INVESTIGATING THE EFFECTS OF CINEMATIC LIGHTING IN 3D ANIMATED SCENES ON VIEWERS' EMOTIONS AND PERCEIVED STORY

A Thesis

by

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ABSTRACT

A key reason for the success of animated films is the effects of cinematic lighting. Many techniques and theories have been devised for the creation of lighting effects, but we still do not understand well enough how such lighting effects may audience's emotional experience and particularly the intended storytelling experience. This thesis investigates the effects of cinematic lighting in 3D animated scenes on viewers' emotions and perception of the narrative. Twenty-six videos of animated scenes were developed with varied colors and lighting designs (high- and low-key lighting). A mixed-design perception study was conducted with 72 participants, 22 of which took part in the study in-person and 50 of which participated in the study via the Amazon Mechanical Turk platform. Qualitative and quantitative data was collected and analyzed using both qualitative coding methods and statistical tests to identify and compare the effects of each lighting designs. The results show how cinematic lighting affects the scenes' emotional impact and story in detail. We also confirmed some of the existing lighting theories.

Based on the findings, this thesis provides guidelines on how specific lighting techniques and colors may be used to affect viewers' emotions and story interpretation in 3D animation.

DEDICATION

For my parents and my husband. Without their love and support this work would not have been possible.

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All work for the thesis was completed independently by the student.

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1. INTRODUCTION

1.1 Introduction

A key reason for the success of animated films is the effects of cinematic lighting. In every movie scene, there are lighting artists who work to ensure that the lighting design in the scene will achieve the stated goals of the movie.

Cinematic lighting does not only play a big role in both live-action and animated film but it can also benefit almost any type of media from photography to interactive game. While it has many great benefits, two of cinematic lighting's most significant roles are enhancing the audience's emotional experience (Birn, 2013) and supporting visual storytelling (Calahan, 1996). Many techniques and theories have been devised by lighting artist to achieve these two goals. This raises the question of how to best choose the lighting techniques that will achieve specific desired effects on the viewers.

This thesis presents a study that investigates how various variables in lighting design, specifically the color of light and lighting styles (High-key and Low-key lighting) affects the viewer's perception of a scene and the viewer herself. Understanding the effects that specific lighting designs have on the viewer will benefit the further study of cinematic lighting and can provide guidelines for lighting artists who want to achieve specific effects and benefit interactive lighting design across various media.

This document consists of 6 sections: Introduction, Background, Methodology, Data Analysis and Results, Discussion and Lighting Recommendations, and Conclusion.

In the next section, Background, we review literatures directly related to cinematic lighting effects on storytelling and emotions. The theories from existing work were also discussed. Methodology section descripts the study design and the methods we used in the study. The procedure we used to develop 3D animated scenes and lighting designs for the study is also explained in detail. Data Analysis and Results section descripts how we analyzed both qualitative and quantitative data as well as presents the effects of cinematic lighting detected from the study. In Discussion and Lighting Recommendation, we discuss the results from the study and put forth the recommendation to be consider for lighting design in 3D animated scenes. Lastly, Conclusion section summarizes the thesis, study limitations and discuss potential future work.

1.2 Research question

How cinematic lighting designs generated from different lighting styles and colors affect 3D animated scenes' emotional and narrative impact?

1.3 Objectives

This thesis addresses lighting design in 3D animated scenes. The goals of the thesis are two-fold: 1) through an empirical study, we determine the emotional and narrative effects of different lighting colors and styles when applied to 3D animated scenes; and 2) we put forth recommendations for the design of lighting in 3D animation for animators, artists, lighting designers and film producers. In our study, animated scenes were created and lit separately using six different lighting colors: red, blue, yellow, green, purple, and neutral, along with two of the most currently popular lighting

styles: High-key and Low-key lighting. Both quantitative and qualitative analyses enable themes to be formulated with respect to design recommendations.

2. BACKGROUND

2.1 Cinematic lighting

Cinematic lighting exists since the advent of film and photography but despite the changing technology of lighting, certain varieties remain. Most of the lighting techniques for compelling, emotive image making are timeless and constant (Schaefer & Salvato, 1984). Lighting can transform an environment and create the mood to influence the audience's emotions so a greater understanding of the story can be achieved (Garcia, 2005).

While lighting in animated film often serves the same propose as the lighting in live-action movies, it is important to note that the approaches are different between the two of them. Sharon Calahan (1996) states that in live-action lighting design, the staging and framing of each scene are done together and require more effort in collaboration since each activity of the director, cinematographer and even the actors affects each other while filming. Conversely, lighting in 3D animation pipeline often happens after modeling, surfacing, staging, framing, set dressing, and animation. The art director in 3D animated film production is also more heavily involved in lighting design and style for the whole film.

Lights are characterized as being either logical or pictorial. On the one hand, when a light appears to be caused by actual light source, it is logical, for example, if it is implied that the light is from a window or a table lamp. On the other hand, pictorial

lighting generally uses lighting directions simply because they produce a pleasing picture (Calahan, 1996).

Calahan (1996) also mentioned that lighting design is not just to make the scene aesthetically pleasing or to simply make the viewer see what is going on but the primary purpose of cinematic lighting is storytelling. It is important to understand the story behind each scene before designing the lighting

Sudeep Rangaswamy (2000) from Pixar Animation Studios broadly classified the role of lighting into the following categories:

1. Directing the viewer's attention
2. Establishing a mood and atmosphere
3. Creating a sense of depth
4. Maintaining visual continuity

Rangaswamy (2000) also mentioned that the use of color can be essential to setting the overall tone for a scene. For example, red lights can excite the viewer while green denotes a more calm setting. Also, if the scene is well-lit it will most likely give a sense of peacefulness to the viewer. In contrast, dark, low-key lighting is often used to indicate danger. The same applies to shadows. Crisp shadows often indicate a cold, sterile environment while soft lights are used in warm settings because they create faint, barely noticeable shadows.

Gerald Millerson (1999) who wrote the book "Lighting for TV and Film" stated similar lighting potentials. He mentioned that light can influence how the audience

responds to a picture, can develop an atmosphere or mood, guide the audience's interest and can also imply time of day and weather.

From our review (Calahan, 1996; Millerson, 1999; Rangaswamy, 2000), there are varied goals when designing cinematic lightings but storytelling and establishing moods to enhance the audience's emotional experience seem to be two of the most important goals of lighting designers.

2.2 Cinematic lighting and moods

Jeremy Birn (2013) stated that most of a movie audience will never consciously see the lighting while they are enjoying the story, but they will feel it instead. Helping to create mood that enhances the audience's emotional experience is a key visual goal of cinematic lighting design.

In Calahan's work (1996), many properties are identified as contributing to the establishment of mood through lighting, the very first one being the lighting style. Even before the viewer has understood the story-point, the lighting style can suggest a feeling for a scene. The mood and character of the scene can be dramatically affected by the range of tone values from light to dark. The light-hearted, happy or comedy scenes are often lit with High-key lighting style. High-key lighting means that the scene is well-lit and there are few shadows and little contrast, giving the viewer a sense of peacefulness (Rangaswamy, 2000). While there might be a few dark areas, the overall brightness is light with a lot of soft fill light and the dark area are soft and few (Calahan, 1996). Figure 1 is an example of high-key lighting in a 3D animated scene created by the author.

Figure 1. An example of high-key lighting

In contrast to high-key lighting, low-key lighting is overall dark with only a few areas being brightly lit to direct the viewer's attention. The darkness is intended to stimulate the viewer's imagination (Calahan, 1996). Figure 2 is an example of low-key lighting in a scene created by the author.

Figure 2. An example of low-key lighting

Lighting style is also often defined by quality of light. Based on Birn's book (2013), the main qualities of light that the viewer notices in a picture are color, brightness, softness, throw pattern, and angle.

The number of logical sources will help determine the mood of the scene. For example, a single soft light from a candle may feel warm and romantic. It is to note that though the number of logical sources is small, the actual number of lights used to achieve a look may be many. This is true in live-action and even more so in lighting for 3D animated scenes (Calahan, 1996).

While the work of Calahan (1996), Birn (2013), and Rangaswamy (2000) is well-known and highly informative, they did not hold a study to test the theories of cinematic lighting's emotional and narrative effects. In this thesis, we held an empirical study with the goal to further the study on the effects in mind.

2.3 Light colors and emotions

The use of color is one of the most powerful tools if lighting designer wants to play with the audience's emotions. The right color can greatly affect the scene's mood or even change the meaning of the scene (Birn, 2013).

Colors can evoke physiological, psychological and emotional responses. Because these responses associate with the viewer's past experiences and cultural heritage, two people can have different reactions to the same color. A person can also have a varied reactions to the same color based on its context of use. However, there are enough common life experiences and contexts within which to draw some generalizations about how color affects us emotionally (Calahan, 1996).

Colors are often characterized as *warm*, *cool* or *neutral*. Neutral colors are desaturated, almost grey looking colors (Calahan, 1996). Red, orange and yellow are generally described as warm colors as opposed to blue and green, which are cool colors (Birn, 2013). Figure 3-5 shows 3D animated scenes with warm, cool, and neutral color.

Birn (2013) has described the meanings of colors in his book as follow:

Red can trigger alarm because it is the color of blood and fire. This is the same reason why people hesitate to push red button or go through red door. The stop sign and signs with strong warning often use red.

Yellow is considered a bright, cheerful color. When the audience sees a scene that is dominated by bright yellow people often expect a happy story.

Blue and green are soothing and relaxing. Blue lighting can also take on sad feelings or create the cold or winter impression. Green is the color of natural

environment since it is the color of trees and grass. However, green lighting can also suggest sickness. A character turning green can look very sick. Light green is also often used in hospitals walls (Birn, 2013).

Figure 3. An example of warm color scene

Figure 4. An example of cool color scene

Figure 5. An example of neutral color scene

It is important to note that while some associations are universally recognized, such as green is the color of natural, red is the color of blood, and yellow is the color of sunshine, other associations are culturally specific. In the United States, the color red is associated with communism so campaigns on the political left would avoid using red color in their advertisements. However, in Canada red and white are the colors of their flag so political advertisements widely feature the color red (Birn, 2013). In Thailand, the color yellow is the King's color. It is thus often associated with royalty and majesty.

Within a narrative film, the meaning of specific colors can be redefined. Characters can have their own color schemes, which might be used in their home environment, props, costumes or even skin colors, especially in 3D animated film. For example, once the audience is subconsciously accustomed to certain colors appearing

with the villains, any new information appearing in the film using the villains' color schemes can appear sinister (Birn, 2013).

