The Effect of Stereoscopy and Lighting upon the Perception of Optical Illusions

I. Abstract

Background

Illusions such as hollow face and Patrick Hughes' art present a perceptually ambiguous image, often being perceived as something that they aren't. Adding depth to these illusions by displaying them in stereo may lead to this problem being overcome. This study will also be exploring the effect light has on our perception of the illusionary object. This project aims to investigate the significance of stereoscopic cues in overcoming optical illusions.

Aims

The aim of this study is to discover the effect stereo has upon the perception of optical illusions and if it allows people to view them for what they truly are. The position of lighting will also be tested and evaluated to see if this alters the results. The aim is to implement a series of optical illusions to be tested on participants and to evaluate the effect of these two variables.

Method

Two optical illusions will be modeled, Hollow Face and Patrick Hughes' "reverspective" using 3D modeling software. This will then be imported into a program to then be displayed in both 2D and stereoscopic 3D. Participants will be shown a series of these optical illusions, in both 2D and 3D, each time being asked a question about it to which they will have to respond which will also be timed. Their answers and how long it took them to answer will be stored to be evaluated at a later point.

Proposed Solution

Models of the optical illusions will be imported into the testing program which will be using JAVA OpenGL. The program will be shown in both 2D and stereoscopic 3D to test the differences between them. The light position will be moved regularly to test the difference of the model being lit from above or below, and the model position will also change so the participant is either looking at the inside or outside of the model, which will be the basis of the results.

Keywords **– Stereoscopic, Hollow Face, Reverspective, Optical Illusions, Depth Perception, Lighting**

II. Introduction

Stereoscopy

Stereoscopy is the technique used for creating the illusion of depth in an image or scene by presenting two offset images separately to the left and right eye of the viewer. The brain then combines these two images to create the perception of depth and the 3D image. The brain makes use of stereopsis cues to determine relative distances and depth in a perceived scene.

Stereopsis is the impression of depth perceived when a scene is viewed by someone with normal binocular vision. Binocular vision creates the two slightly different images due to the different positions of the eyes on the viewer's head, and these when combined create the illusion of depth.

The factors that can influence the perception of depth are shown in Figure 1.

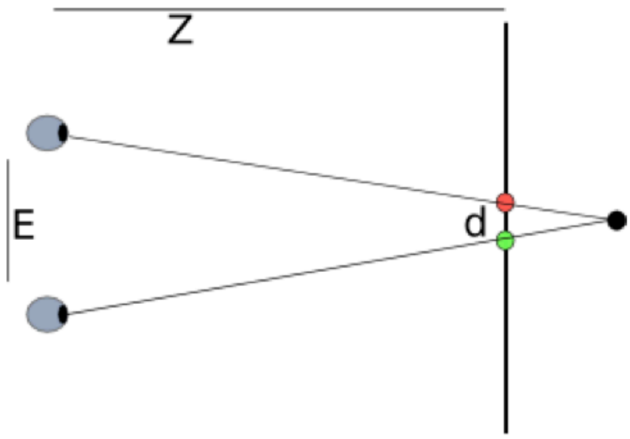

Figure 1 - The basic geometry of binocular vision (Binoclarity 2013)

The red and green points on the diagram represent the the points that the two eyes view onn the screen. These are fused by the brain so it appears to be a single image in depth, behind the screen. The disparity on the screen is d, the larger this is, the more depth is percieved. E is the inter-occular seperation, the smaller this is the more percieved depth the viewer sees. Z is the viewing distance and the larger this is the more depth is percieved. (Binoclarity, 2013)

Optical Illusions

Optical illusions are defined as "a visual experience in which a discrepancy exists between our perceptual judgment and the actual physical character of the original stimulus." The process of viewing the illusion develops as the viewer becomes aware of the difference between the subjective and objective information. When optical illusions are created with recognizable images, the viewer's reaction becomes the product of expectation, experience and trusting certain visual cues. (Carraher and Thurston, 1966: 9)

There are two different types of illusions. Illusions with a physical cause such as a disturbance of light between the objects and the eyes, and cognitive illusions due to the misapplication of knowledge. (Gregory, 1997) This project will be looking at the second type of illusion. The illusions that will be used are Hollow Face and Patrick Hughes' "Reverspective".

