

ENHANCEMENT OF COLOR-DEPENDENT FRASER–WILCOX ILLUSION BY ADDING DELAY TO ONE OR MORE PRIMARY COLOR COMPONENTS

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ABSTRACT

The color-dependent Fraser–Wilcox optical illusion is a type of motion illusion, and specific coloring is indispensable. Although the mechanism has not been fully elucidated, a difference in the latency among three kinds of cones in the retina may be related. In this study, a stimulus figure was photographed with a web camera, divided into three primary colors of RGB, subjected to different delay processing to simulate different delay times among the three kinds of cones, and synthesized. Processing, an open-source computer programming language, was employed in the experiment. Results showed that the amount of illusion increased when the red component was delayed against the two other color components. Furthermore, reverse illusion occurred when the green component was delayed against the other components. These experimental results support the hypothesis that the illusion is caused by the difference in latencies among the three types of cones of the retina.

1. INTRODUCTION

Optical illusion, which is an illusion caused by the visual system, can be classified into several categories. Among them, motion illusion is such that motion appears different from actual motion. A typical example is Fraser–Wilcox optical illusion [1], which was reported in 1979, in which disks appear to be rotating in spite of the fact that they are perfectly stationary. Kitaoka presented a series of “optimized Fraser–Wilcox optical illusions” in which the amount of illusion was considerably increased. He also classified his stimulus figures into types [2]. Among them, Type V is different from others because specific color combination (typically red and blue) is indispensable. The difference in latency among three kinds of cones (and/or rods) in the retina may be related to this phenomenon, because each of the three types of cones roughly corresponds to each of the three primary colors of red, green, and blue (RGB). Interestingly, Type V illusion becomes strong when the figure is shaken at about 4–6 Hz [3,4]. This type of illusion has recently been called the color-dependent Fraser–Wilcox illusion [5] because color combinations other than red and blue are allowed. Moreover, under dim conditions, the illusion becomes very strong and a reverse illusion also occurs [6,7]. Although hypotheses about the mechanism

[7,8] have been proposed, experimental verification is still insufficient.

2. EXPERIMENTAL SYSTEM

In order to elucidate this problem, experiments to delay specific primary color components relative to other components were necessary. However, we could not find such a prior study. Therefore, we produced an experimental system that could add different latencies among the three primary colors using a PC, as well as investigated the changes in the amount of illusion. As shown in Figure 1, the experimental system consisted of a camera, a PC, and a display. First, each frame acquired by the camera was divided into the three primary colors of RGB. Each color component was either delayed by one frame or not delayed. The resultant color components were combined together by a color synthesizer and then sent to the display of the PC.

These processes must be executed in real time. Furthermore, we changed the frame rate with software because the strength of the illusion might depend on the frame rate. Therefore, we used Processing [9] as the development environment. Its maximum frame rate is 60 fps but an arbitrary integer less than that can be set. Figure 2 shows a screenshot of the system.

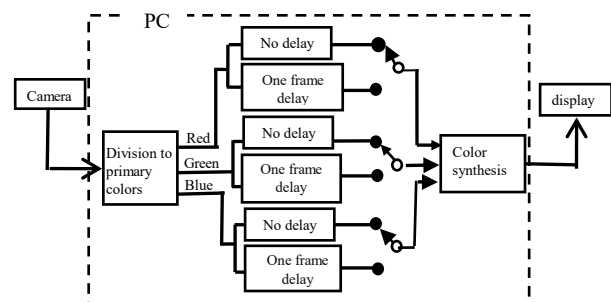


Figure 1. Block diagram of the experimental system.

3. EXPERIMENTAL RESULT

Figure 3 shows one of the eight stimulus figures used in the experiment, all of which were designed by Kitaoka [5]. We printed the figure with a color inkjet printer (EPSON PM-G860) and shook it by hand. In photopic vision, the disk appears to rotate clockwise. We photographed it with a web camera and displayed it on a

liquid crystal display of a PC in real time using this system.

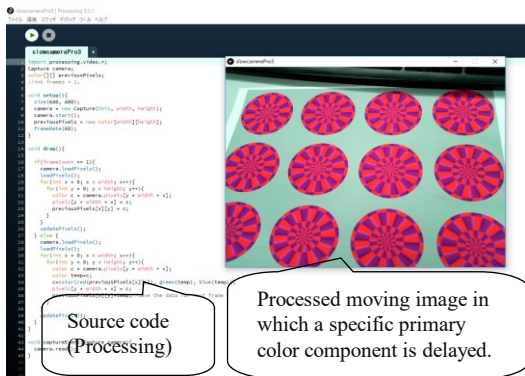


Figure 2. Screenshot of the display.

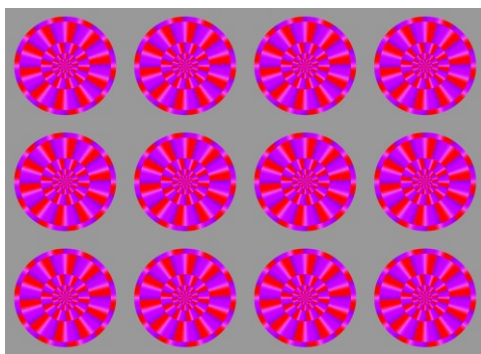


Figure 3. Optimized Fraser-Wilcox illusion Type V [5]

When no delay was given to all the primary color components, the strength of the illusion was unchanged even when the figure that passed through the system was observed. However, when delay of one frame was inserted only to the red component, the orientation of the rotation was the same (clockwise), but the illusion became strong. When one frame delay was inserted only to the green component, both an increase in the amount of illusion and the reverse illusion, namely, counterclockwise rotation, were observed. Notably, a slight increase in the amount of illusion was observed when one frame delay was inserted only to the blue component.

Subsequently, the frame rate was changed. When the frame rate was less than 20 frames per second (fps), the increase in the amount of illusion was minimal. Therefore, at least 30 fps was necessary to increase the amount of illusion. When the frame rate was 60 fps, the disks in the figure appeared to move more clearly than those in the case of 30 fps, which suggested that the illusion amount could be increased with a short delay of about 17–33 ms. However, further experiments using high-speed cameras are necessary.

4. CONSIDERATION

Although we are unsure how the following fact is related to this research, we conducted experiments in which the

green component was completely eliminated and only the remaining red and blue components were displayed. We found that even a person with color vision abnormality could correctly read numbers in Ishihara color test plates, which are commonly used for inspecting color vision abnormality.

5. CONCLUSION

We developed an experimental system in which an image taken by a camera was divided into three primary colors of RGB, and some of the color components were delayed relative to other color components. With the system, we found that the color-dependent Fraser-Wilcox illusion became strong when red or another color component was delayed for one frame period. Therefore, the difference in latency among the three types of cones may be related to this illusion. We also found that the amount of illusion rose by increasing the frame rate up to 60 fps, which indicated that a short latency of about 17–33 ms is sufficient to affect the strength of the illusion.

6. REFERENCES

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