This concept appeared in Disney/Pixar's Inside Out where the main characters are five personifications of a young girl's basic emotions. Each character has their own color scheme. The character Joy has bright yellow skin while Sadness's skin is blue. Fear's color is purple, Disgust's color is green and Anger is the red skinned character who explodes in flame when he is angry (Pixar's Inside Out, 2015).

More broadly beyond films and movies, much research in experimental and cognitive psychology has addressed the link between color and emotions. In Michael Hemphill's study on adults' color-emotion associations (1996) 20 men and 20 women were asked to complete a questionnaire about their favorite colors, recording their emotional responses and the reasons for their answer. Colored cardboards were used to represent 10 different colors in this study. Based on their responses, brighter colors got more positive responses than darker colors. Positive responses related to happy, excited and relaxed, while negative responses related to anxious, boring and sad. (Hemphill, 1996)

In Kaya and Epps's study (2004), different colors were shown on a computer screen to college students. The latter were asked about their emotional response they associate with each color. The results were that the colors green and yellow attained the most positive responses. Emotional responses for the green color indicated the feelings of relaxation, calmness, happiness, comfort, peace, hope, and excitement. Similarly, yellow was seen to be lively and energetic and elicited positive emotions including

happiness and excitement. They mentioned that the color blue revealed positive emotions (calmness) as well as negative ones (sadness). Red also had the similar results by indicating both positive (romance) and negative (fight and evil) emotions. Finally, the color purple elicited the feelings of relaxation and calmness (Kaya & Epps, 2004).

Valdez and Mehrabian (1994) conducted 3 studies addressing the effects of colors' brightness, saturation and hue on emotions. The results show that the participants' pleasure increased with brightness more than saturation. Their arousal level increased linearly with color saturation but decreased when color brightness increased. Dominance level increased linearly with color saturation and decreased with increases in color brightness. On the contrary, relationships of hue to emotions were weak, especially for arousal and dominance reactions (Valdez & Mehrabian, 1994).

While there is a large body of literature on the psychology of color, the colors were often shown as solid color on screen or paper. This thesis specifically explores the effects of light colors in computer animation lighting designs.

2.4 Cinematic lighting and storytelling

Visual storytelling is a broad topic and consists much more than just lighting. Most of the time lighting is not noticeable on a conscious level to the audience but lighting adds depth and richness to the story and visual experience (Calahan, 1996). In her work, Storytelling through Lighting, Calahan (1996) mentioned that the primary purpose of lighting is storytelling. In lighting design, the lighting designer attempts to reveal the vision of the director who is the storyteller. It is extremely important to understand the story and motivation behind each shot and how they relate to the whole

story. Even before the viewer understand the whole story-point, the lighting style can suggest a feeling for a scene.

Calahan adapted the principle knowledge and theories from design, fine art, photography, illustration, cinematography, and the psychology of visual perception, and developed the theories and suggestions of how to create lighting design that can enhance storytelling in computer graphic (Calahan, 1996).

Shots are often on screen very shortly and the effectiveness of storytelling for each shot depends on how quickly the viewer eye is led to the key story element. The simple act of placing the lights can change the composition and focus point of the shot (Calahan, 1996).

For lighting in 3D animated film, exaggeration is often used by both animator and lighting designer. Purely natural or physically corrected lighting is often not enough to create drama and captivating the viewer. Pushing the limits of reality can create magic and beauty that connects the imagination with the story being told (Calahan, 1996).

Lighting can also conveying the time of day and seasons which is important to place the story and illustrate the passages of time. In the early morning, the rising sun casts long shadows, and the color of the light is slightly blue. At noon, when the sun is overhead, the lack of shadows tends to flatten the images and make color appear less vibrant and interesting while in the evening, the shadows are long, and the color of the light appears redder from the sunset (Calahan, 1996).

Lighting style, color and direction can affect the audience's impression for certain characters. It can also tell the audience about the character's situation or

emotional state of mind. Hard edged shadow and dark lighting are commonly used to signify an evil or criminal character or situation. Direct lighting from overhead can look gloomy when the character is looking down. However the same overhead lighting can look uplifting and hopeful if the character looks up toward the light. (Calahan, 1996).

There is a need to create a specific lighting design for each unique story. How the story is told, structured and how it should be experienced will require specific lighting approaches to direct viewer's attention for effective storytelling (Adenuga, 2016).

Oriyomi Adewale Adenuga's work, Adapting cinematic and theatrical lighting to virtual reality storytelling focuses on translating principles of cinematic and theatrical lighting into virtual world storytelling. He explored the use of cinematic lighting to direct viewer attention and enhance storytelling in visual reality world.
The study illustrated the samples of his lighting approaches, adapted from the use of light contrast, light color, fading lights, pulsing light, and follow spotlights. The study provides the insight of effective ways to design lighting in virtual world scenarios to best benefit storytelling. He created guidelines to be considered when using lighting to direct viewer attention in virtual reality storytelling. (Adenuga, 2016).

Many works and studies on storytelling through lighting (Adenuga, 2016; Calahan, 1996; Rangaswamy, 2000) were created for educational purposes to be guidelines for lighting artists. However, it is noteworthy that a study were not conducted to test these theories.

2.5 Lighting approach

In both Birn's book (2013) and John Kahrs's (1996) work, they have mentioned *Three-point lighting* which is one of the most popular and basic approaches. The three points in three points lighting consists of 3 lights that each has a different role. A *key light* is the primary source of illumination (Kahrs, 1996). It is often brighter than other lights illuminating the subject and usually casts the most visible shadows in the scene (Birn, 2013). A common key light placement provides 3/4 illumination. 3/4 refers to the fact that the majority of the subject, for example, someone's face is illuminated (Kahrs, 1996). Figure 6 shows an example of a key light in a ¾ placement. The key light position also depends on what is motivate the scene (Birn, 2013).

A fill light softens, filled the shadows that are created by the key light and make more of the subject visible (Birn, 2013; Kahrs, 1996). On a real set, there are two different categories of fill light. One kind of fill light could be called *natural ambient*. That is, the light that reflects off of objects lit by general illumination. The other kind of fill light is *added fill*, or lights that are added by the filmmaker to fill the shadows, making them softer (Kahrs, 1996). In three-points lighting, the fill light is added fill. Figure 7 shows an image with a key light and a fill light.

A rim light which sometimes called a back light provides highlights and created a defining edges to separate the subject from the background (Birn, 2013). In some cases rim light can to bring a stylized quality to the image. When it has no relationship to what might occur naturally in the scene, it tends to looks very stylized but in a good way. It's often what separates ordinary life from Hollywood film. The rim light often positioned

directly opposite from the key light (Kahrs, 1996). Figure 8 shows an example of three-point lighting with key light, fill light and rim light. Figure 9 shows an example of lighting placement in three-point lighting approach.

Key, fill, and rim light are not only the lights in three-point lighting, they are commonly used in cinematic lighting in general including lighting designs in our study. Three-point lighting technique was also used when we lit the scenes for the study.

Figure 6. An example of a scene with a key light

Figure 7. An example of a scene with a key light and a fill light

Figure 8. An example of three-point lighting with key, fill and rim light

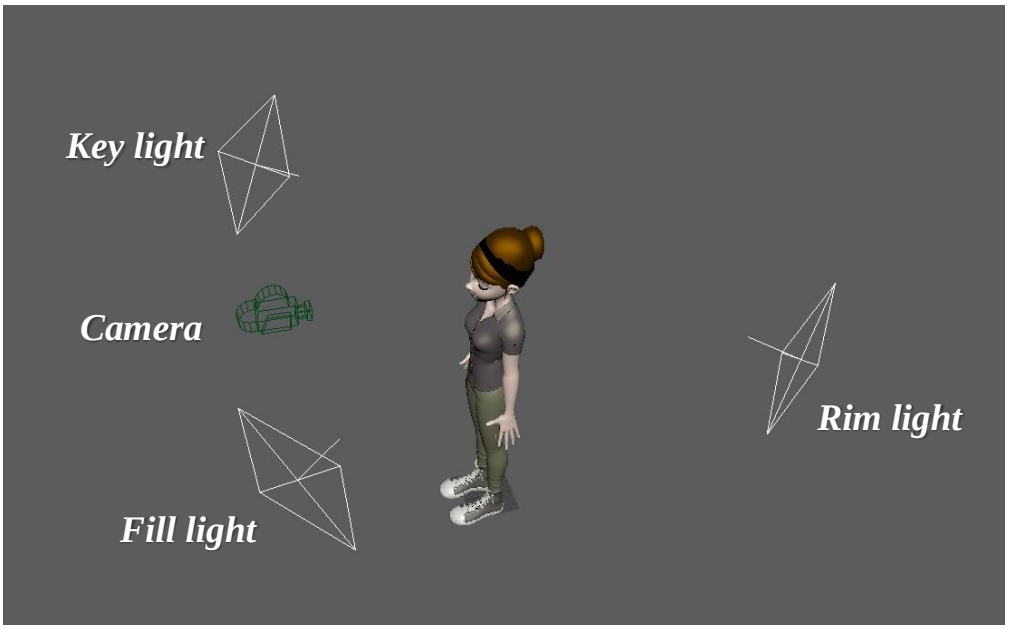

Figure 9. Three-point lighting setup and placement from the scene

2.6 Interactive lighting

Real-time rendering and rendering techniques used in interactive entertainment have improved in recent years, including interactive lighting. In El-Nasr and Hosrwill's study (2004) they developed a new real-time lighting design model based on cinematic lighting design theory. The model automatically and in real-time adapts the lighting to the changing and unpredictable situation according to the design goals which are supplying visual focus, dramatic tension, providing mood, and maintaining visual continuity. Their model, ELE (Expressive Lighting Engine) uses optimization to balance the many visual design goals suggested by cinematic lighting design theory and accommodates the unpredictability of the interactive environment. The model also

automatically adapts the lighting to suit the situation and enhance the tension and emotional stimulation.

Based on the number of characters in the frame and the dramatic importance of their action, ELE determines where to direct viewers' attention. Then dynamically assigns lights to visible areas in the scene. Once lights are assigned to specific areas, ELE selects angles and colors for each light. The light setup is then given to the rendering engine to render the frame (El-Nasr & Horswill, 2004).

In Joshua Tanenbaum & Angela Tomizu (2007) study, they created a prototype for an interactive multimedia storytelling project. The prototype is intended to be closer to the experience of reading a comic book with choices for user to choose. They used techniques from film and comic book for conveying happy, scary, and melancholy mood. In their work, colors and brightness are the major factors to create the mood and enhances visual storytelling. The user's choices that mapped to happy narrative results cause an incense in the color yellow and a small amount of the color red to create impression of a bright, sunny day. Choices mapped to scary results increase blue values while darkening the image. Melancholy image is represented using muted color values giving the impression of a rainy afternoon. (Tanenbaum & Tomizu, 2007).