1. *Hollow Face Illusion*

The Hollow Face illusion (also known as Hollow-Mask illusion) is an optical illusion in which the perception of a concave mask of a face appears as a normal convex face. This is because faces are very rarely hollow. The viewer seeing the mask as convex is so strong that depth cues such as shading and shadows are countered. (Gregory, 1997)

The orientation of the mask, the direction of lighting, shading, and surface colour have all been found to affect the illusion. When the mask is upright, lit from above, with typical shading and pigmentation the effect of the illusion is enhanced. (Hill and Johnston, 2007)

Figure 2 shows an example of the hollow face.

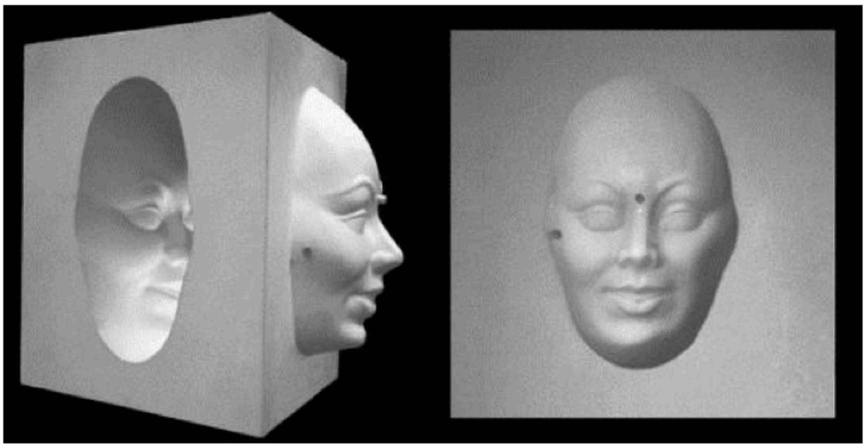

Figure 2 - Hollow Face Illusion (Króliczaka, et al., 2006)

2. *Patrick Hughes' "Reverspective" Illusion*

Patrick Hughes (born 20 October 1939) is the creator of "reverspective", an optical illusion on a 3-dimensional surface where the parts of the picture which seem farthest away are actually physically the nearest. When the paintings are viewed from the front they give the impression of viewing a painted flat surface that shows a perspective view. However as soon as the viewer moves their head, the 3D surface accentuates the depth of the image and provides a disorientating impression. (Hughes, 2013)

The artwork "Vanishing Venice" (*Figure 3*) will be the illusion used within this project, which is painted upon flat topped pyramids. The top of the pyramid which is closest to the viewer appears to be in the distance and the base of the pyramid appears to be the closest to the viewer.

Figure 3 - Vanishing Venice by Patrick Hughes

Project aim

This study will be researching whether displaying the Hollow face illusion and the reverspective illusion in stereoscopic will have any effect on how well people can view the illusion. The effect of the light position will also be looked at. It has been previously found that the viewers perception of the Hollow Face illusion is altered when light from above or below. We will be investigating if it still has this effect when in 2D and stereoscopic, and see what effect it has upon the reverspective illusion.

Deliverables

1. ***Minimum Objectives***
    - Model 2-3 optical illusions and write a program that will be able to import these models and manipulate them.
    - Allow the program to be interactive to users. The model should be able to be manipulated with either a mouse or keys.
    - Models should be able to be shown in both 2D and stereoscopic 3D

2. ***Intermediate Objectives***
    - Participants will be tested. The program will show the participant a series of the same illusion and they will have to select answers for it.
        - Hollow Face – The participant will be shown either the inside or outside of the mask. They will have to say if they believe it is the inside or outside, and then the model will change.
        - Patrick Hughes – The participant will be shown the model with the centre either closest or furthest.
    - The results will be gathered and stored in a text file. The results will contain the participants answer, and the actual answer so they can be compared.
    - The time it takes for the participant to give an answer after the image is displayed on the screen will be calculated and stored with the answers.

3. ***Advanced***
    - Allow the light to move around the object. Keep the test the same, but each time the model changes move the light so it is either above or below the object.
    - Store the light position with the other results so a correlation can be found between the two.
    - Add a Graphical User Interface (GUI) to make improve user interaction.

