

# Spatial color mixing and color illusions

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## ABSTRACT

*Any color can be made from black and white stripes. In this article, I will explain the principles of color illusion based upon spatial color mixing and show how it is created.*

## 1. INTRODUCTION

Color illusions can be classified into color assimilation and color contrast. Both are hue illusions. Color assimilation is a phenomenon in which the color of a target area is perceived as the same hue as the surrounding color. Fig. 1 shows an example.



**Fig. 1** This picture is grayscale; however, by placing colored lines on it, it appears a color image.

Color contrast is a phenomenon in which the hue of the target area is perceived in the opposite direction to that of the surrounding colors. Fig. 2 shows an example.



**Fig. 2** The window area of this train appears red; however, none of the pixels have a red hue; they are all gray, grayish blue-green, or grayish green.

Here, I introduce a new color illusion based on spatial color mixing. This color illusion has properties of both assimilation and contrast.

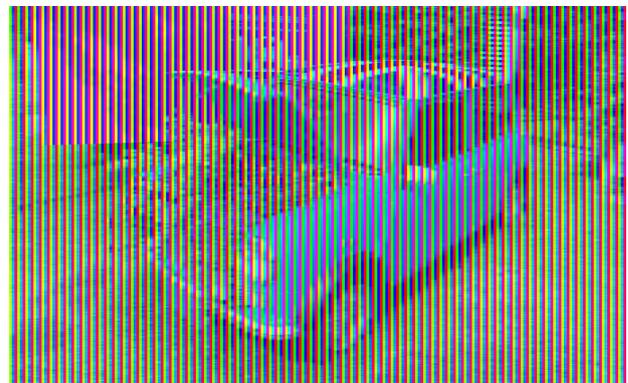
## 2. SPATIAL COLOR MIXING

Studies have shown that if three appropriate colors are chosen, a full-color image can be represented. These primary colors are typically red, green, and blue. They can be mixed by projecting them in the same location, or by placing them side by side. The latter is referred to as spatial color mixing. Fig. 3 shows an example of this.



**Fig. 3** This image is composed of lines of three colors: red, green, and blue.

As spatial color mixing involves three primary colors being placed side by side, it allows room for each color to mix with the other two. What happens if we add green to the red lines, blue to the green lines, and red to the blue lines? Subsequently, Fig. 4 is obtained. Although Fig. 4 is brighter than Fig. 3 because of the added colors, there is no issue with its appearance [1].



**Fig. 4** This image is composed of lines of three colors: yellow to green, cyan to blue, and magenta to red.

Moreover, what happens if we add blue to the yellow-to-green lines, red to the cyan-to-blue lines, and green to the magenta-to-red lines? Subsequently, Fig. 5 is obtained. Although Fig. 5 is brighter than Fig. 3 and Fig. 4 because more colors are added, the image is still clearly visible [2]. Fig. 5 can be represented as spatial color mixing of cyan, magenta, and yellow as the three primary colors. However, this does not imply that subtractive color mixing exists in spatial color mixing.



**Fig. 5** This image is composed of lines of three colors: white to cyan, white to magenta, and white to yellow.

### 3. SPATIAL COLOR MIXING ACCOMPANIED BY COLOR ILLUSION

Fig. 4 was created by adding red, green, and blue colors to Fig. 3. What happens when only green and blue are added to Fig. 3? Precisely, we add green to the red line and blue to the green line. Subsequently, Fig. 6 is obtained. In this image, objects that were originally red appear to be reddish; however, red hues are no longer in the pixels as the pixel colors are yellow to green, cyan to blue, or blue to black. Red is represented by a combination of yellow, blue, and black. This phenomenon could be evaluated as color constancy; however, it can also be recognized as a color illusion.



**Fig. 6** This image is composed of lines of three colors: yellow to green, cyan to blue, and blue to black. Perceived red is illusory.

### 4. SPATIAL COLOR MIXING WITH TWO COLOR LINES

Thus far, three primary colors have been arranged in independent lines. However, it is also possible to place two primary colors in a single line. What happens when the green line and blue one in Fig. 3 are mixed into one line? The mixed line includes green, blue, their mixed colors. Fig. 7 shows an example.