These studies (El-Nasr & Horswill, 2004; Tanenbaum & Tomizu, 2007) are just two of many interactive lighting technologies that has emerged. New interactive lighting technologies are always developing and the understanding of specific lighting design's effects to the viewer and story can benefit these technology. If we know the relationship of lighting and viewer's emotion and story interpretation. It may be possible to combine

the knowledge with interactive technology to creative interactive real-time lighting based on the viewer's emotion.

3. METHODOLOGY

3.1 Study design

In our study, each participant looked at 6 video clips in one random color of light, as such: 2 scenes X (2 lighting styles + 1 video with no cinematic lighting). The variable color had 6 levels: red, green, yellow, blue, purple, and neutral. The videos for each color used variations of high-key lighting and low-key lighting styles, as shown in Table 1. A base condition of the scene without cinematic lighting was also added for each scene. The independent variables thus were lighting style (High-key lighting and Low-key lighting) and colors of light. The dependent variables were viewer's emotions and story interpretation. After looking at each video the participants were asked to answer survey questions about how they felt and the story they perceived in the scenes. The protocol of how the study was run is detailed in appendix B.

Table 1. Videos generated from lighting styles variations

Lighting technique	Color					
	Red	**Green**	**Yellow**	**Blue**	**Purple**	**Neutral**
High-key lighting	A shot with red tone lighting and using high-key lighting technique	A shot with green tone lighting and used high-key lighting technique	A shot with yellow tone lighting and used high-key lighting technique	A shot with blue tone lighting and used high-key lighting technique	A shot with purple tone lighting and used high-key lighting technique	A shot with neutral lighting and used high-key lighting technique
Low-key lighting	A shot with red tone lighting and used low-key lighting technique	A shot with green tone lighting and used low-key lighting technique	A shot with yellow tone lighting and used low-key lighting technique	A shot with blue tone lighting and used low-key lighting technique	A shot with purple tone lighting and used low-key lighting technique	A shot with neutral lighting and used low-key lighting technique

3.2 Study participants

The study was conducted with 72 participants over 18 years old. Twenty-one of the participants were recruited through the Texas A&M University bulk email system. These 21 participants, consisting of Texas A&M University students and employees, participated in the study in a face-to-face session with the researcher in an on-campus lab. Survey forms were administered in the sessions, and an interview was conducted during the study. The rest 51 study participants were recruited from and have anonymously participated online through the Amazon Mechanical Turk platform. Participants over 18 years old who are interested could participate regardless of age,

gender, occupation, and nationality. Demographics of the participants can be found in Appendix F.

The online participants watched the video clips and filled out the survey forms through Mechanical Turk. No interview was conducted for the online participants. However, the interview questions were converted to written open-ended survey questions for online participants. While we did not expect the online participants to provide as long or in-depth answers to the open-ended questions as compared to the face-to-face participants in an interview format, the data gathered was still valid.

Results from the study *Running Experiments on Amazon Mechanical Turk* (Paolacci, Chandler, & Ipeirotis, 2010) shows that Mechanical Turk is a reliable source of experimental data and the obtained results did not substantially differ from results obtained in a subject pool at a large university (Paolacci et al., 2010).

3.3 Study materials

3.3.1 Scenes setup

For this study, two different 3D animated scenes were created in Autodesk Maya. A rigged female character model is a free character for animators from the *Free Rig* project by José Manuel García Alvarez and Antonio Méndez Lora (Alvarez & Lora, 2014). The props and room models were from *Lighting Challenges Forum* (Vacek & Tousek, 2006).

It is important to note that in this study we chose to use the stylized character designed with cartoon features. The animated scenes have stylized (cartoon) looks as opposed to realistic looks which may affect the results because stylized animation

usually has light hearted feels to it and is often considered less serious or intense compare to realistic looks.

After simple textures were applied to the character, props and background, we animated two different scenes. In the first scene the female character is sitting at a desk, using a computer until her facial expression suggests that she saw something on the screen (termed ‘Computer scene’ henceforth). This scene is 4 seconds long. Figure 10 shows a still image from this scene.

In the second scene, we changed the character’s skin tone slightly, hair and cloths color. The scene shows the character opening a door from her room without showing her face (termed ‘Door scene’ henceforth).. This scene is 2 seconds long. Figure 11 shows a still image of from scene.

We created the two scenes intentionally such that in one, the character’s face is shown, but not in the other scene. This was to allow for greater generalization of our results since in animated films, not every scene that the viewer can see characters’ faces. We also restrained the character from showing any specific expression such as smiling, frowning or have any specific expression through body languages so that the participants can freely perceived the story in any direction based on the different in lighting alone.

Figure 10. The Computer scene

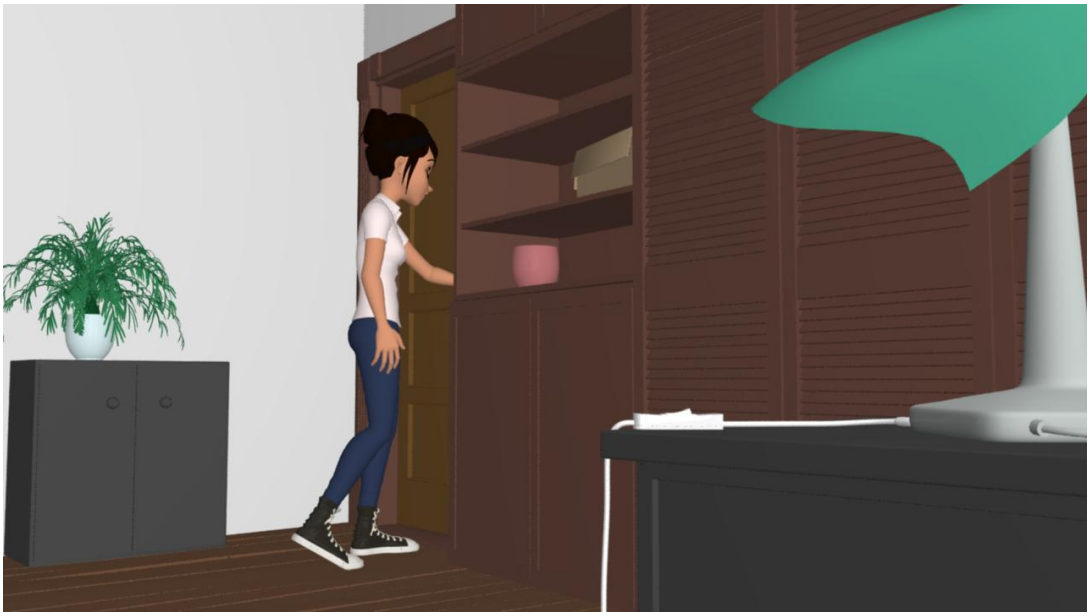

Figure 11. The Door scene

3.3.2 Applying lighting

After setting up the two scenes, we applied each scene with 12 different lighting designs: 6 colors X (2 lighting styles). One scene with no cinematic lighting design was also be generated. In total, we generated 26 videos, as such: 2 scenes X [(6 colors X (2 lighting styles)) + 1 video without cinematic lighting]. *Mental Ray* was used for lighting and rendering.

HSL color model

Lighting colors and values were picked and adjusted using HSL (hue, saturation, and lightness) color chooser in Autodesk Maya. A picture of the color chooser can be found in Appendix E. HSL is common cylindrical-coordinate representations of points in an RGB color model ("HSL and HSV," 2017). HSL color swatches ("HSL and HSV," 2017) were adjusted and applied. Ranges of the hue values used for each light color in this study are listed below.

- Red: H=350-5
- Blue: H=170-240
- Yellow: H= 20-55
- Purple: H= 245-290
- Green: H= 90-150
- Neutral: Varied colors with low saturation values (S= 0.05-0.45)

Applying lighting to the Computer scene

Three-point lighting was the main approach used in this scene with additional fill-lights to make the background visible. We first applied environment lighting using

image based lighting. Image-based lighting is typically used to create high quality reflections from an environment (Bjorke, 2004). Then three-point lighting technique was used to light the character. The three-point lighting process started with the key light, then the fill light and the rim light in order. Figure 12 shows the lights and how they were placed. All lights are area lights except the point lights, which were used to create the eye highlights.

Three additional fill lights were used to light the background and make the room more visible. The first light was placed right below the ceiling shining down. The second light was right above the floor shining up to simulate light bouncing off the ground. The third light was on the right side of the scene shining to the wall on the left.

The character's eyes were lit separately to create highlights in them that the key light can't provide. Eye highlights help make a character look alive (Birn, 2013). We used two lights for the eyes, one fill light and one point light to create eye highlights.

In total, 8 lights were used in this scene. Their values were adjusted to achieve high-key and low-key lighting styles. Figure 13 shows the lighting process.

