Neurophysiological Pathways in Optical Illusions
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Abstract

Optical illusions are all around us in our daily lives. Their main method of action is to manipulate the brain into perceiving an image that differs from reality. Due to the illusion's nature, it can activate certain pathways in the nervous system and allow us to perceive an image in a certain way. The visual and processing pathway of the human brain can be analyzed to illustrate the response when exposed to a physiological or cognitive illusion. This review summarizes our current understanding of visual sensing and its various responses to optical illusions, utilizing several well-known examples.

Introduction

There are three main classes of optical illusions: physical, physiological, and cognitive [4].

Physical illusions occur because of a property or characteristic of the external environment. The reason for perceiving the discrepancy from reality is not intrinsic to the human brain or visual pathway. An example of this is the bending of a stick placed in a glass of water. The discrepancy is not caused by the human brain, but by the optics of water [4].

Physiological illusions occur because of manipulation of the visual or processing pathway. These are presumed to be caused by strong stimuli of the eye and brain. This causes a physiological imbalance which can alter perception [4].

Cognitive illusions occur because of the brain's interaction with the environment, causing it to make unconscious inferences about an object's nature. These inferences cause a discrepancy between perception and reality [4].

Understanding physiological and cognitive illusions and their effects on the brain can lead to a better understanding of the brain and its functions.

1: Physiological Illusions

Physiological illusions are due to the manipulation of the brain and visual processing.

1.1 Afterimage Illusion

After staring at the top picture (**Figure 1**) for about 30 seconds, then looking at a blank area, a negative afterimage will appear in your vision [9].

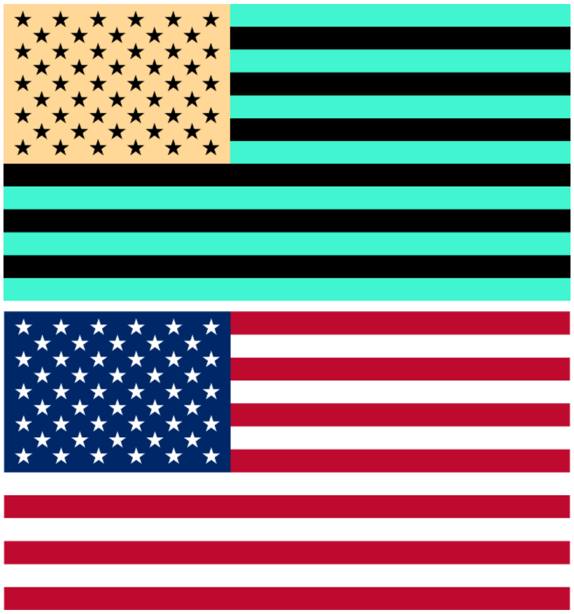

Figure 1. *An example of an afterimage illusion. Figure adapted from [9].*

The afterimage illusion is a classical example of a physiological illusion, most specifically, a physiological fiction. Several phenomena happen in the brain during this illusion:

Neural fatigue, and subsequently habituation of the eye (**Figure 2**). In the imprinting phase, light (the visual stimulus) is transferred into the eye which reaches the photoreceptors, causing them to fire. Eventually, due to prolonged stimulus, the receptors begin to fatigue. The cones, receptors responsible for perceiving color, become desensitized.

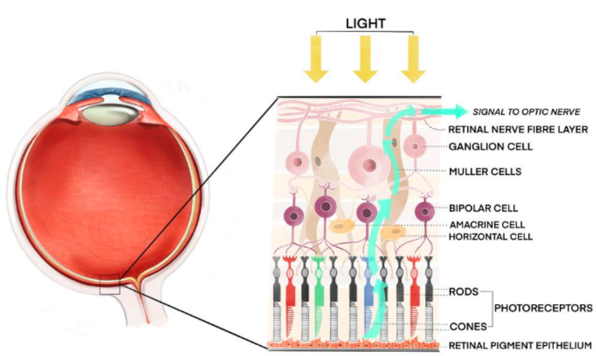

Figure 2*. Light hits the photoreceptors at the retina after being transferred by the ganglion, muller, bipolar, amacrine, and horizontal cells. Figure adapted from [14].*

The reason for the appearance of a negative image is due to the opponent process theory. Opponent process theory suggests that the human visual system perceives different colors in an antagonistic manner. There are opponent channels, each of which consists of two opposing colors (**Figure 3**). When a cone becomes desensitized and vision is quickly shifted to a uniform white light stimulus (the blank area), the opposite cones in the channel begin to fire at a greater strength than the original. Since the cones in the channel are paired antagonistically, a negative image with opposite colors is perceived [9, 6].

