Analysis of Gaze on Optical Illusions

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Abstract

A comparison of human gaze patterns on illusions before and after a simple color manipulation is presented. The optical illusions used include Fraser's illusion, Akiyoshi Kitaoka's *Rotating Snakes*, and the Necker cube. All of these images were then modified in an attempt to render the illusion non-illusory. The images are then shown to 8 participants, split into two groups of 4. Each group will be shown an equal amount of modified and original images.

CR Categories: H.1.2 User/Machine Interaction

Keywords: illusion, gaze, eye tracking

1 INTRODUCTION

Discovering a study of how art is viewed became the primary inspiration for curiosity of how optical illusions are viewed. These two fields, art and illusions, have much in common. In fact, a specific art movement, op art, combines the perceptual knowledge associated with illusions and the compositional and functional properties of art. Both of these concepts seek to inform viewers of particular phenomena, whether it be the simple compositional balance of Mondrian's work or the baffling effect of Akiyoshi Kitaoka's control over and understanding of human perception. Evidently, they also both require a viewer—an interpreter, perhaps.

Eye tracking capabilities will be immensely helpful in determining how illusions are viewed. With simple color modifications to each of the images presented in the experiment, a new image will be created that is intended to not have the illusory effect. Scan-path and fixation data will be gathered and analyzed from both groups in an attempt to describe the illusions and their effect on gaze patterns. The main goal of this experiment is to gain a better understanding of perception and the phenomena associated with the manipulation of perception.

It is expected that the scan-paths of the images will be noticeably altered upon image modification. The path should become more focused while still retaining the same compositional integrity of the original image. This observation should correlate with the absence of the illusory effect.

2 BACKGROUND

The Fraser illusion was first discovered in 1908 by psychologist Sir James Fraser. It is also called the false spiral illusion as it causes the viewer to perceive a spiral pattern where there are only concentric circles. This phenomenon is caused by a misalignment in a sequence of patterns which causes a misinterpretation of the image. [1]

Kitaoka utilized his understanding of perception in order to induce movement in his *Rotating Snakes*. This phenomena is called a peripheral drift illusion and is associated with luminance change. The high amount of detail change cause every saccade and blink to become overloaded with information and thus cause induced motion. It was found in Martinez-Conde's 2012 experiment that with increased amounts of transient oculomotor events like microsaccades and blinks the intensity of the illusion increases. [2]

The Necker cube was found in 1832 by the Swiss crystallographer Louis Albert Necker and has informed Gestalt psychologists on the theory of multi-stability. This theory defines an object as being perceived from multiple possible perspectives. The cube switches its back and front/top and bottom faces depending on perspective. The cube has also been used in tests on capacity for direct attention. [4]

The main inspiration for this experiment came from two prior experiments describing how art is viewed. Quiroga and Pedreira sought to understand how compositional components of artwork effected viewers scan-paths. In their experiment, they used three images and altered them enough to change composition. This is the basic framework of this experiment as well. Their studies showed that the artists' intended composition reflects intended patterns within a viewer's gaze. The artist wants the viewer to look at certain places and move to others in a certain way. Such is the goal and the aspiration of compositional perfection. This experiment mainly had issues with whether the participant had seen the work prior to the experiment. The authors suggest that this is the difficulty of experimenting with art, its subjective and complex perceptive qualities make it hard to quantify and provide stable and consistent stimuli. [5]

In another eye tracking study on perception of art, Massaro et. al. examine and explain top down versus bottom up processing of paintings depicting nature and humans. Top-down processing is pattern recognition from contextual stimuli. Bottom-up processing deals with pure perceptual stimuli. The authors concluded that content with human subjects maintained top-down contextual processing in the viewer's visual exploration. Conversely, bottom-up processing—tested with changes in color and visual complexity/detail—dominated the scan patterns of content largely

containing nature. Therefore, dynamic interest in human-content will be determined by the viewer's interpretations of the feelings and actions of the subject in the image. Their main problem arose when they were attempting to determine what causes dynamic interest in nature-content. They suggest that the data obtained from the experiment would point toward basic visual complexity and there would be a correlation between visual dynamism and eye-movements. However, they found this was not true and determined that even when considering nature, humans still empathize as though we understand the "feelings" of nature. Essentially they were agreeing with Quiroga and Pedreira's paper in suggesting that art is subjectively interpreted and is difficult to quantitatively analyze what makes a piece interesting. [3]

This subjective interpretation is what this experiment hopes to eliminate, at least with the interpretation and gaze patterns of optical illusions. Illusions have specific sequencing and compositional requirements to facilitate illusory effect, thus, it should be easier to make informed observations on the gaze of illusions with a decent understanding of how perception works.

