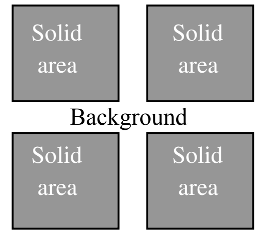


Figure 12. Solid area and background color in Experiment 4.

Table 2. Combination of Colors Used in Experiment 4

Sample No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Background	R	G	B	G	B	R	W	Bk
Solid area	G	B	R	R	G	B	Bk	W

3.4.2 Results and Discussions

The results, shown, in Fig.13, are plotted using the levels of each color component (R, G, B). The same color components as the block patterns are mainly indicated in chosen color patch, in Figure 13, almost commonly for each test image. As expected, these results confirm the basic understanding of the black and white pattern tests; due to lateral inhibition, the illusional spot is the same color as the solid area. This tendency was especially strong for the color pair Green and Red. However, we note that sometimes the illusional spots took colors that differed from those of the solid area and the background; this tendency was rather strong for the color pairs of (4) G/R) and (6) (R/B).

The above results reconfirm the findings of the basic Herman Grid pattern (black and white) experiments: lateral inhibition occurs in the responses of the cones L, M, and S in the retina.

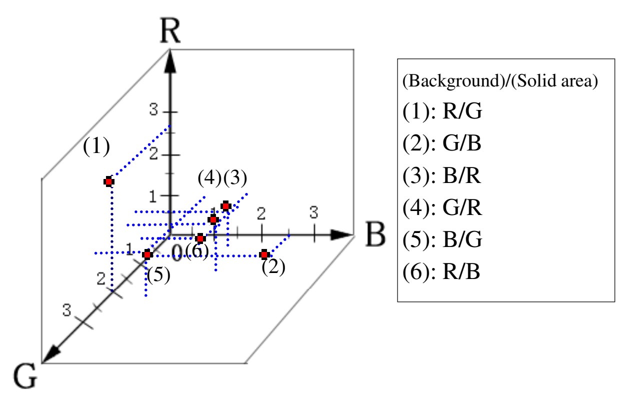


Figure 13. Levels of primary color components in the chosen patches in Experiment 4

4. Summary

Evaluations of the Herman Grid illusion effect were carried out as the first step toward creating a more effective image processing scheme that better utilizes the characteristics of human vision. Results of the experiments are summarized as follows:

1) Gray levels of illusional spots remained basically unchanged in the viewing angle range of 0~5 degrees except at the center gazing point.
2) Gray level of illusional spot was highest when the gap width ratio was around 7%~10% of pattern pitch.
3) The gray level ratio of illusional spots to the block pattern was around 30% for all block pattern gray levels examined.
4) Results collected using colored Herman Grid patterns support the assessment that lateral inhibition occurs in the responses of each cone type L, M, and S.

References

1. N. Ebata, et al.: "Perception of Motion Pictures using several popular Illusion Patterns", Extended Abstracts (The 49th Spring Meeting); The Japan Society of Applied Physics and Related Societies, (2002).
2. Peter H. Lindsay & Donald A. Norman: "Human Information Processing: An Introduction to Psychology 2nd Edition" Academic Press, Inc. New York, pp 204-227 (1977).
3. N. Ebata, et al.: "Quantification of Herman Grid illusion", Extended Abstracts (The 51st Spring Meeting); The Japan Society of Applied Physics and Related Societies, (2003).

Biography

Naoki Ebata was born in 1979. He received his B.S degree in 2002 from Tokai University. He is expected to receive his M.S. degree from the Graduate School of Tokai University in 2004. He is now engaged in a study of human vision at Tokai University.