Optical Illusion in Which Line Segments Continue to Grow or Shrink by Displaying Two Images Alternately

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Abstract: A new illusion has been discovered, wherein line segments, when alternately displayed with their tonal inversion or monochromatic images for approximately 120 ms each on a monochromatic background, seem to grow or shrink continuously. For instance, if the first image features black line segments on a white background and the second image shows the inverse brightness, switching between these two images causes the line segments to give the illusion of continuous expansion. Although a single line segment suffices, aligning multiple line segments parallel to each other enhances the effect of this illusion. This illusion can be achieved using achromatic colors, such as black and white, as well as chromatic colors, such as red, blue, and green. Specifically, when using an image with a black line segment on a red background alongside its brightness-inverted counterpart, the line segments appear to steadily decrease in length. Our hypothesis suggests a comparison between the mechanisms of this illusion and the changes in water volume in a pond.

1 INTRODUCTION

Optical illusions are related to vision. Illusions involving the movement of objects are collectively called “motion illusions.” A new motion illusion, in which the line segments continuously grow by displaying two still images alternately for approximately 120 ms each, was discovered by Mihara and Yanaka. As depicted in Fig. 1, one image features black line segments on a white background, whereas the other presents a tone-reversed version of these segments. When these images are presented alternately, each for approximately 120 ms, the line segments create the illusion of stretching continuously in one direction. The moment when the line segments appear to shrink is imperceptible, despite their physical lengths remaining unchanged. This phenomenon is likely a result of the malfunctioning motion detectors within the human visual system and the subsequent perception of line segments becoming longer.

Conventionally, a phenomenon called “apparent motion” is evident in railroad crossing alarms, where a red light seems to shift from left to right despite merely two red lamps alternating in blinking. However, in this scenario, the movement of the light spot will always be bidirectional instead of unidirectional. Introducing a third state where both lamps are extinguished can render the movement unidirectional. Yet, this condition is akin to expanding the number of images used to three. Moreover, by further increasing the number of images to four, a more seamless one-directional motion, referred to as “four stroke motion,” becomes possible [Mather, G.].

However, although only two images are used in this illusion, the line segments seem to stretch continuously. The moment the line segments shrink is not perceived in this case. Notably, this illusion is color dependent because its strength is influenced by variations in the background and line segment colors. Moreover, different combinations of colors can yield a reverse illusion, wherein the line segments appear to shorten progressively.

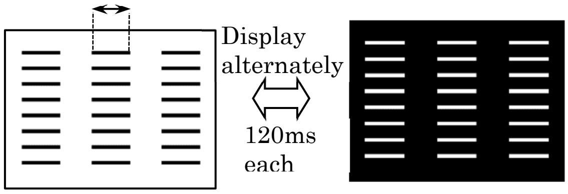

Figure 1: Example of a line-segment shortening illusion.

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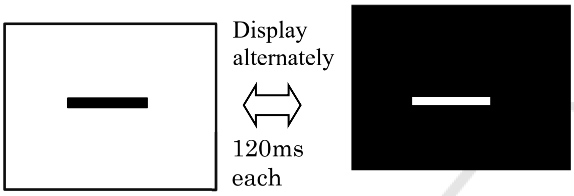
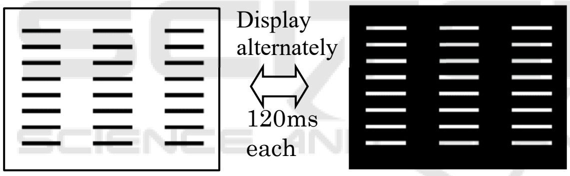
2 ILLUSION USING MONOCHROME IMAGES

This optical illusion can be generated from monochrome and color images. Here, we will discuss the scenario where two monochrome images are used. As illustrated in Figure 2 (a), when alternating between an image featuring a black line segment on a white background and its tone-reversed counterpart every 120 ms, the line segment appears to elongate continuously. This optical illusion remains consistent regardless of whether the line segment is oriented horizontally, vertically, or diagonally. Notably, employing multiple parallel line segments, as depicted in Figure 2 (b), amplifies the illusion compared to using a single line segment.



(a) Stimulus consisting of a line segment.

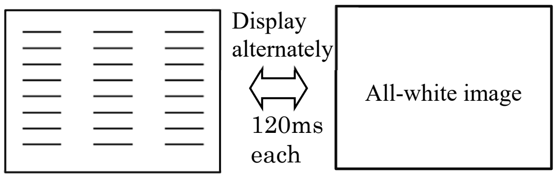


(b) Stimulus consisting of multiple line segments.

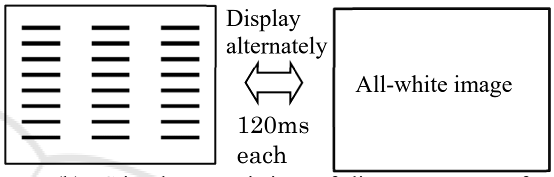
Figure 2: Optical Illusion in which Line Segments Continue to Grow.