3 METHODOLOGY

This section outlines the specifications of the device used, information about participants, experimental design, procedure, and stimuli used.

3.1 Apparatus

The equipment used to capture eye movements is GP3 Desktop Eye-Tracker by GazePoint, a pupil-corneal reflection video based eye tracker. It has an accuracy of 0.5 to 1 degree of visual angle. It has a 60Hz sampling rate. The images were shown on a 22" LCD display receiving from a Windows machine running Windows 7 OS. The software used in the experiment is

3.2 Participants

The number of participants used is twenty, ranging in age from 18-37. All participants are from the Clemson University area. Ten participants will be shown the original images and ten participants will be shown the modified images.

3.3 Experimental Design

The design of this experiment is between subjects as it is studying the gaze patterns between the group with original images and the group with modified images. The experiment is 3 by 2 in that it contains three stimuli with two versions.

3.4 Procedure

The participants are each greeted and prompted to calibrate with the eye tracker being used. The participant is then prompted to view the images on the screen and then answer the question associated with the image after viewing. The images will be viewed for thirty seconds each with a thirty second question-answering period in between each view. After all three images are viewed by the participant, he/she will be prompted to answer the final question on the questionnaire and dismissed.

3.5 Stimuli

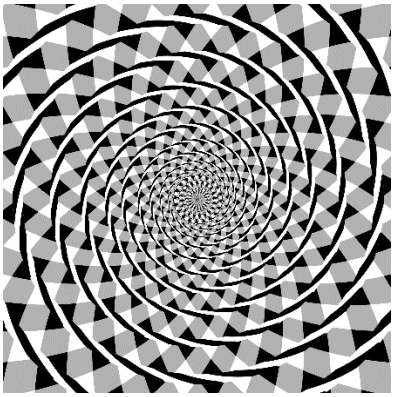

Figure 1: Fraser's Spiral

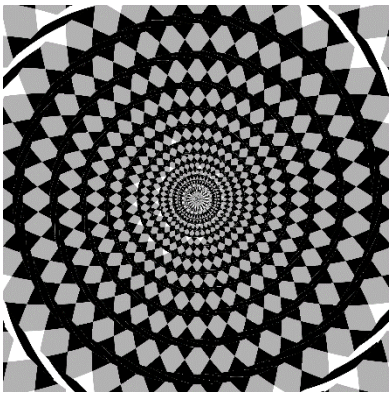

Figure 2: Fraser's Spiral with connected circles

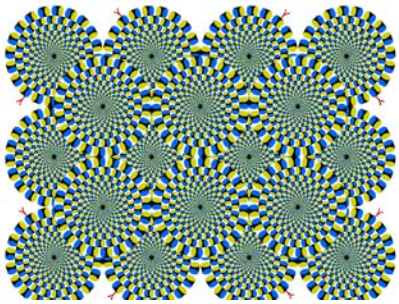

***Figure 3: Akiyoshi Kitaoka's* Rotating Snakes**

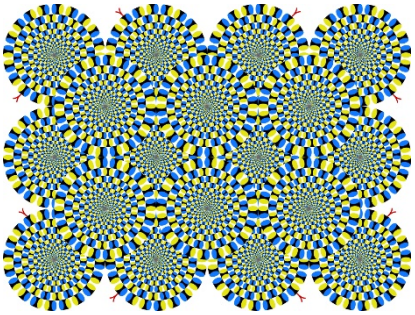

Figure 4:* Rotating Snake *with consitent, not alternating, luminance. Blue and yellow circles are not alternating

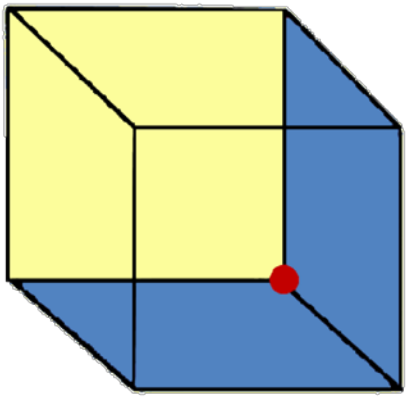

Figure 5: Necker's cube

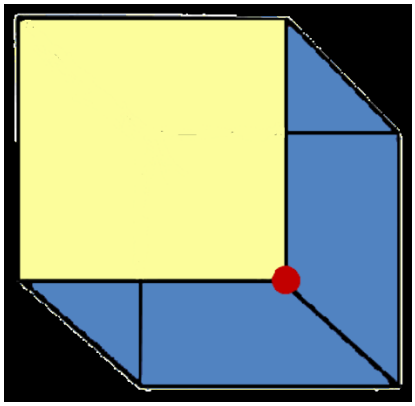

Figure 6: Necker's cube, with ambiguity removed. Draw through line has been eliminated.