III. Design

This section will be looking at the design of the project. The requirements for the program and experiments will first be identified and the priority of them being implemented assessed. The design of the program written for the experiments will be explained and the process of the experiments will be discussed.

The design of this project is split into two sections: implementation and the experiment. The implementation will be the creation of the models to be used within the experiments, and the creation of the program to run the experiments. The experiments themselves will be using participants that have volunteered to take part and will involve running the programs and gathering the participant's answers.

The implementation will need to be thoroughly tested before the experimentation can begin. It will be very time consuming and difficult to get participants to return if the experiments have to be restarted because of some error.

Requirements

1. Functional Requirements

ID	Requirement	Priority
1.	The program must display the model in 2D	High
2.	The program must display the model in stereoscopic	High
3.	Two optical illusions must be modeled and imported into program.	High
4.	Participants must be able to interact with the program	High
5.	The program must time how long it takes for participants to answer	High
6.	The program should follow a sequence altering the variables each turn.	High
7.	The program must collect the results and store them	High
8.	There should be an equal number of all possible combinations	High
9.	Implement the light to move position	Medium
10.	Implement the orientation of model to change	
11.	Implement a GUI	Low

2. Nonfunctional Requirements

ID	Requirement	Priority
1.	The model of hollow face should resemble a face for the effect to work well	High
2.	Models for both 2D and Stereo tests should be as similar as possible. Same size, shading, angle etc.	High
3.	The experiment should not take the participant more than 15 minutes	Medium
4.	The experiment should always try to be carried out on the same display for each participant	Medium

Factors influencing perception

There are many factors that can change our perspective of objects in front of us and there have been many studies researching these. These are some of the key factors that will be taken into consideration for the design of this project.

1. Light from above

Studies have shown that these types of illusions, particularly hollow face, are heavily affected by light. Illusions lit from above are usually stronger making them harder to overcome. (Hill H, 1993). The lighting affects the shading of the object, which is one of the key sources for depth information, and when this is altered it can change how we percieve an object. A study found that our brains automatically assume objects are lit from above, because in real life objects usually are, and will therefore determine if an object is concave or convex based on this assumption. However, if an object is lit from underneath this will mean that these assumptions are wrong and will actually be the opposite. Figure 4 displays this theory. Group

A are percieved as convex and B appear to be concave. However if these were turned upside down the opposit would be thought. (Ramachandran, 1988)

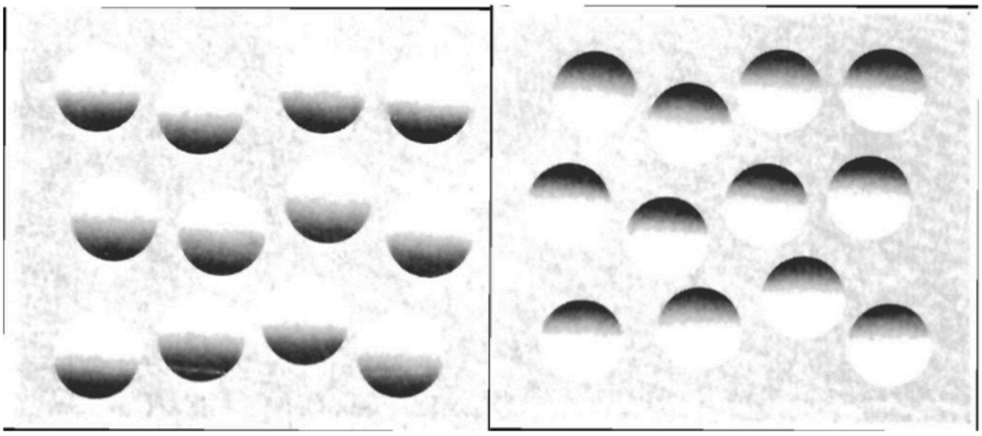

Figure 4 - Left is group A, Right is group B (Ramachandran, 1988)

2. *Inversion Effect*

A study on both the hollow face illusion and a reverspective illusion found that the illusion is weakened when the stimuli are inverted. The inversion effect was statistically significant for the hollow face, but not for the reverspective. This was believed to show that faces and scenes are processed differently. (Papathomas & Bono, 2004)

3. *Convexity Preference and Familiar Shapes*

The hollow face illusion was thought to be affected by the fact that it is a familiar shape and because people will always see the face. It was believed that when inverted it should make the illusion less effective as it then looked less like a face. However, other studies using other stimuli instead of a face have shown that this works for other objects as well, as depth inversion still occurs for objects that are not familiar such as the Hollow-Potato (Hill & Bruce, 1994). This therefore suggests that the effectivness of the illusion is due to preference for convexity.