The duration of the stimulus presentation influences the magnitude of the illusion. When the two images alternate every 120 ms, the line segment appears to grow infinitely. However, altering the switching interval can influence this effect. For instance, shortening the interval to 50 ms causes the image to switch before the line segments are fully stretched, thereby diminishing the illusion's intensity. Conversely, extending the switching interval, such as to 180 ms, results in a momentary pause after the line segment stretches, thereby reducing the perceived magnitude of the illusion.

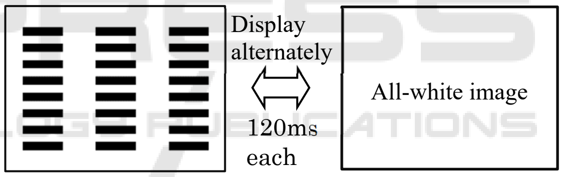
Using an image featuring a black line segment on a white background, along with its tonal inversion, proved effective in creating the impression of progressively elongating line segments. However, we encountered challenges in generating the illusion of decreasing line segment lengths using this method. Therefore, we experimented with all-white and all-black images, moving beyond sole reliance on tonal inversion images. As a result, as shown in Figure 3, we found that alternately displaying a black line image on a white background and an all-white image at 120 ms each produced the illusion that the line segments were gradually shortening. Notably, this effect is more pronounced when the line segment is thicker, as depicted in Figure 3 (c).



(a) Stimulus consisting of thin line segments.



(b) Stimulus consisting of line segments of medium thickness.



(c) Stimulus consisting of thick line segments.

Figure 3: Optical Illusion in which Line Segments Continue to Shrink.

3 ILLUSION USING COLOR IMAGES

Although black-and-white images have been used up to this point, similar illusions can be created using color images. An ordinary PC can handle approximately 16 million colors, an extensive range that is impractical to exhaustively examine. To streamline our exploration, we have constrained the color options: the line segments are limited to white or black, while the background color is confined to the three primary colors (e.g., red, yellow, and blue). Consequently, the number of feasible combinations is 2 × 3 = 6.

3.1 Alternate Display with Complementary Color Image

Inverting the gray scale of a monochrome image corresponds to finding the complementary color in a color image.

The outcomes of generating complementary color images for each of the six images and displaying them alternately for 120 ms each are depicted in Figure 6. Each color component has been represented in 8-bit integers as follows:

Black (0,0,0)
Red (255, 0, 0)
Green(0, 255, 0)
Blue(0, 0, 255)
Magenta (255, 0, 255),
Cyan (0, 255, 255),
Yellow (255, 255, 0)
White (255, 255, 255)

3.2 Alternate Display with Single-Color Image

As described in the previous chapter, in scenarios involving black-and-white images, the alternating presentation of the image featuring drawn line segments and the all-white image, each presented for 120 ms , induces the illusion that the line segments seem to contract.

Likewise, with color images, the illusion of contracting line segments is achieved by alternately displaying the image with the all-white image, as depicted in Figure 5.

4 RELATION TO KNOWN OPTICAL ILLUSIONS

The phenomenon described here is similar to γ motion, which is usually explained as follows: Upon turning on a light in a darkroom, it is perceived to radiate from the center to the periphery. Conversely, when the light is turned off, it is perceived as shrinking from the periphery to the center. This phenomenon, in which an image appears to expand and contract with the changes in luminance, is known as γ motion, a type of apparent motion.

However, the phenomenon described in this work has the following distinguishing properties.

1. Only elongation or contraction is perceived.
2. What is perceived depends not only on luminance but also on chrominance.