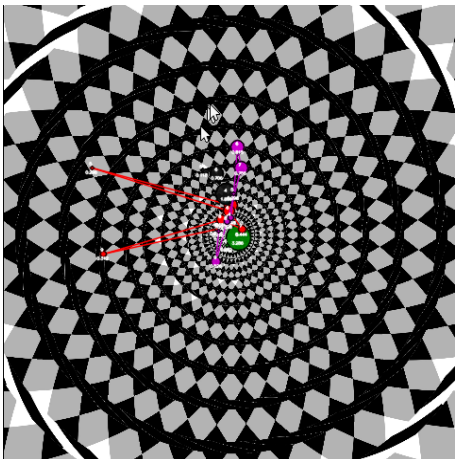

Figure 8: Four scanpaths over non-illusory Fraser's Spiral

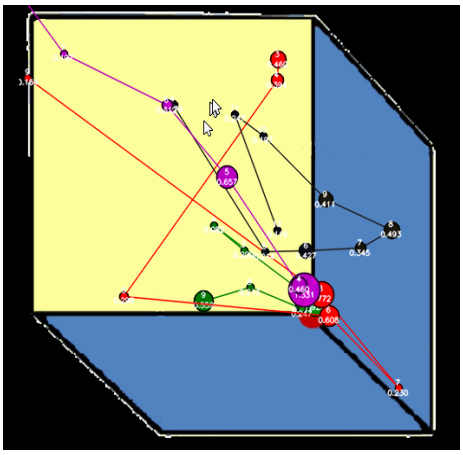

Figure 9: Four scanpaths over non-illusory Necker's cube

4 RESULTS

4.1 Non-illusory image scanpaths

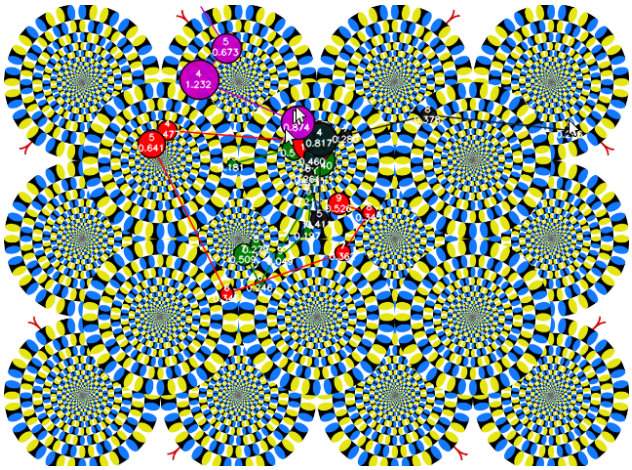

Figure 7: Four scanpaths over non-illusory **Rotating Snake**

4.2 Illusory image scanpaths

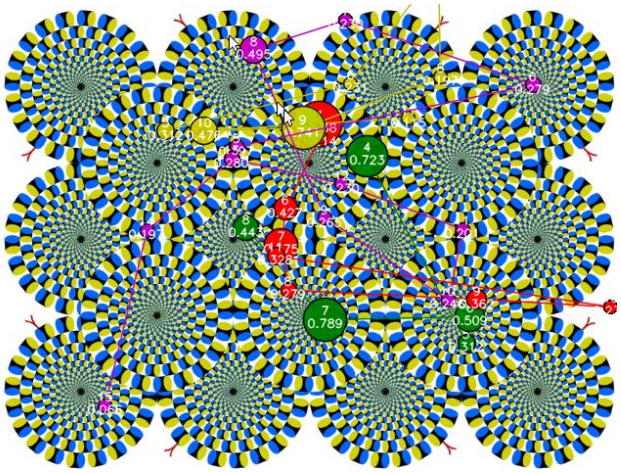

Figure 10: Four scanpaths over illusory **Rotating Snakes**

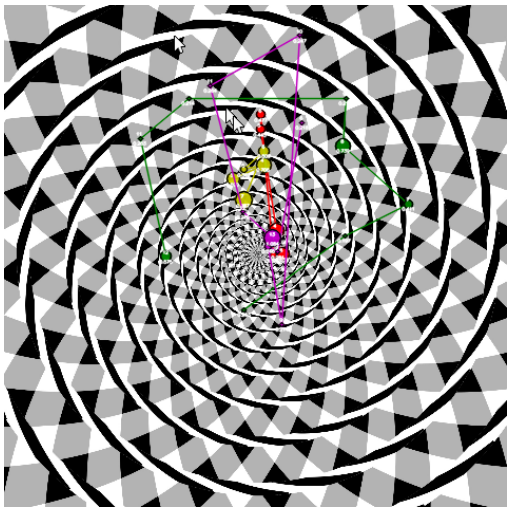

Figure 11: Four scanpaths over illusory Fraser's Spiral

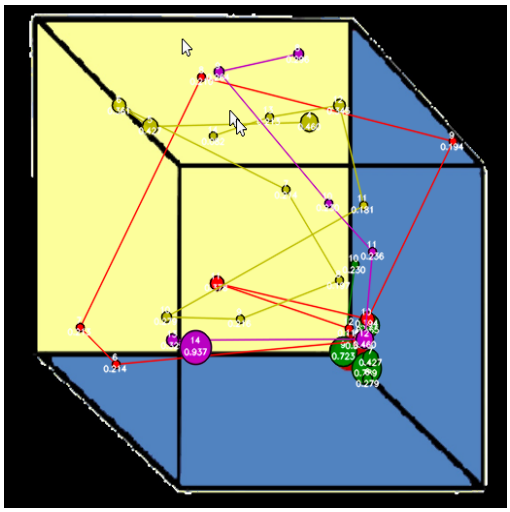

Figure 12: Four scanpaths over illusory Necker's cube

In Sections 4.1 and 4.2, the eight participant's colored scanpaths are shown overlayed on their respective non-illusory and illusory images.

From a qualitative perspective, scanpaths are more sporadic in the images when the illusions were present.

As seen in a comparison between Figure 7 and Figure 10, the fixation points in the illusory image are more dispersed.

As seen in a comparison between Figure 8 and Figure 11, the same can be said for the illusory image. The points, on average, are much more focused in the center in the non-illusory version.

Figure 9 and Figure 12 exhibit interesting behavior concerning the scanpaths over them. The scanpaths in Figure 9 follow a diagonal pattern from the bottom right corner to top left corner. While this could be considered less sporadic, Figure 12 exhibits a similar non-sporadic patterning following the corners of the cube.

After performing a one way ANOVA comparing the number of fixations for each image set, significant results according to *p* values was not found. Various box plots obtained from the test are shown below in Figures 13-15. All users' fixation data was used.