**Fig. 7** This image is composed of lines of two colors: red to black, and mixed colors of green and/or blue to black.

### 5. SPATIAL COLOR MIXING WITH TWO COLOR LINES ACCOMPANIED BY COLOR ILLUSION

What happens when green and blue are added to Fig. 7? More precisely, as the green and blue are added to the red line, subsequently, Fig. 8 is obtained. In this image, objects that were originally red appear to be reddish; however, red hues are no longer in the pixels because pixel colors are white to cyan or mixed colors of green and/or blue to black. Red is represented by a combination of white and black. Fig. 8 shows the two-color line counterpart of Fig. 6.



**Fig. 8** This image is composed of lines of two colors: white to cyan, and mixed colors of green and/or blue to black.

### 6. EXAMPLES OF THIS TYPE OF COLOR ILLUSION

Fig. 9 shows a demonstration, using a can of Coca-Cola, which gained popularity on social networking sites in 2021.

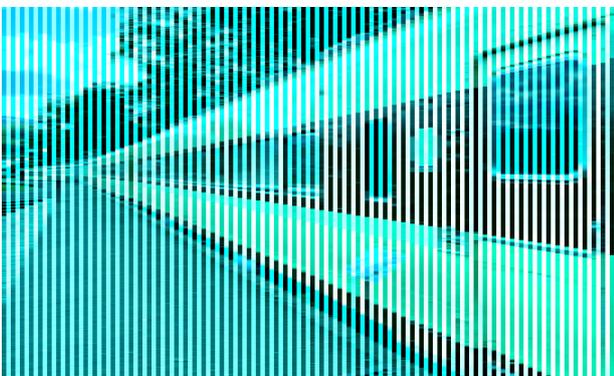
The can appears reddish; however, the reddish section consists of black and white stripes.



**Fig. 9** This Coca-Cola can appears reddish, though the image is composed of black and white stripes.

In this example, it is common to suspect that the red color is due to our memory of the brand's famous color; however, this is not the case. To clarify this issue, we can use another example. Observe Fig. 10. Not many people would know about the previous JNR express colors.

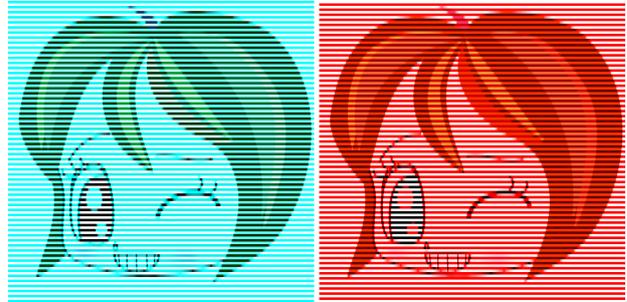
In addition, as Fig. 10 is the counterpart of Fig. 2, this technique of painting red objects with black and white stripes shows that it belongs to the phenomenon of color contrast.



**Fig. 10** The window area of this train appears red, but the color is composed of black and white stripes.

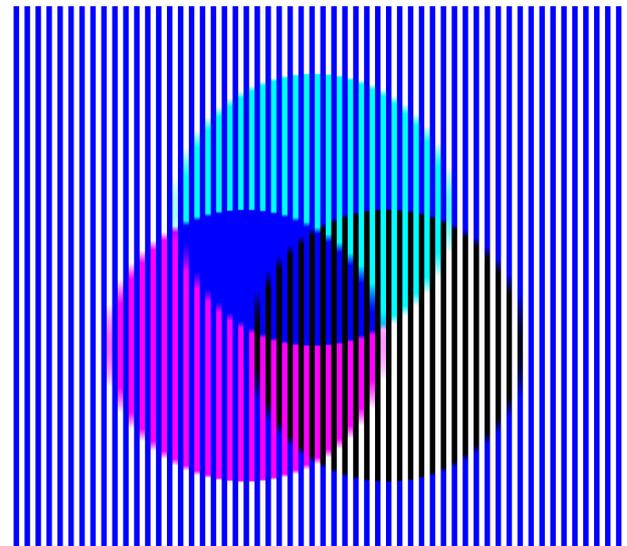
The examples of illusions shown thus far have been based on photographic subjects and involve red objects. This is because the effect is empirically convincing under these conditions.

This effect can also be achieved using simple illustrations rather than photographs. Fig. 11 shows an example.



**Fig. 11** The eye in the left image appears reddish and that in the right appears to be bluish, though both are composed of black and white stripes.

This effect can also be observed in simpler images. Fig. 12 shows an example. The lower right circle that does not overlap with other circles appears yellowish, although the area is composed of black and white stripes.