4. *Binocular and Stereoscopic Vision*

Studies have found that illusions involving depth are made stonger when viewed in binocular vision. Stereoscopic depth information is the most effective cue to concavity as a solution. (Hill H, 1993) This should therefore mean that when viewed on a 2D display the illusions should be a lot stronger than when it is in stereoscopic and harder to get the correct answer.

Implementation

1. *Choice of Language*

Due to previous knowledge, Java was selected to create the program for the experiment. To create a 3D program, OpenGL (Open Graphics Library) was needed. OpenGL allows the rendering of 2D and 3D graphics. JOGL is a wrapper library that allows OpenGL to be used with Java programming so this was imported into the program.

2. *Modeling Illusions*

The hollow face model was originally modeled in Sculptris and then imported into Blender where the back faces of the model were removed to create the hollow mask. This was then imported into the program as a Wavefront object file which included face, normal and texture coordinates so it could then be modeled in JOGL.

The reverspective model has not been created yet. However, this will also be made within Blender. The pyramid will be a simple shape to create, and the texture will be taken from the painting itself and will be added to be model. This again will be imported into the program as a Wavefront object file.

Both models will be scaled within the program so they fit on the screen.

3. *Implementation of the program*

There are three main parts to the program, displaying the 2D image, displaying the stereo 3D image, and importing models to the system. The 2D code sets up a canvas, camera and lighting and then using the importing classes, it displays the model that was created. This is placed in the center of the window and scaled to fit on the screen.

The 3D code works similarly but this time has to set up two cameras at two different positions to create the images for each eye. The distances described in section 2, such as the viewing distance, are defined in this class to fit the display that will be used in the experiment.

4. *Lighting*

The lighting for the scene will be created from one light source. As part of the experiment is to see whether the position of the lighting has an effect on the ability to overcome an optical illusion, the lighting will need to be moved throughout the trial. The lighting will start above the object directly. Each time the object rotates through the trial the lighting will also move so it is either above or below the object.

5. *User Interaction*

Participants are required to interact with the program to give their answers. This will be done by pressing certain keyboard keys or by clicking on buttons on a GUI. Currently the program is set to use the keys as input as creating a GUI is low priority, however a GUI could be implemented at a later date as this could improve the user interaction.

There will be a key that will start the program and then two keys that will be the two answer options for the participants. When the participants are ready they will hit the start key and then continue with the test giving their answers until it is complete.

Experiment Process

This section will be describing the process of gathering participants and having them carry out the experiment. The experiment has been written to display the 3D models of the Hollow Face and Vanishing Venice in both 2D and stereoscopic. The aim of the test will be to gather the results for each type of illusion so we can determine whether optical illusions are easier to overcome when presented in stereoscopic, and if the direction of light has any effect on the results.

1. *Participants*

The program created will be tested upon participants to gather the results. Participants will be volunteers from Durham University. At least 15 participants will be required for the study, but if more can be gathered then that would be good for the analysis of results.

For the participants to take part in the trial they will need to be able to view 3D images as this is the basis of the experiment and could give misleading results if they are unable. From the study by Jones in 2001, it was found that about 3% of people are unable to see binocularly (stereo blind) and another 7% of people have limited 3D vision. There are therefore around 90% of people who are able to view 3D properly, but even within this group there can be a wide range in stereo ability. (Binoclarity, 2013) Even people who are able to view 3D, can sometimes get unacceptable side-effects such as headaches and nausea. To make sure these people do not take part in the study and affect the results, they will have to take a small test before they continue to the actual experiment.