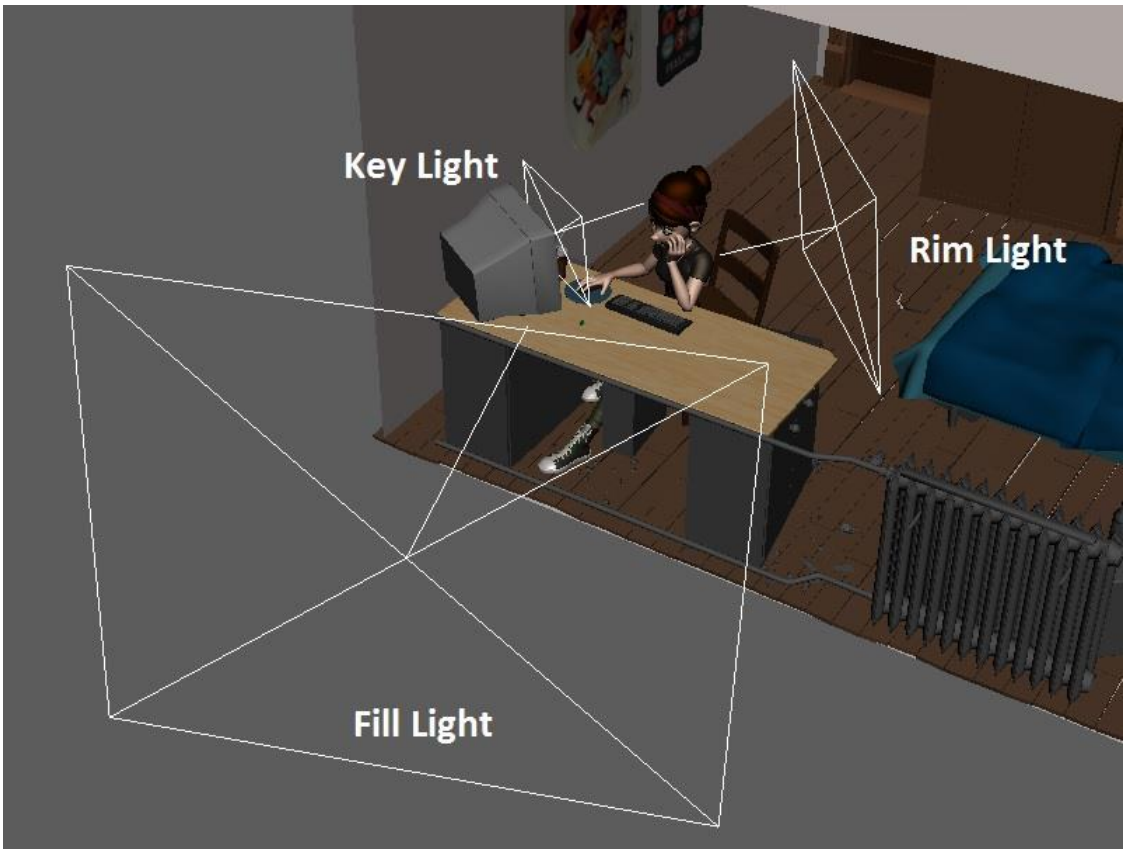

Figure 12. Three-point lighting's lights placement in the Computer scene

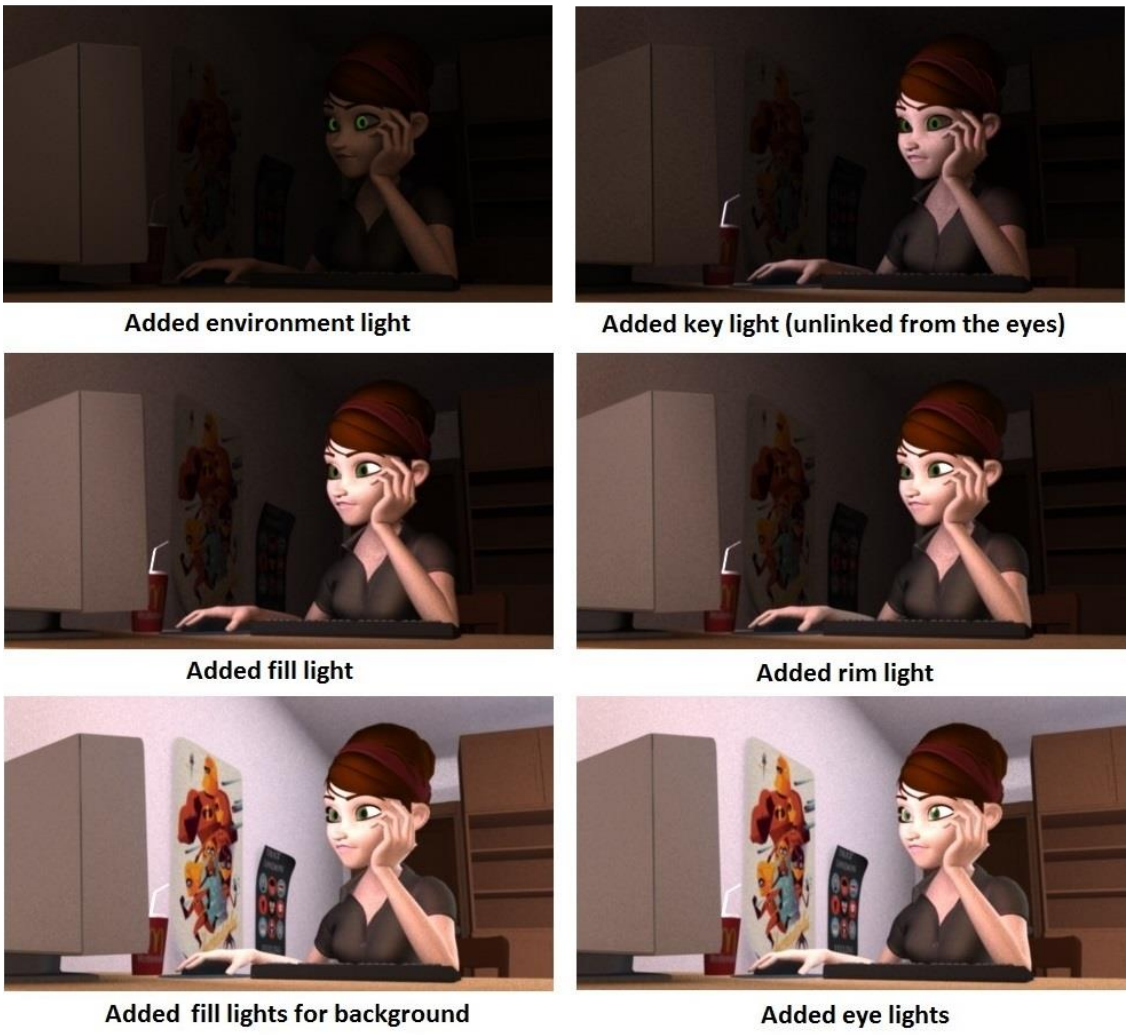

Figure 13. An example of lighting process for the Computer scene

High-key lighting

To approach high-key lighting in this scene, we set the key light's intensity to be in the range of 0.1-0.2. The scale of key light is 28.6, 23.0, 44.7 (x, y, z). The fill light's intensity is in the range of 0.1-0.15. The fill light scale is 114.1, 91.9, 178.2. The rim light's intensity is in the range of 0.025-0.06. The rim light scale is 55.4, 55.4, 55.4. For the three additional fill lights for the background, they have the intensity in the range of

0.03-0.14. For the high-key lighting style, the fill light for the eyes is in grey color with 0.2 intensity. The point light for the eye highlights is in white color with 0.9 intensity.

The difference in bright ness between the main key and fill light or the key-to-fill ratio was approximately 1.5:1 which resulted in bright and low contrast lighting.

We applied lighting and rendered the Computer scene with high-key light in 6 light colors red, blue, yellow, purple, green and neutral. To achieved the overall bright, well lit look of high-key lighting (Calahan, 1996) we made a subjective decision to make the light colors intensity lower when applied high-key lighting to the scene. When the light color is too intense it creates the darker impression to the scene. We also slightly changed some of the lights intensity when lighting with different colors to make the lights compliment the color more.

The reason of these subjective decisions was that good lighting setups were developed from the needs of the situation (Calahan, 1996) and one lighting intensity or property may complement one color but not with the others. To not limit some lighting properties to certain numbers or rules would be closer to how a lighting designer would work in real life (Birn, 2013; Calahan, 1996). However, we did limit the lights intensity within the specific range for consistency. Figure 14 shows the Computer scene lit with high-key lighting technique in 6 light colors.

Figure 14. The Computer scene lit with high-key lighting in 6 light colors

Low-key lighting

When applying low-key lighting for this scene, all lights position and scale were the same as when we applied high-key lighting. However, the light colors' saturation was higher (between 0.48-1) and lights intensities were adjusted to make to scene darker and achieve low-key lighting look. The main key light intensity was in the range of 0.1-

0.20. The main fill light (in three-point lighting set up) intensity was in the range of 0.01-0.05. The rim light intensity was in the range of 0.045-0.5. The key-to-fill ratio was kept approximately 5:1 which resulted in higher contrast shot.

For the additional fill lights for the background. The floor light and the ceiling light intensity were in the low range of 0.001-0.01 and the fill right from the right of the scene has 0.04-0.1 intensity across all colors. The eye lights had the same intensity but color were changed to support the more saturated lighting. Figure 15 shows the Computer scene lit with low-key lighting technique in 6 light colors.

Figure 15. The Computer scene lit with low-key lighting in 6 light colors

The scene without cinematic lighting

Though the scene was not lit with any cinematic lighting style, an ambient light with 0 ambient shade were placed in the scene to make the scene visible for the viewer. Figure 10 shows the Computer scene without cinematic lighting design.

Apply lighting to the Door scene

In this full shot scene we did not use the traditional three-point lighting like in the Computer scene. We first applied environment lighting using image based lighting. In this scene we did not make the image based lighting primary visible, so the image wouldn't show up from outside the door. Then 5 lights in total were placed: a key light, a rim light from the door, 2 fill lights and a point light from the lamp. Note that the point light from the lamp was not used when lit with high-key technique since the room is already bright and well lit. Based on Birn's suggestion that a light without a purpose or motivation should not be added (Birn, 2013) we made a subjective decision that the dim light from the lamp would not serve any significant purpose in the high-key lighting for this scene, thus we did not use it while applying high-key lighting.

The lighting process was similar with the first scene. We started with the key light then added both fill lights followed by the rim light and lastly we added the point light for the lamp (in low-key lighting scenario). Figure 16 shows where the key light and the rim light were placed in this scene. One fill light was placed right under the ceiling shining down. Another fill light was placed right above the floor shining up. The point light was placed inside the lamp where the light bulb is supposed to be. All the lights except the point light in the lamp were area lights. Figure 17 shows the process of lighting the Door scene.