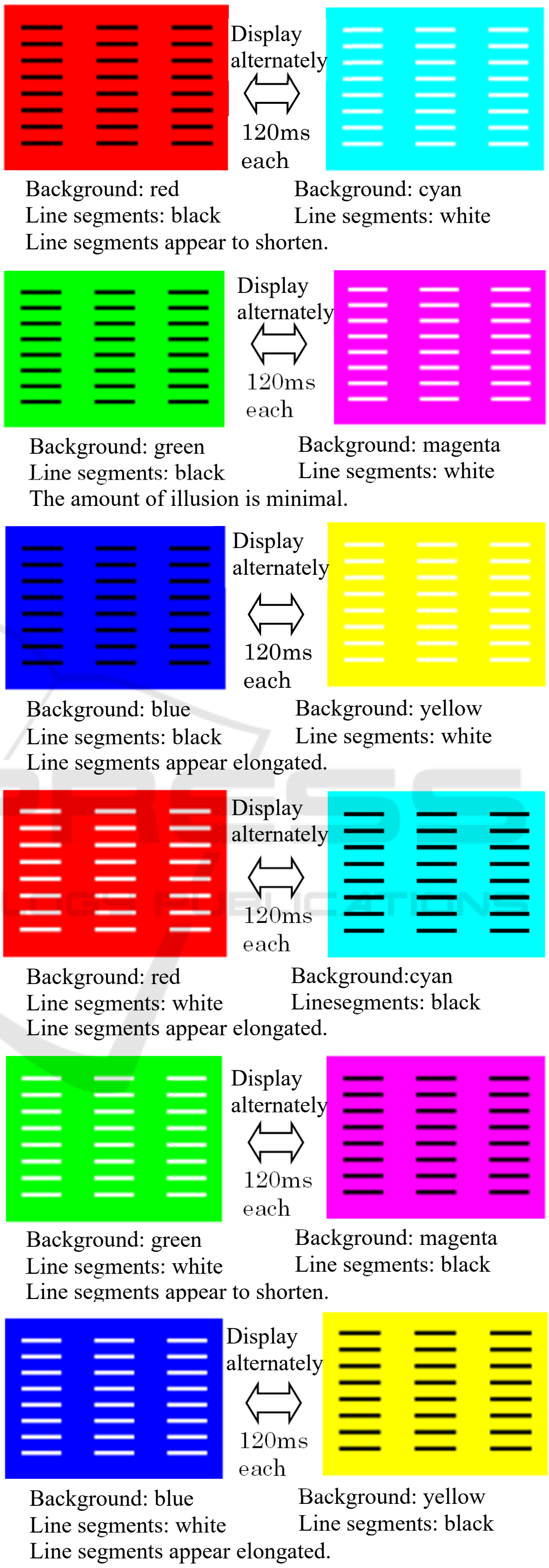
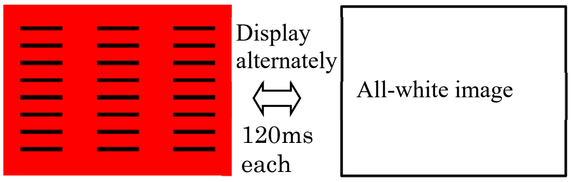


Figure 4: Alternate display with complementary color image.

3. Stretching occurs only in the direction of the line segment.

Therefore, investigating whether the discovered phenomenon is a kind of γ motion or not is essential.



Background: red
Line segments: black
Line segments appear to shorten.

Figure 5: Alternate display with single-color image.

5 HYPOTHESIS OF THE MECHANISM

We will elucidate the mechanism behind this optical illusion by comparing it to water accumulation in an elongated, oval-shaped pond, as depicted in Figure 6. The bottom of the pond exhibits a concave structure, with the central region deeper and gradually shallowing toward the shore. When observing the water surface directly from above, it appears as a line segment, yet it is, in fact, a lengthy, slender ellipse. Given that evaporation steadily occurs from the water surface, the water volume diminishes, causing the apparent length of the line segment to reduce progressively. During continuous rainfall, the pond water level rises, causing the line segments to lengthen. In instances of intermittent rainfall, the line segments extend during rainy periods and contract during rainless intervals. This elucidation clarifies why the line segments exhibit a cyclic expansion and contraction pattern.

However, the actual process involves distinct actions: when a line segment stretches, it solely elongates, and when it contracts, it only diminishes in length. This phenomenon manifests when the speeds of expansion and contraction remarkably differ. For instance, if a line segment extends gradually but contracts swiftly, then the duration for contraction is too brief to be perceptible, resulting in the continuous perception of growth. Conversely, when a line segment elongates rapidly but shrinks at a slower pace, it appears consistently to contract. This concept constitutes our hypothesis regarding the mechanism underpinning this optical illusion. However, at this stage, it remains a hypothesis, warranting further verification in future studies.

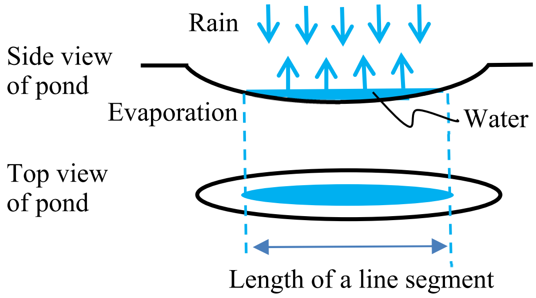


Figure 6: Hypothesis comparing the mechanism of this illusion to changes in the volume of water in a pond.

6 CONCLUSION

By alternately displaying an image with a black line on a white background and an image with the reversed gradation at approximately 120 ms intervals, an optical illusion in which line segments appear to continuously grow occurs. Furthermore, by coloring the background with a specific color, a reverse illusion, in which the line segments continue to shrink, can be created. The actual length of the line segment does not change. It is proven by viewing the screen with a ruler. Nevertheless, the line segment appears to expand and linger or increasingly become shorter . In this respect, this illusion is similar to Kitaoka's optimized Fraser– Wilcox illusion [Kitaoka]. We hope that this discovery will provide clues for understanding our visual system more deeply and lead to the development of a new animation system based on a new principle.

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