Before the participants take part in the experiment they will also be required to fill in a consent form to make sure they are happy to take part and will be given instructions for the experiment which will explain what it is about and what they have to do. A post trial questionnaire will also be given to gain any extra information from the participants and ask questions about the experiment.

2. *Setting up the experiment*

The first step will be to sit the participant in front of the display at a set distance. The distance will need to be kept consistent so the depth perception in the stereoscopic test is the same for all participants. As many people taking part in the study may not have seen the optical illusions that have been implemented, the participants will be shown examples of the optical illusions so they are familiar of what it is and what they are supposed to be looking for. They will be told what they will have to do for the experiment and will be shown how to interact with the program. They will not be told that the experiment is timed but to select the answer as soon as they have an answer. This will hopefully reduce the amount of guesses. The participants will also not be told about the moving of the light source.

3. *Titmus Stereo Test*

Before participants are allowed to take part in the experiment their eyesight will be tested and will be checked that they can view images in stereo. This is done using a Titmus test. The Titmus test includes two polarized images at right angles to each other. When these are viewed through polarized filters, one image is shown to the left eye and another to the right eye. An example of this is the Titmus Fly Stereotest. When viewed correctly the house fly should appear in depth and the participant is asked to touch the wing of the fly. Stereopsis is indicated if the participant reaches in front of the plane of the stereogram. (Howard & Rogers, 1995)

4. *The experiment*

To remove order effects from the study, which can be a confounding variable, the order in which the participants carry out the experiments will change each time. This means some participants may start with 2D and others with stereoscopic, and some participants may start with the Hollow Face and others with Reverspective. The order of the lights and model moving will also change each time.

The screen will start blank when the program begins, and when the participant is ready they will be able to start the program by hitting a button. This will display the first image of the illusion and will also begin the timer.

For both illusions the participants will have two options for their answer. In the hollow face task the options will be inside or outside, whether the face shown is the inside or outside of the mask. For the reverspective illusion the options will be closest or furthest. This is referring to the center of the image which always appears to be the most distant point.

When one of these answers is selected, their choice is recorded as well as the correct answer, the time taken and the position of the light. The next scene will automatically be displayed in which the model may have rotated, light position may have been moved or both.

The timer will also be reset.

When the participant has completed the test the answers they gave will be stored in a text file to be analyzed at a later date. They will complete 4 tests in total for the experiment, 2D Hollow Face, 3D Hollow Face, 2D Reverspective, and 3D Reverspective. When they have completed all four they will be asked to answer a post-trial questionnaire and then they will be free to leave. The experiment in total should not take any longer than 15 minutes.

5. Experiment combinations

To make sure that the data can be analyzed properly at a later date, there will need to be equal numbers of all possible combinations that will occur during the tests.

The four tests within the experiment will be: 2D Hollow Face, 3D Hollow Face, 2D Reverspective, and 3D Reverspective. Within each of these tests there will be 20 scenes of the models. For Hollow Face there will be 10 scenes of the inside of the mask and 10 scenes of the outside. For Reverspective there will be 10 closest and 10 furthest. As well as these there will be 10 scenes with the light above the object and 10 with the light below the object. Figure 5 shows all the different combinations.

	2D				**Stereoscopic**			
Light position	Hollow Face Mask		Reverspective		Hollow Face Mask		Reverspective	
	Inside	Outside	Closest	Furthest	Inside	Outside	Closest	Furthest
Above	5	5	5	5	5	5	5	5
Below	5	5	5	5	5	5	5	5
Subtotal	10	10	10	10	10	10	10	10
Subtotal	20		20		20		20	
Total	40				40			

Figure 5 - Table showing all combinations of variables within the experiment

Possible Future Ideas

If there is time to implement and retest participants a possible idea for future tests would be to invert the models. It has been found that inverting these optical illusions can reduce the effect of them. The inversion effect on Hollow face has been found to be statistically significant, but not for a scene stimulus such as Reverspective. (Papathomas & Bono, 2004) It would be interesting to see if the same results would be found when displayed in 2D and Stereoscopic.

Another variable that could be tested for the Hollow Face illusion would be the texture of the model. It has been found that having a realistic face with the right texture and colouring can have an impact on how well people overcome the illusion. (Papathomas & Bono, 2004) This could be tested by adding a texture to the current model.

IV. References

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