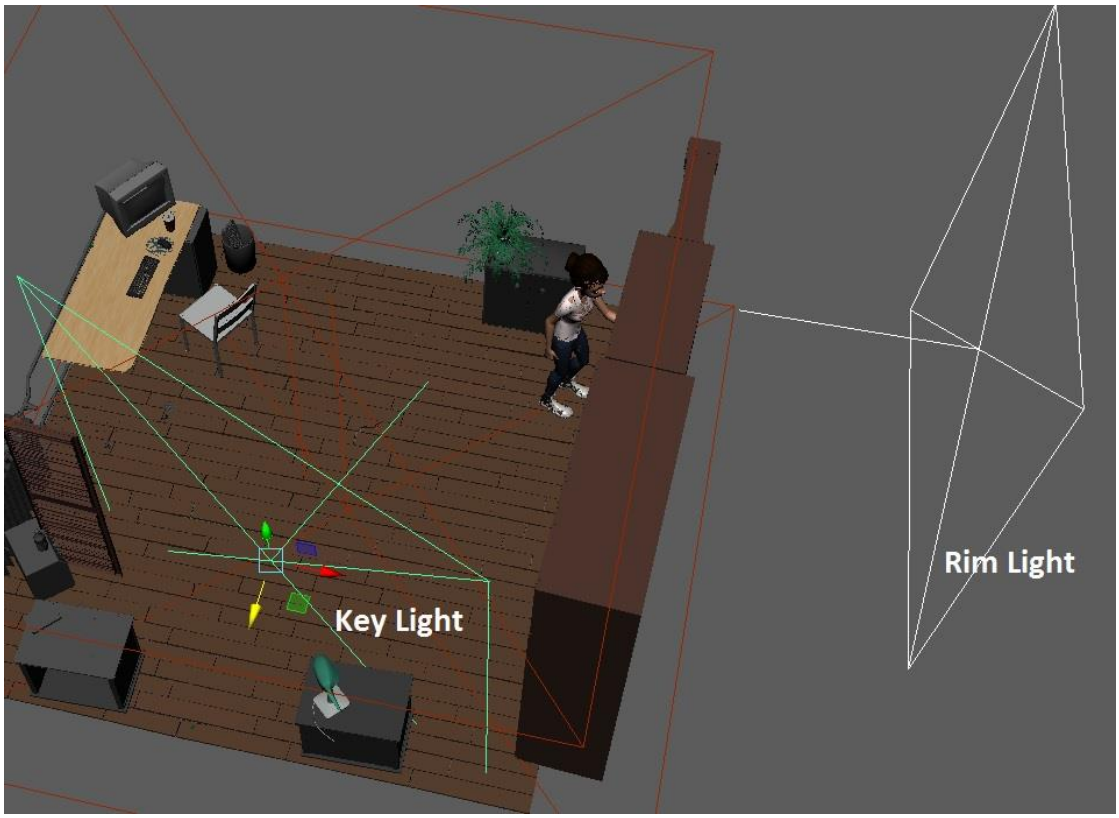

Figure 16. Lights placement in the Door scene

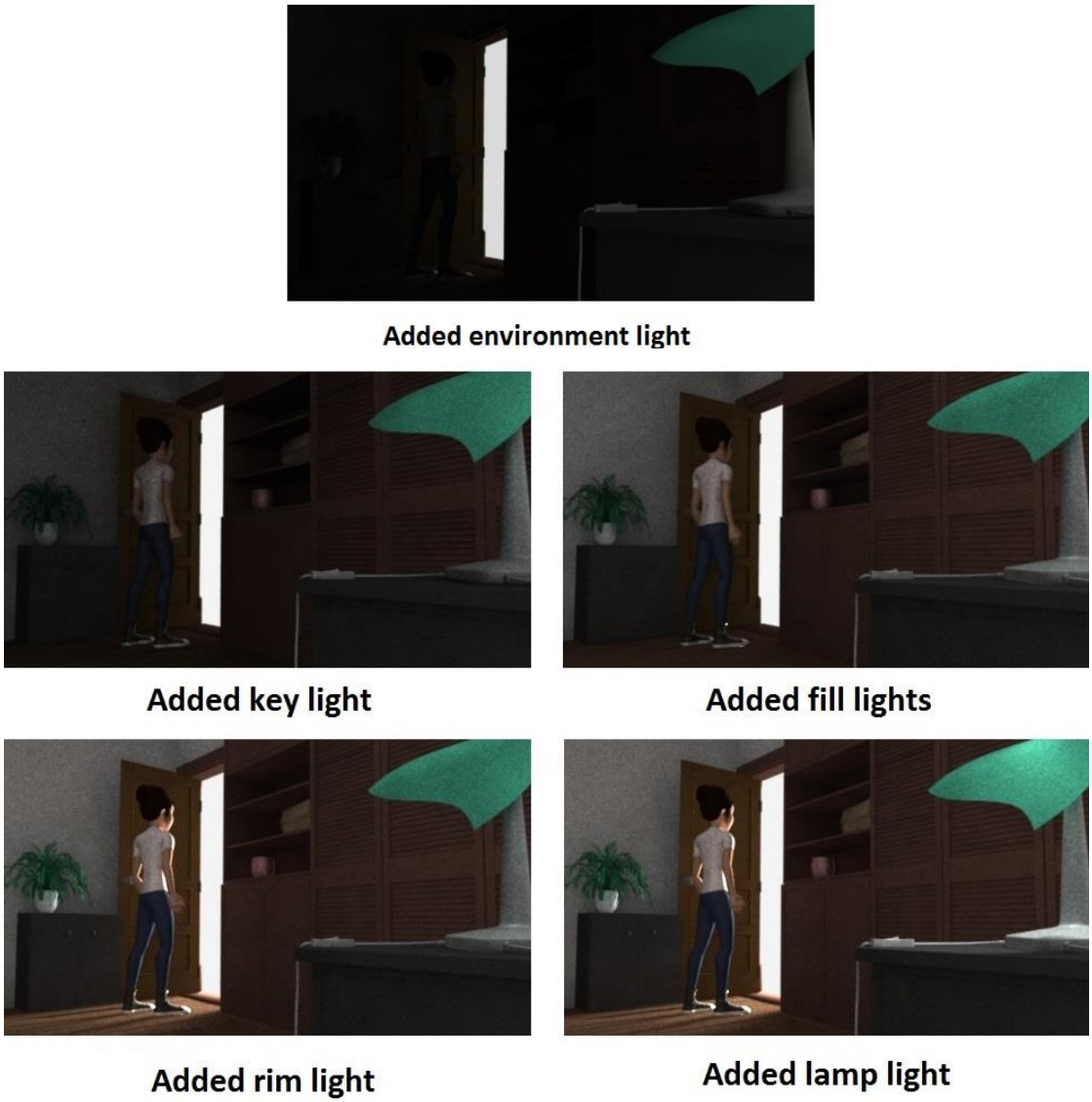

Figure 17. An example of lighting process for the Door scene

High-key lighting

When we applied the lighting in this scene using high-key lighting technique, the key light was set to be in the range of 0.1-0.20 and scaled 172.8, 172.8, 172.8. The fill light placed right below the ceiling had 0.01 intensity and its scale is 232.5, 258.9, 232.5

while the fill light placed right above the floor has 0.06 intensity and scaled 258.2, 258.2, 258.2. The rim light from outside the door had 0.15 intensity and its scale were 172.8, 172.8, 172.8. The key-to-fill ratio was approximately 10:1. The ratio of rim light and fills light was 5:1. This resulted in bright and low contrast lighting. Figure 18 shows the Door scene lit with high-key lighting technique in 6 light colors.

Figure 18. The Door scene lit with high-key lighting in 6 light colors

Low-key lighting

To approach low-key lighting to this scene, we applied the key-light with 0.02 intensity. Both fill lights has 0.01 intensity. The rim light from the door has the intensity in the range of 0.6-1. These lights had the same scale as when we lit this scene with high-key lighting technique. Lastly, the point light in lamp has 0.6 intensity. Similarly to the Computer scene, when we lit the Door scene the light colors are more saturated with the saturation between 0.6-1. The camera background color was adjusted to be in the same color as the lights but less saturated (0.2-0.7). The key-to-fill ratio was 2:1 but the ratio between rim and fill light was approximately 80:1 resulted in high contrast lighting once the character opens the door. Figure 19 shows the Door scene lit with low-key lighting technique in 6 light colors.

Figure 19. The Door scene lit with low-key lighting in 6 light colors

The scene without cinematic lighting

The video of the scene with no cinematic lighting design was generated with only an ambient light with 0 ambient shade. The ambient light is not a part of any cinematic lighting design but was placed to make the scene visible for the viewer. Figure 11 shows the Door scene without cinematic lighting design.

3.3.3 Composition

After the scenes were lit and rendered (generated), we used the NUKE program to give the scenes' foreground and background the blur effect to create depth for the scenes and direct the viewer's focus to the character.

3.4 Study measures

The emotions felt by the viewer were measured using the PANAS-X scale (Watson & Clark, 1994) immediately after each video viewing. The PANAS-X scale can be used validly to assess short term, state effect. Not only can the scale measure positive and negative affect but also four basic negative emotions (fear, hostility, guilt, and sadness), three basic positive emotions (joviality, self-assurance, and attentiveness), and four more complex affective states (shyness, fatigue, serenity, and surprise) (Watson & Clark, 1994)

In additional, we will measure participants' emotions before and after the study with Self-Assessment-Manikin scales (Bradley & Lang, 1994).

Open ended questions such as "What do you think made you feel that way?", "What do you think she saw?", and "What do you thing the story is about?" were asked immediately after the viewing of each scene video to assess how the viewer perceive the story. For the participants who participated in person, 3 open ended questions from the questionnaire were converted into an audio interview. Detailed survey questions can be found in appendix A.

4. DATA ANALYSIS AND RESULTS

4.1 Data analysis

4.1.1 Quantitative data analysis

Quantitative data analysis was done in the *IBM SPSS Statistics* software. We used one-way and two-way ANOVAs to detect whether there are any significant differences among the effects created by the various lighting styles for the scenes.

One-way and one-way Welch ANOVA were conducted to determine if the emotional effects were different for different lighting designs. One-way ANOVA (analysis of variance) is statistical test used to determine whether there are any statistically significant differences between the means of two or more independent groups (Laerd Statistics, 2015). Since the one-way ANOVA is an omnibus test statistic and cannot tell us which lighting designs were significantly different from each other (Laerd Statistics, 2015), Tukey and Games-Howell post hoc tests were conducted to identify the lighting designs.

A two-way mixed ANOVA was conducted to examine the effects of lighting style and light color on emotional effects. Two-way mixed ANOVA (analysis of variance) is statistical test used to determine whether there is an interaction effect between two independent variables on a continuous dependent variable (i.e., if a two-way interaction effect exists) (Laerd Statistics, 2015).

4.1.2 Qualitative data analysis

Qualitative data analysis was done in *MAXQDA: Qualitative Data Analysis* software using grounded theory qualitative coding method. *Coding* describes the process of selecting part of the data material, for example a paragraph and assigning a code to it (VERBI Software, 2016). In this study, an axial coding process was performed whereby for each question, categories were formed from respondents' answers. After every participant's answers were examined and coded, counts were made in terms of frequency of answers. We then analyze the data by comparing the codes for each question across the answers from every lighting style.

For the question "What do you think is the story of this scene?" we coded the participants' answers by similar event or story. We then grouped the answers by the story theme such as suspense, positive or scary. For the question "Do you think lighting affects movie scene? If yes, how do you think lighting can affect the scene?" We first coded the answers into two codes, "lighting affects movie scene" and "lighting does not affect movie scene". Then we categorized the answers of how lighting affect movie scene into codes such as "lighting affects emotions" or "lighting affects time of day".