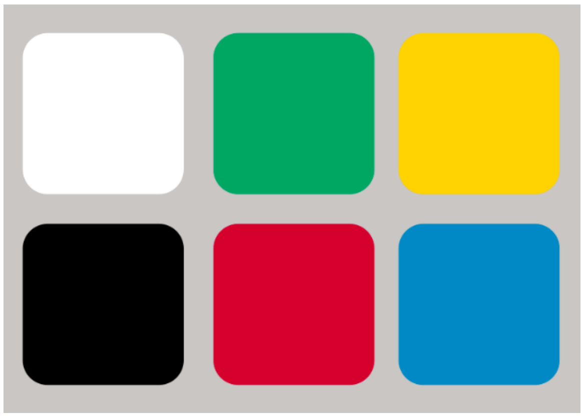

Figure 3. *The Opponent Process Theory. Colors paired vertically are antagonists. Figure adapted from* [17].

1.2 Hermann Grid Illusion

Black bulbs appear at intersections in peripheral vision. However, when focusing on one intersection, the bulb vanishes.

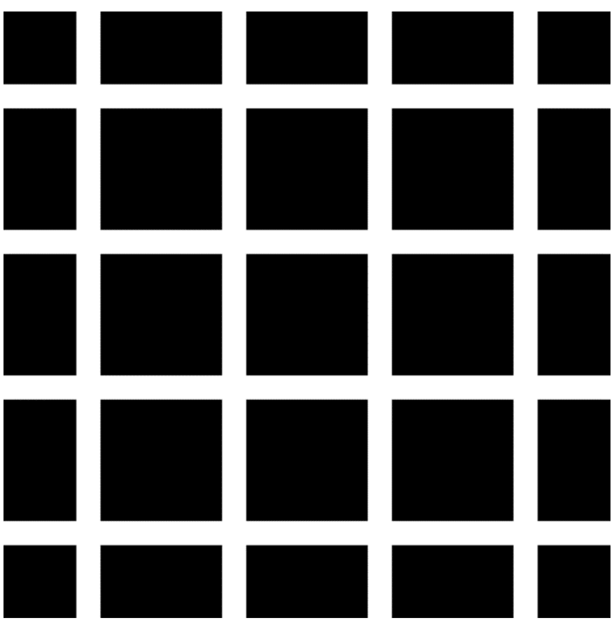

Figure 4*. The Hermann Grid Illusion. Figure adapted from* [16].

Another example of a physiological illusion; this phenomenon is caused by a concept called lateral inhibition. In simple terms, lateral inhibition is the tendency of an excited neuron to inhibit the activity of neighboring neurons. It is the prevention of the lateral spread of action potential between neurons. To sharpen the signal of one neuron, the activity of neighboring neurons is inhibited (**Figure 5**) [1, 13].

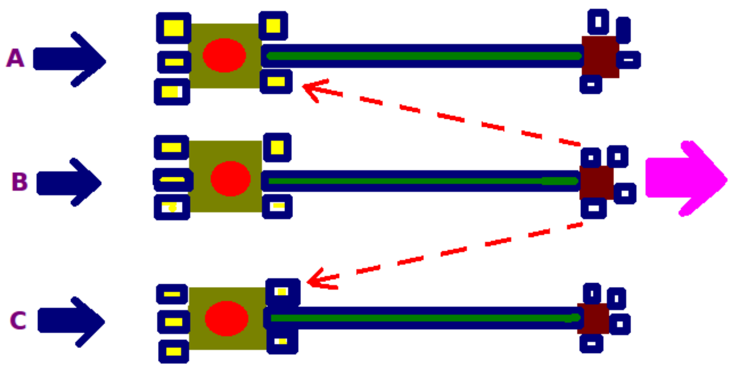

Figure 5*. Lateral inhibition. To sharpen the response of Neuron B, Neurons A and C are inhibited. Figure adapted from* [18].