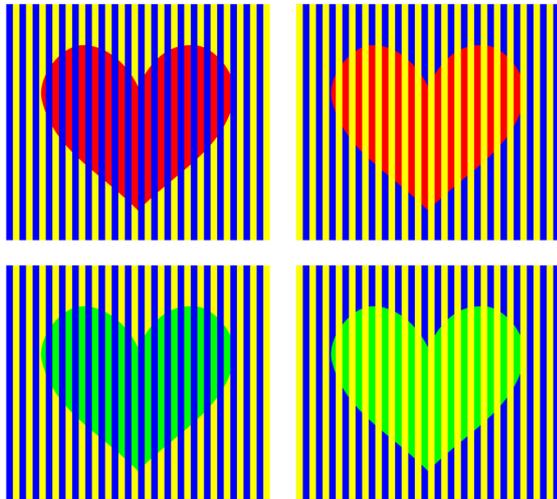


**Fig. 12** The lower right circle that does not overlap with other circles appears yellowish, though the area is composed of black and white stripes.

## 7. RELATION TO THE MUNKER ILLUSION

The Munker illusion is a phenomenon in which targets are placed on a certain color background, and stripes of another color are placed on top of them. Color assimilation is induced from the color of the stripes, and color contrast is induced from the background [3, 4]. In Fig. 13, the red heart in the upper-left image appears magenta, while that in the upper-right image appears orange. Moreover, the

green heart in the lower left image appears cyan, while that in the lower right image appears yellowish green.



**Fig. 13** The Munker illusion. The red heart appears magenta (left) or orange (right). The green heart appears to be cyan (left) or yellowish green (right).

The Munker illusion can be explained in the context of spatial color mixing with two primary color lines. For example, Fig. 14 is an image composed of lines of two colors: one shows blue to black and the other displays colors of red and/or green (including yellow hues) to black.

This image shows that magenta, the color of the lower left portion of the circle that does not overlap with other circles, is represented by a combination of red and blue stripes. The background is composed of blue and yellow stripes. These are consistent with the Munker illusion, where the red heart appears magenta in the upper-left image of Fig. 13.

Fig. 14 also shows that cyan, which is painted in the upper portion of the circle that does not overlap with other circles, is represented by a combination of green and blue stripes. The background is composed of blue and yellow stripes. These results are consistent with the Munker illusion, where the green heart appears cyan in the lower left image of Fig. 13.

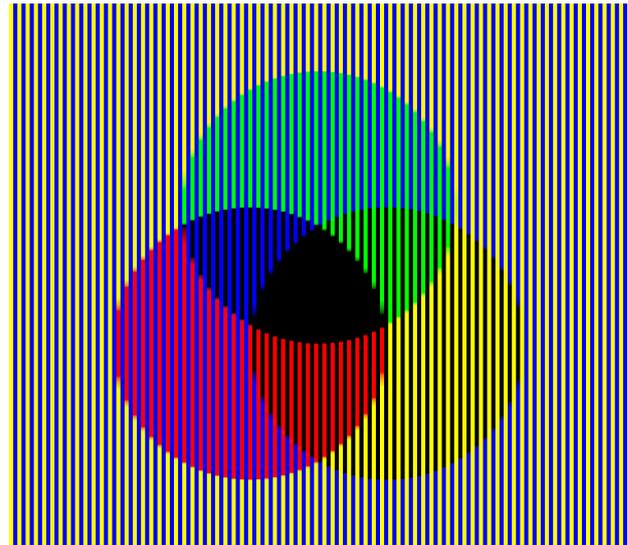
In addition, the illusory yellow shown in Fig. 12 can also be represented in the form of the Munker illusion in Fig. 15.

## 8. CONCLUSION

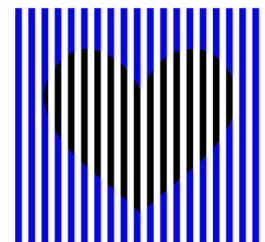
By investigating spatial color mixing, new color illusions are found, and conventional color illusions can also be well explained.

## 9. ACKNOWLEDGMENT

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**Fig. 14** The lower left portion of the circle that does not overlap appears magenta, which is composed of red and blue stripes. The upper portion of the circle that does not overlap appears cyan, which is composed of green and blue stripes. The background is composed of blue and yellow, and therefore has the same configurations as those of the Munker illusion shown in the left two images of Fig. 13.



**Fig. 15** The heart composed of black and white stripes appears yellowish.

## 10. REFERENCES

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