4.2 Results

For simplicity's sake we will refer to variations in cinematic lighting designs used in this study by using the terms 'lighting style' and 'light color'. For example, "High-key Red" mean a lighting design with High-key lighting style and red light color. "No lighting" means the scenes did not use cinematic lighting design.

In this thesis “affect” is used as a verb meaning “to influence or make a difference to” while “effect” is used as a noun meaning “a result or influence” (Oxford Dictionaries, 2014). However in official PANAS-X scale, some scales such as positive and negative were called “affect” and we decided to refer to those scales by their official name.

Also, there are differences between moods and emotion. Mood last longer than emotions. Moods can last for hours or days while emotions can be very brief, lasting for seconds or minutes. Emotions often have specific cause or reason while moods do not. Moods can also influence emotions. For example, a person in irritable mood will not be able to modulate anger as much as a person who are not in irritable mood (Ekman & Davidson, 1994). However, moods in this thesis referred to film moods which is defined as the affective character of a film, an expression of emotion and point of view. Film moods are capable of triggering viewers’ emotions (Plantinga, 2012).

4.2.1 Lighting design and emotions

Positive affect

In PANAS-X positive affect is one of the general dimension scales comprised of the following qualities: active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud and strong (Watson & Clark, 1994).

Table 2 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs that provides the highest positive affect are “High-key Green” (n=38, M=24.7, SD=7.8), followed by “Low-key Green” lighting design (n=38, M=22.0, SD=9.2), “Low-key Yellow” (n=34, M=19.9, SD=10.3), and “High-key

Yellow" (n=34, M=19.7, SD=10.0) in order. It is noteworthy that there is very little difference in positive affect between "High-key Yellow" and "Low-key Yellow" (0.12, 95% CI [-8.34, 8.58], p=1.00). Also, the video with "No lighting" design has relatively high positive affect (n=206, M=19.7, SD=8.8).

Additionally, a result from one-way Welch ANOVA showed that positive affect was statistically significantly different between different lighting designs, Welch's F(12, 173.684) = 4.770, p = < .0005. Games-Howell post hoc analysis revealed that the mean decrease from "High-key Green" to "High-key Neutral", "Low-key Purple", "High-key red", "High-key Purple", "Low-key Neutral", "No lighting" and "Low-key red" was statistically significant (p = < 0.05)

Table 2. Descriptive statistics for the lighting designs' Positive Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	19.74	8.77
High-key Red	38	17.11	7.01
Low-key Red	38	18.18	8.56
High-key Blue	32	19.50	8.27
Low-key Blue	32	19.38	9.56
High-key Yellow	34	19.74	10.05
Low-key Yellow	34	19.85	10.25
High-key Purple	30	16.87	7.82
Low-key Purple	30	15.93	6.53
High-key Green	38	24.74	7.82
Low-key Green	38	21.97	9.18
High-key Neutral	34	15.74	3.96
Low-key Neutral	34	18.44	6.36
Total	618	19.29	8.54

Negative affect

In PANAS-X negative affect is one of the general dimension scales comprised of the following qualities: afraid, scared, nervous, jittery, irritable, hostile, guilty, ashamed, upset, and distressed (Watson & Clark, 1994).

Table 3 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest negative affect are "High-key Neutral" (n=34, M=14.4, SD=5.6), "Low-key Purple" (n=30, M=14.3, SD=4.4), and "Low-key Red" (n=38, M=14.0, SD=5.8)

A one-way Welch ANOVA was conducted and Games-Howell post hoc analysis revealed that the mean decrease from "Low-key Purple" to "High-key Yellow" (3.30, 95% CI [0.20, 6.39]) was statistically significant (p = 0.028).

Table 3. Descriptive statistics for the lighting designs' Negative Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	11.39	3.10
High-key Red	38	13.37	6.18
Low-key Red	38	13.97	5.82
High-key Blue	32	11.13	2.21
Low-key Blue	32	13.22	4.79
High-key Yellow	34	10.97	2.02
Low-key Yellow	34	11.12	2.76
High-key Purple	30	11.27	3.22
Low-key Purple	30	14.27	4.42
High-key Green	38	12.29	3.45
Low-key Green	38	12.74	3.51
High-key Neutral	34	14.35	5.61
Low-key Neutral	34	13.03	4.39
Total	618	12.24	4.05

Joviality

In PANAS-X Joviality scale was comprised of 8 factors: happy, joyful, delighted, cheerful, excited, enthusiastic, lively, and energetic (Watson & Clark, 1994).

Table 4 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest joviality affect are “High-key Green” (n=38, M=19.3, SD=7.3), “High-key yellow” (n=34, M=16.7, SD=10.4), and “Low-key Yellow” (n=34, M=16.5, SD=9.6) in order.

Results from the one-way Welch ANOVA showed that joviality affect was statistically significantly different between lighting designs, Welch's $F(12, 174.282) = 5.291$, $p = < .0005$. Games-Howell post hoc analysis revealed that the mean decrease from “High-key Green” to “Low-key Purple”, “High-key Neutral”, “Low-key Neutral”, and “Low-key red” and the mean decrease from “No lighting” to “High-key Neutral” and “Low-key Purple” were statistically significant ($p = < 0.05$).

Table 4. Descriptive statistics for the lighting designs' Joviality Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	16.07	8.74
High-key Red	38	14.50	7.91
Low-key Red	38	13.13	8.13
High-key Blue	32	15.19	7.42
Low-key Blue	32	13.22	8.06
High-key Yellow	34	16.71	10.39
Low-key Yellow	34	16.50	9.57
High-key Purple	30	14.73	7.80
Low-key Purple	30	11.10	5.14
High-key Green	38	19.26	7.34
Low-key Green	38	16.11	7.92
High-key Neutral	34	11.06	4.26
Low-key Neutral	34	12.97	6.35
Total	618	15.10	8.25

Self-assurance

In PANAS-X Self-Assurance scale was comprised of 6 factors: proud, strong, confident, bold, daring, and fearless (Watson & Clark, 1994).

Table 5 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest self-assurance affect are "High-key Green" (n=38, M=13.7, SD=6.4), "Low-key Green" (n=38, M=12.6, SD=5.6), "Low-key Neutral" (n=34, M=11.1, SD=5.8), and "High-key Blue" (n=32, M=11.0, SD=5.9).

Results from the one-way Welch ANOVA showed that self-assurance was statistically significantly different between lighting designs, Welch's F(12, 172.652) = 3.019, p = 0.001. Games-Howell post hoc analysis revealed that the mean decrease from “High-key Green” to “High-key Neutral” and “Low-key Purple”, the mean decrease from “Low-key Green” to “High-key Neutral” and the mean decrease from “No lighting” to “High-key Neutral” were statistically significant (p = < 0.05).

Table 5. Descriptive statistics for the lighting designs’ Self-Assurance Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	10.76	5.14
High-key Red	38	9.79	4.74
Low-key Red	38	9.66	4.08
High-key Blue	32	11.00	5.92
Low-key Blue	32	10.75	6.36
High-key Yellow	34	9.88	4.11
Low-key Yellow	34	10.47	4.93
High-key Purple	30	9.20	5.70
Low-key Purple	30	8.87	4.01
High-key Green	38	13.71	6.37
Low-key Green	38	12.61	5.61
High-key Neutral	34	8.59	3.02
Low-key Neutral	34	11.09	5.75
Total	618	10.61	5.24

Attentiveness

In PANAS-X Attentiveness scale was comprised of 4 factors: alert, attentive, concentrating, and determined (Watson & Clark, 1994).

Table 6 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest attentiveness affect are “High-key Green” (n=38, M=12.7, SD=4.1), “Low-key Green” (n=38, M=12.0, SD=5.3), “Low-key Yellow” (n=34, M=9.6, SD=4.9), and “Low-key Blue” (n=32, M=9.4, SD=5.0).

A result from one-way Welch ANOVA showed that self-assurance affect was statistically significantly different between lighting designs, Welch's $F(12, 173.438) = 4.523$, $p = < 0.0005$. Games-Howell post hoc analysis revealed that the mean decrease from “High-key Green” to “High-key Neutral”, “High-key Purple”, “Low-key Purple”, “High-key Red”, “No lighting”, “Low-key Red” and “Low-key Neutral” and the mean decrease from “Low-key Green” to “High-key Purple”, “High-key Neutral”, “Low-key Purple” and “High-key Red” were statistically significant ($p = < 0.05$).

Table 6. Descriptive statistics for the lighting designs' Attentiveness Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	9.35	4.70
High-key Red	38	8.39	3.63
Low-key Red	38	8.97	4.16
High-key Blue	32	9.22	4.67
Low-key Blue	32	9.41	5.02
High-key Yellow	34	9.24	4.61
Low-key Yellow	34	9.56	4.85
High-key Purple	30	7.30	3.83
Low-key Purple	30	7.87	3.61
High-key Green	38	12.74	4.14
Low-key Green	38	12.03	5.34
High-key Neutral	34	8.18	2.89
Low-key Neutral	34	9.21	3.67
Total	618	9.40	4.55

Fear

In PANAS-X Fear scale was comprised of 6 factors: afraid, scared, frightened, nervous, jittery, and shaky (Watson & Clark, 1994).

Table 7 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest fear affect are "Low-key Red" (n=38, M=10.1, SD=5.2), "Low-key Purple" (n=30, M=10.0, SD=5.0), "Low-key Neutral" (n=34, M=8.9, SD=4.2), and "High-key Red" (n=34, M=8.9, SD=5.2) in order.

A result from one-way Welch ANOVA showed that fear affect was statistically significantly different between different lighting designs, Welch's $F(12, 170.047) = 4.860$, $p = < 0.0005$. Games-Howell post hoc analysis revealed that the mean decrease

from “Low-key Red” to “High-key Blue”, “High-key Yellow” and “No lighting” and the mean decrease from “Low-key Purple” to “High-key blue” were statistically significant ($p = < 0.05$).

Table 7. Descriptive statistics for the lighting designs’ Fear Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	6.85	2.25
High-key Red	38	8.89	5.24
Low-key Red	38	10.11	5.25
High-key Blue	32	6.53	1.29
Low-key Blue	32	8.41	3.86
High-key Yellow	34	6.74	1.58
Low-key Yellow	34	6.94	2.96
High-key Purple	30	7.00	2.20
Low-key Purple	30	9.97	4.99
High-key Green	38	7.74	3.10
Low-key Green	38	8.26	2.85
High-key Neutral	34	8.62	3.82
Low-key Neutral	34	8.91	4.15
Total	618	7.75	3.44

Hostility

In PANAS-X Hostility scale was comprised of 6 factors: angry, hostile, irritable, scornful, disgusted, and loathing (Watson & Clark, 1994).