In this illusion, a group of neurons that constitute the receptive field plays an essential role. In the center of this receptive field, the photoreceptors *excite* their respective ganglion cell. This causes the intersection to be sharper and not have a black bulb. However, due to lateral inhibition, the neighboring receptors *inhibit* their ganglion cell. This causes the intersection to become dull and have a black bulb [1, 13]. Because of lateral inhibition, at points of intersections with greater intensity, the intersection appears darker in peripheral vision due to the inhibition of ganglion cells, but areas in central vision do not appear darker [1, 13].

2. Cognitive Illusions

Cognitive illusions are due to the brain's inferences about the environment.

2.1 Ponzo Illusion

The line on the top appears to be longer than the line on the bottom, even though they are the same length.

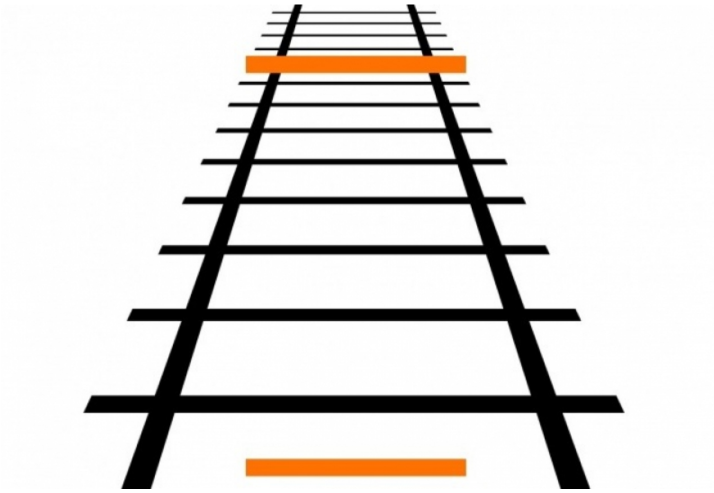

Figure 6. *The Ponzo Illusion. Figure adapted from* [16].

This illusion suggests that the human brain determines an object's size by its background, in other words, we judge size based on its relativity to its environment.

The railroad tracks in this illusion serve to provide a perspective of the two lines. Since the line at the top of the picture is at the point where the railroad tracks are far away, and the line at the bottom is at the point where the tracks are up close, they are perceived as different sizes when their real size is identical [16, 12]. If the two lines are identical in length, we interpret the farther one as longer as that is the way our brain gives the reason why a line farther away can be the same length as one which is close up [8].

Thus, the reason for this illusion is a cognitive one.

2.2 Ebbinghaus Illusion

The orange dot which is surrounded by large blue dots (**Figure** 7) appears larger than the orange dot surrounded by small blue dots, even though they are the same size.

This illusion once again shows that the brain's perception of size depends on an object's relativity to its environment. In this case, the size of the orange dots depends on the size of the blue dots. The brain will assume that an object with large things surrounding it is smaller, and an object with small things surrounding it is larger [15]. The cause of this illusion, for these reasons, is also cognitive.

Additional evidence shows the effect of one's environment on cognitive illusions.