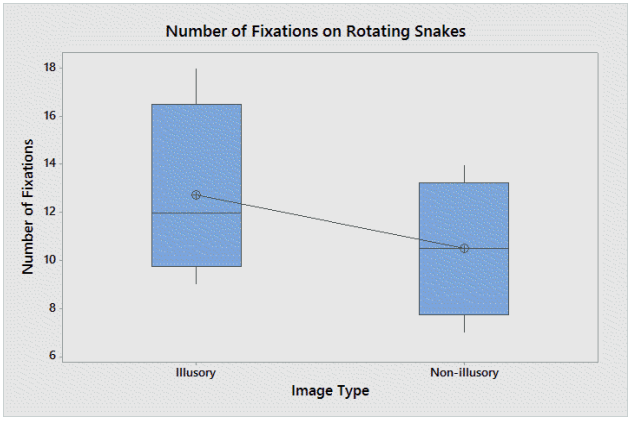

Figure 13

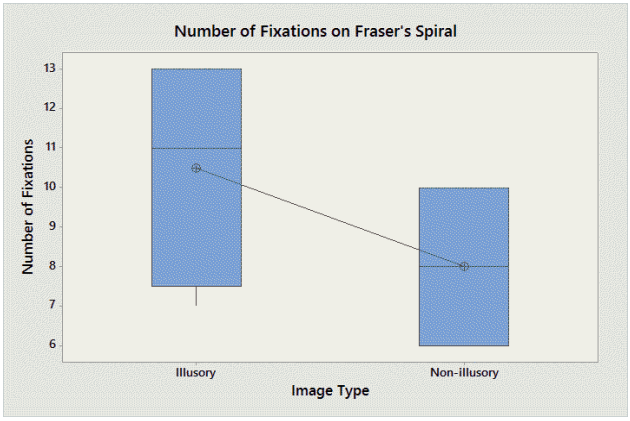

Figure 14

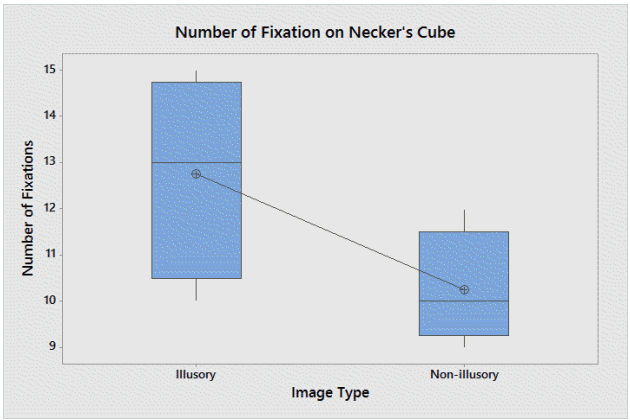

Figure 15

For an example in understanding the graphs, consider Figure 13 dealing with the *Rotating Snakes* illusion. The lowest number of fixations between all users viewing the illusory image is around 10 fixations. The highest number is around 16. These values come with some variation denoted by the extending lines. The average amount of fixations is denoted by a line inside the box.

In terms of the *Rotating Snake* image set, a *p* value of 0.380 was recorded. However, Figure 13 shows a lower number of fixations in the non-illusory image.

In terms of the Fraser's Spiral image set, a *p* value of 0.235 was recorded. Much like Figure 13, Figure 14 shows a lower number of fixations in the non-illusory image.

In terms of the Necker's cube image set, a *p* value of 0.098 was recorded, by far the closest value to significance. Similar to the other plots, Figure 15 still shows a lower number of fixations in the non-illusory image.

5 DISCUSSION

After qualitatively assessing the results of tracking gaze over illusory and non-illusory images, the original hypothesis stands supported. The original hypothesis held that if an illusion is present an image becomes more dynamic in terms of gaze patterns. For an image to be dynamic within this study, gaze patterns would need to be distributed throughout the image as opposed to focused in areas with longer fixation times.

In the *Rotating Snakes* illusion, perceived motion is elicited the more the viewer moves his/her eyes over the image and is strongest in the periphery. Thus, the viewer is more inclined to move his/her gaze, responding to peripheral sensory input. This action, in turn, causes more perceived motion. This cyclical quality is what makes the illusion cause more dynamic gaze patterns. The quantitative analysis of the *Rotating Snakes* image set reports that the amount of fixations is lower for the non-illusory image. Therefore, more time is spent during each individual fixation. This assessment meets the qualification set by the hypothesis.

In the Fraser's Spiral images, the perceived concentric pattern determines how dynamic the gaze pattern is. Because the repeated circles in the non-illusory image, the viewer's gaze is drawn towards the center, where the pattern's vanishing point is; thus, most fixations are seen near the center of the image. Because of perceived spirals in the illusory image, the viewer's gaze tends to wander through the spirals, searching for closure between separated circles. Therefore, scanpaths are more distributed throughout the image. Observing the plots of fixations on the Fraser's Spiral image set denotes fewer fixations on the non-illusory image. As with the *Rotating Snakes* analysis, the qualifications for the hypothesis are met, signifying that the illusory image causes more, shorter fixations, thus, a more dynamic image.

The scanpaths over the Necker's cube images are a bit more cryptic. Most fixations are on the red dot on the cube, which is expected solely because of the difference in color between the surroundings and the dot. The non-illusory image's scanpaths follow a diagonal pattern that corresponds to the skew of the image, which proves interesting. This patterning is mostly due to compositional qualities. People tend to gaze in the direction that an object is pointing. This diagonal scanpath patterning, however, is not readily apparent in the illusory Necker's cube image. Unless this occurrence is completely coincidental, this phenomena is most likely due to the fact that the illusion causes the figure to switch perspectives—the yellow box and red dot exist at both the front and back of the cube. Therefore, the viewer is more inclined to search for a "correct" perspective. Another interesting component of these images is the fact that most fixation data is concentrated in the yellow area. As with the red dot, this patterning is mostly due to attention to differences in color. As with both other qualitative analyses, the plot of fixations on the Necker's cube image set supports the hypothesis.

6 CONCLUSION

After performing the experiment and observing the gaze patterns over stimuli, the original hypothesis is proven. Despite being a largely qualitative study, simple observation of scanpaths can prove to be quite insightful as to how people view images. Most, if not all, psychophysical theories about the cause and effect of these illusions is supported by the experiment. The images that contained illusory qualities caused a more dynamic gaze pattern, meaning that gaze was more distributed about the image. It would be interesting to further study the effect of illusion in real world applications, such as "weaponized" distractions or for purely entertainment and artistic purposes.

7 REFERENCES

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