Table 8 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest hostility affect are “Low-key

Green" (n=38, M=8.4, SD=2.9), "High-key Red" (n=38, M=8.3, SD=3.1), "High-key Green" (n=38, M=8.2, SD=2.2), and "Low-key Red" (n=38, M=7.8, SD=2.4).

A result from one-way Welch ANOVA showed that there were no statistically significant differences in hostility affect between the different lighting designs, Welch's $F(12, 172.464) = 1.142$, $p = 0.329$.

Table 8. Descriptive statistics for the lighting designs' Hostility Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	7.49	2.28
High-key Red	38	8.32	3.14
Low-key Red	38	7.82	2.38
High-key Blue	32	7.38	2.00
Low-key Blue	32	7.22	1.56
High-key Yellow	34	7.21	1.74
Low-key Yellow	34	7.44	2.19
High-key Purple	30	7.40	1.99
Low-key Purple	30	7.17	2.02
High-key Green	38	8.21	2.22
Low-key Green	38	8.45	2.93
High-key Neutral	34	7.74	3.14
Low-key Neutral	34	7.44	2.85
Total	618	7.61	2.38

Guilt

In PANAS-X Guilt scale was comprised of 6 factors: guilty, ashamed, blameworthy, angry at self, disgusted with self, and dissatisfied with self (Watson & Clark, 1994).

Table 9 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest guilt affect are “High-key Neutral” (n=34, M= 7.4, SD=3.0), “High-key Red” (n=38, M=7.4, SD=3.5), “Low-key Blue” (n=32, M=6.9, SD=2.6) and “High-key Green” (n=38, M=6.8, SD=2.3) in order.

A result from one-way Welch ANOVA showed that there were no statistically significant differences in guilt affect between the different lighting designs, Welch's $F(12, 175.424) = 1.178$, $p = 0.302$.

Table 9. Descriptive statistics for the lighting designs’ Guilt Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	6.58	1.95
High-key Red	38	7.42	3.49
Low-key Red	38	6.61	1.84
High-key Blue	32	6.50	0.98
Low-key Blue	32	6.94	2.56
High-key Yellow	34	6.38	1.67
Low-key Yellow	34	6.21	1.20
High-key Purple	30	6.40	1.65
Low-key Purple	30	6.30	0.65
High-key Green	38	6.79	2.27
Low-key Green	38	6.24	1.08
High-key Neutral	34	7.44	2.98
Low-key Neutral	34	6.65	2.51
Total	618	6.64	2.06

Sadness

In PANAS-X Sadness scale was comprised of 5 factors: sad, blue, downhearted, alone, and lonely (Watson & Clark, 1994).

Table 10 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest sadness affect are “Low-key Blue” (n=32, M=6.8, SD=3.1), “High-key Blue” (n=32, M=6.5, SD=2.4), and “High-key Neutral” (n=34, M=6.5, SD=2.6).

A result from one-way Welch ANOVA showed that there were no statistically significant differences in sadness affect between the different lighting designs, Welch's $F(12, 174.576) = 1.083$, $p = 0.377$.

Table 10. Descriptive statistics for the lighting designs’ Sadness Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	5.89	2.39
High-key Red	38	6.29	2.34
Low-key Red	38	5.79	1.34
High-key Blue	32	6.53	2.42
Low-key Blue	32	6.84	3.09
High-key Yellow	34	5.62	1.81
Low-key Yellow	34	5.62	1.63
High-key Purple	30	5.57	1.36
Low-key Purple	30	6.07	1.64
High-key Green	38	6.26	2.11
Low-key Green	38	5.84	1.44
High-key Neutral	34	6.47	2.62
Low-key Neutral	34	6.09	1.78
Total	618	6.02	2.16

Shyness

In PANAS-X Shyness scale was comprised of 4 factors: shy, bashful, sheepish, and timid (Watson & Clark, 1994).

Table 11 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest shyness affect are "Low-key Neutral" (n=34, M=5.5, SD=2.8), "High-key Neutral" (n=34, M=4.9, SD=1.9), and "High-key red" (n=38, M=4.8, SD=1.9).

Table 11. Descriptive statistics for the lighting designs' Shyness Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	4.53	1.34
High-key Red	38	4.84	1.92
Low-key Red	38	4.55	0.98
High-key Blue	32	4.41	0.80
Low-key Blue	32	4.19	0.64
High-key Yellow	34	4.68	1.66
Low-key Yellow	34	4.65	1.32
High-key Purple	30	4.37	0.76
Low-key Purple	30	4.17	0.38
High-key Green	38	4.47	2.05
Low-key Green	38	4.34	0.91
High-key Neutral	34	4.88	1.90
Low-key Neutral	34	5.47	2.77
Total	618	4.57	1.48

Fatigue

In PANAS-X Fatigue scale was comprised of 4 factors: sleepy, tired, sluggish, and drowsy (Watson & Clark, 1994).

Table 12 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest fatigue affect are “Low-key Neutral” (n=34, M=5.2, SD=2.0), “High-key Yellow” (n=34, M=5.1, SD=2.2), “Low-key Yellow” (n=34, M=5.1, SD=2.3), and “High-key Neutral” (n=34, M=5.1, SD=1.8).

A result from one-way Welch ANOVA showed that there were no statistically significant differences in fatigue affect between the different lighting designs, Welch's $F(12, 176.281) = 1.521$, $p = 0.120$.

Table 12. Descriptive statistics for the lighting designs’ Fatigue Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	4.95	2.27
High-key Red	38	4.61	1.31
Low-key Red	38	4.66	1.63
High-key Blue	32	4.34	0.97
Low-key Blue	32	4.50	1.05
High-key Yellow	34	5.12	2.23
Low-key Yellow	34	5.12	2.33
High-key Purple	30	5.00	1.74
Low-key Purple	30	4.43	1.10
High-key Green	38	4.39	1.08
Low-key Green	38	4.79	2.09
High-key Neutral	34	5.06	1.76
Low-key Neutral	34	5.18	2.04
Total	618	4.83	1.90

Serenity

In PANAS-X Serenity scale was comprised of 3 factors: calm, relaxed, and at ease (Watson & Clark, 1994).

Table 13 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest serenity affect are “High-key Green” (n=38, M=7.9, SD= 3.5), “High-key Yellow” (n=34, M=7.1, SD=3.9), “Low-key Yellow” (n=34, M=6.9, SD=4.5) and “Low-Key Neutral” (n=34, M=6.8, SD=3.5).

A result from one-way Welch ANOVA showed that serenity affect was statistically significantly different between different lighting designs, Welch's $F(12, 173.914) = 7.707$, $p = < 0.0005$. Games-Howell post hoc analysis revealed that the mean decrease from “High-key Green” to “Low-key Purple”, “Low-key Blue”, “Low-key Red”, and “High-key Red” ,the mean decrease from “Low-key Neutral” to “Low-key Purple”, The mean decrease from “Low-key Green” to “Low-key Purple”, The mean decrease from “High-key Yellow” to “Low-key Purple” and The mean decrease from “No light” to “Low-key Blue”, “Low-key Purple”, “High-key Red”, and “Low-key Red” were statistically significant ($p = < 0.05$).

Table 13. Descriptive statistics for the lighting designs' Serenity Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	7.18	3.48
High-key Red	38	4.97	2.51
Low-key Red	38	4.76	2.93
High-key Blue	32	5.50	2.95
Low-key Blue	32	4.56	2.42
High-key Yellow	34	7.15	3.89
Low-key Yellow	34	6.88	4.50
High-key Purple	30	5.40	2.55
Low-key Purple	30	4.17	1.95
High-key Green	38	7.92	3.51
Low-key Green	38	6.58	3.57
High-key Neutral	34	6.56	3.64
Low-key Neutral	34	6.79	3.49
Total	618	6.38	3.48

Surprise

In PANAS-X Surprise scale was comprised of 3 factors: amazed, surprised, and astonished (Watson & Clark, 1994).

Table 14 shows descriptive statistics for each lighting design. The results demonstrate that the lighting designs with the highest surprise affect are "High-key Yellow" (n=34, M=6.2, SD=3.7), "High-key Green" (n=38, M=5.6, SD=3.2), "Low-key Yellow" " (n=34, M=5.5, SD=3.0), and "Low-key Green" (n=38, M=5.5, SD=2.5).

A result from one-way Welch ANOVA showed that there were no statistically significant differences in surprise affect between the different lighting designs, Welch's $F(12, 173.197) = 1.714$, $p = 0.067$.

Table 14. Descriptive statistics for the lighting designs' Surprise Affect

Lighting Design	N	Mean	Std. Deviation
No lighting	206	5.37	2.88
High-key Red	38	4.97	2.72
Low-key Red	38	5.13	2.63
High-key Blue	32	5.28	2.40
Low-key Blue	32	5.44	1.98
High-key Yellow	34	6.18	3.66
Low-key Yellow	34	5.53	3.05
High-key Purple	30	5.40	2.97
Low-key Purple	30	5.23	3.23
High-key Green	38	5.58	3.21
Low-key Green	38	5.50	2.48
High-key Neutral	34	4.15	1.54
Low-key Neutral	34	5.29	2.52
Total	618	5.33	2.79

The difference between lighting styles

We compared emotional effects between high-key, low-key and no lighting style. Specifically, the PANAS-X's Positive affect, Negative affect, basic negative emotion scales (Fear, Hostility, Guilt, Sadness) and basic positive emotion scales (Joviality, Self-Assurance, Attentiveness). Table 15 shows descriptive statistics for each lighting design.

A one-way ANOVA was conducted to determine if Positive affect, Negative affect, basic negative emotion scales and basic positive emotion scales were different for different lighting styles. The lighting styles were classified into three groups: High-key lighting (n = 206), low-key lighting style (n = 206), and no lighting style (n=206). The results are listed as follows:

Positive affect

Positive affect increased from the low-key lighting style (M = 19.1, SD = 8.2) and high-key lighting style (M = 19.1, SD = 8.2), to no lighting (M = 19.7, SD = 8.8), but the differences between lighting styles was not statistically significant, F(2, 615) = 0.441, p = 0.644. It is noteworthy that while the positive affect of high-key and low-key lighting are equal, they are both different from the positive result of no lighting style.

Negative affect

Negative affect increased from no lighting style (M = 11.4, SD = 3.1) to high-key lighting style (M = 12.3, SD = 4.3), to low-key lighting style (M = 13.0, SD = 4.5), Negative affect was statistically significant between lighting styles, F(2, 615) = 8.819, p < .0005. Tukey post hoc analysis revealed that the mean increase from no lighting to low-key lighting was statistically significant, (1.7, (95% CI [0.73, 2.58], p = < .0005).