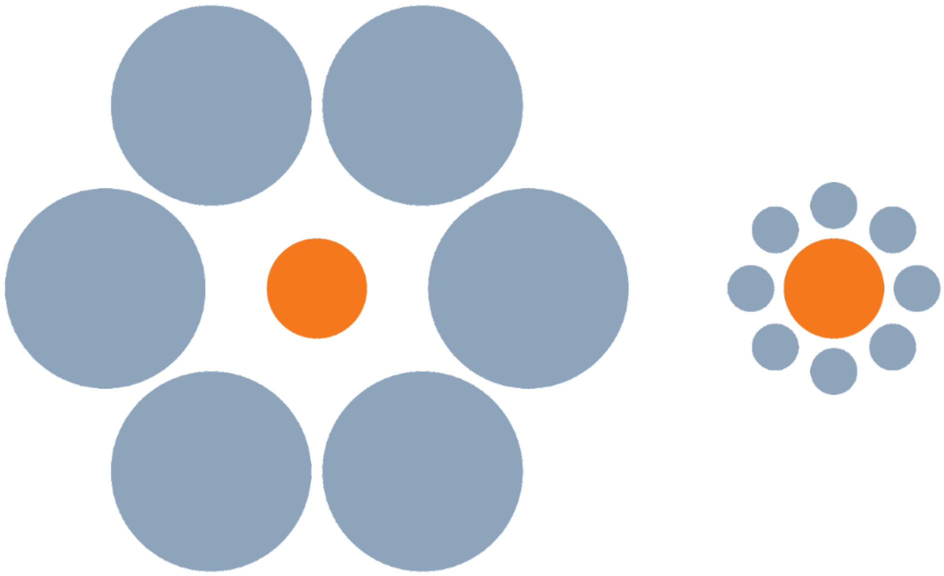

Figure 7. *The Ebbinghaus Illusion. Figure adapted from [2].*

2.3 Culture on Cognition

In a study done by Kitmaya et al. (2003), Japanese and American subjects were tasked with redrawing the square (**Figure 8**): once absolutely the same in size inside with another square, and once proportional to the original square in another square.

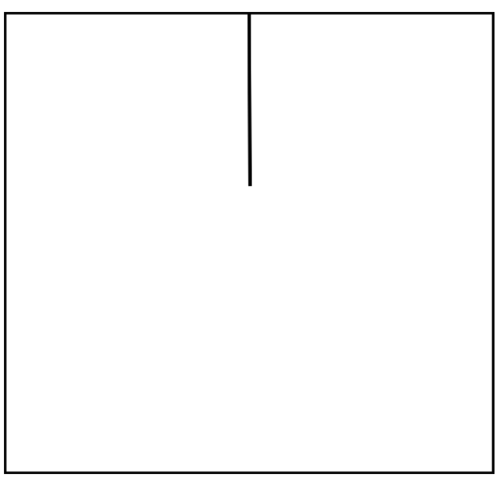

Figure 8. *The Framed Line Test. Figure adapted from [3].*

This study was to illustrate the effects of culture on cognitive activity. Japanese and American subjects were used due to their different cultures and societal practices. While Americans were more focused on individualism and freedom, the Japanese were more focused on interdependence and collectivism [7, 11]. Thus, a more *analytical* culture emerged in the West while a more *holistic* culture emerged in the East [11].

Results showed that Americans were better at drawing the absolute line, while Japanese were better at drawing the relative line.

Furthermore, fMRI imaging with a different study by Hedden and colleagues in 2009, shows the activation of different brain regions in American and East Asian subjects when presented with a visual stimulus. These results show that neural activity is in fact shaped to an extent by one's culture [5].

With this in mind, we can reasonably conclude that cognitive illusions are in fact due to our brain and its experiences, causing the inferences to be different based on our environment.

3. Conclusions

Physiological and cognitive illusions manipulate visual pathways and brain inferences to make us perceive something different from reality.

Through physiological illusions, strong stimuli to the eye and brain are received, causing photoreceptors to fatigue in the afterimage illusion, or cause the inhibition of peripheral photoreceptors in the grid illusion.

Through cognitive illusions, due to the brain's learning and experiences, various inferences are made about an image, albeit different from reality. The Ponzo and Ebbinghaus illusions both manipulate the brain's size perception: perspectives with the Ponzo and the size of neighboring objects with the Ebbinghaus.

Cognition is also impacted by culture. As shown by the Kitayama experiment, subjects of different cultures are better at certain tasks and perceive objects in different ways. This means that some cognitive illusions will only look similar due to similar experiences, and some cognitive illusions will look different.

Understanding physiological and cognitive illusions allows us to get a better understanding of the brain, cognition, and its visual pathways.

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