Basic positive emotion scales

Basic positive emotion scales increased from the low-key lighting style (M = 11.3, SD = 5.4) and high-key lighting style (M = 11.7, SD = 5.4), to no lighting (M = 12.0, SD = 5.7), but the differences between lighting styles was not statistically significant, F(2, 615) = 0.914, p = 0.401. It is noteworthy that the difference between high-key group and low-key lighting group are lesser compared to the difference between each of them with no lighting style group.

Basic negative emotion scales

Basic negative emotion scales increased from no lighting style (M = 6.7, SD = 1.8) to high-key lighting style (M = 7.1, SD = 2.2), to low-key lighting style (M = 7.2,

SD = 1.9). Basic negative emotion scales was statistically significant between lighting styles, F(2, 615) = 4.0, p =0.019. Tukey post hoc analysis revealed that the mean increase from no lighting to low-key lighting was statistically significant, (0.5, (95% CI [0.07, 0.98], p =0.019).

Table 15. Descriptive statistics for each lighting style

Scale	Lighting	N	Mean	Std. Deviation
Positive Affect	High-Key	206	19.06	8.19
	Low-Key	206	19.06	8.66
	No Lighting	206	19.74	8.77
	Total	618	19.29	8.54
Negative Affect	High-Key	206	12.28	4.31
	Low-Key	206	13.04	4.46
	No Lighting	206	11.39	3.10
	Total	618	12.24	4.05
Basic Negative Emotion Scales	High-Key	206	7.09	2.17
	Low-Key	206	7.22	1.91
	No Lighting	206	6.69	1.77
	Total	618	7.00	1.97
Basic Positive Emotion Scales	High-Key	206	11.67	5.38
	Low-Key	206	11.33	5.43
	No Lighting	206	12.06	5.69
	Total	618	11.69	5.50

The difference between light colors

A one-way Welch ANOVA was conducted to determine if the PANAS-X's positive affect, negative affect, basic negative emotion scales and basic positive emotion scales were different for different light colors. The results show that there were

statistically significant different between light colors all four scales as follows. (Descriptive statistic for the four scales can be found in Appendix C)

Positive affect

The positive affect was statistically significantly different for different color of light, Welch's $F(6, 222.790) = 6.557$, $p < .0005$. Games-Howell post hoc analysis revealed that the decreases from green light to no lighting ($p=0.035$), red ($p=0.001$), purple ($p < .0005$) and neutral ($p < .0005$) were statistically significant, as well as the decreases from no lighting to purple ($p=0.048$).

Negative affect

The negative affect was statistically significantly different for different color of light, Welch's $F(6, 214.128) = 5.657$, $p < .0005$. Games-Howell post hoc analysis revealed that the decreases from red light to yellow ($p= 0.011$) and no lighting ($p=0.032$) were statistically significant, as well as the decreases from neutral to yellow ($p= 0.003$) and no lighting ($p= 0.011$).

Basic positive emotion scales

The basic positive emotion scales was statistically significantly different for different color of light, Welch's $F(6, 219.836) = 3.152$, $p = 0.006$. Games-Howell post hoc analysis revealed that the decreases from green lighting to no lighting ($p=0.036$), red ($p=0.001$), blue($p=0.047$), purple($p<0.0005$) and neutral($p<0.0005$) were statistically significant, as well as the decreases from no lighting to purple($p=0.018$) and neutral($p=0.031$).

Basic negative emotion scales

The basic negative emotion scales was statistically significantly different for different color of light, Welch's F(6, 222.917) = 7.030, p < .0005. Games-Howell post hoc analysis revealed that the decreases from red lighting to yellow lighting (p= 0.037).

Interaction between lighting style and light color

Two-way mixed ANOVAs were conducted to examine if there is an interaction between the color of light and lighting style on the PANAS-X's positive affect, negative affect, basic negative emotion scales and basic positive emotion scales. The results are as follows.

Positive affect

There was a statistically significant interaction between the light color and lighting style on positive affect, F(10, 420) = 2.077, p = 0.025, partial η2 = 0.047.

Green: There was a statistically significant effect of lighting style on positive affect for the green light color group, F(2, 74) = 8.254, p = 0.001, partial η2 = 0.182.

- For green light color, positive affect was statistically significantly decreased in low-key lighting style compared to high-key lighting style (M = 2.80, SE = 0.80 mmol/L, p = 0.004) and no lighting style (M = 3.60, SE = 0.93 mmol/L, p = 0.002).

Neutral: There was a statistically significant effect of lighting style on positive affect for the neutral light color group, F(2, 66) = 4.212, p = 0.019, partial η2 = 0.113.

- For neutral light color, positive affect was statistically significantly decreased in high-key lighting style compared to low-key lighting style (M = 2.70, SE = 0.87 mmol/L, p = 0.011).

Negative affect

There was a statistically significant interaction between the light color and lighting style on negative affect, $F(10, 420) = 2.800$, $p = 0.002$, partial $\eta 2 = 0.062$.

Red: There was a statistically significant effect of lighting style on negative affect for the red light color group, $F(2, 94) = 6.148$, $p = 0.003$, partial $\eta 2 = 0.116$.

- For red light color, negative affect was statistically significantly increased in low-key lighting style compared to high-key lighting style (M = 2.19, SE = 0.77 mmol/L, p = 0.019) and no lighting style (M = 2.92, SE = 0.97 mmol/L, p = 0.013).

Blue: There was a statistically significant effect of lighting style on negative affect for the blue light color group, $F(2, 62) = 7.292$, $p = 0.001$, partial $\eta 2 = 0.190$.

- For blue light color, Negative Affect was statistically significantly increased in low-key lighting style compared to no lighting style (M = 2.63, SE = 0.83 mmol/L, p = 0.011).

Purple: There was a statistically significant effect of lighting style on negative affect for the purple light color group, $F(2, 58) = 9.697$, $p < 0.0005$, partial $\eta 2 = 0.251$.

- For purple light color, Negative Affect was statistically significantly increased in low-key lighting style compared to high-key lighting style (M = 3.00, SE = 1.00 mmol/L, p = 0.017) and no lighting style (M = 3.30, SE = 0.81 mmol/L, p = 0.001).

Green: There was a statistically significant effect of lighting style on negative affect for the green light color group, $F(2, 74) = 3.56$, $p = 0.033$, partial $\eta 2 = 0.088$.

Basic positive emotion scales

There was a statistically significant interaction between the light color and lighting styke on basic positive emotion scales, $F(10, 420) = 3.312$, $p < 0.0005$, partial $\eta 2 = 0.073$.

Red: There was a statistically significant effect of lighting style on basic positive emotion scales for the red light color group, $F(2, 94) = 4.38$, $p = 0.015$, partial $\eta 2 = 0.085$.

- For red light color, basic positive emotion was statistically significantly increased in high-key lighting style compared to low-key lighting style (M = 1.40, SE = 0.50 mmol/L, p = 0.022).

Blue: There was a statistically significant effect of lighting style on basic positive emotion scales for the blue light color group, $F(2, 62) = 6.51$, $p = 0.003$, partial $\eta 2 = 0.174$

- For blue light color, basic positive emotion was statistically significantly increased in no lighting style compared to low-key lighting style (M = 2.27, SE = 0.74 mmol/L, p = 0.013).

Green: There was a statistically significant effect of lighting style on basic positive emotion scales for the green light color group, $F(2, 74) = 6.838$, $p = 0.002$, partial $\eta 2 = 0.156$.

- For green light color, basic positive emotion was statistically significantly decreased in low-key lighting style compared to high-key lighting style ($M = 1.66$, $SE = 0.54$ mmol/L, $p = 0.012$) and no lighting style ($M = 1.99$, $SE = 0.59$ mmol/L, $p = 0.006$).

Neutral: There was a statistically significant effect of lighting style on basic positive emotion scales for the neutral light color group, $F(2, 66) = 3.540$, $p = 0.035$, partial $\eta 2 = 0.097$.

- For neutral light color, basic positive emotion was statistically significantly increased in low-key lighting style compared to high-key lighting style ($M = 1.81$, $SE = 0.58$ mmol/L, $p = 0.011$).

Basic negative emotion scales

There was no statistically significant interaction between the light color and lighting style on basic negative emotion scales, $F(10, 420) = 1.647$, $p = 0.91$, partial $\eta 2 = 0.038$.

Causes of the emotional effects

After the participants answered each PANAS-X scale we asked them “What made you feel that way?” We separated the answers into three groups by the style of lighting used in shown videos, including the videos without cinematic lighting (no

lighting). We then coded the qualitative data in MAXQDA program. Table 4.15 shows the codes from each lighting styles.

The table demonstrates that story anticipation has the highest frequency in high-key lighting and no lighting style group, while it has the second highest frequency in the low-key lighting style group. Lighting has the highest frequency in low-key lighting group, second highest frequency in high-key lighting group and has the least frequency between the three groups in no lighting group. Character's reaction and overall character's expression have relatively high frequency in all three group. Overall character's expression also has the second highest frequency in no lighting group.

Table 16. Codes from the question "What made you feel that way?"

High-Key lighting	freq	%	Low-key lighting	freq	%	No lighting	freq	%
Story anticipation	24	17.0%	Lighting	50	36.2%	Story anticipation	21	15.3%
Lighting	18	12.8%	Story anticipation	22	15.9%	Overall character's expression	18	13.1%
Character's reaction	18	12.8%	Character's reaction	16	11.6%	Overall content	18	13.1%
Curiosity about what will happen next	16	11.3%	Curiosity about what will happen next	15	10.9%	Lighting	15	10.9%
Overall content	13	9.2%	Overall character's expression	10	7.2%	Character's reaction	14	10.2%
Overall Color	10	7.1%	Time of day	6	4.3%	Curiosity about what will happen next	10	7.3%
Scenes' repetition	10	7.1%	Overall Color	5	3.6%	Character's movement and acting	9	6.6%
Time of day	8	5.7%	Character's action	3	2.2%	Character's action	9	6.6%
Character's action	6	4.3%	Scenes' repetition	3	2.2%	Scenes' repetition	7	5.1%
Overall character's expression	5	3.5%	Animation's quality	3	2.2%	Time of day	5	3.6%
Character's movement and acting	4	2.8%	Character's movement and acting	2	1.4%	Props	4	2.9%
Animation quality	4	2.8%	Overall content	1	0.7%	Overall Color	3	2.2%
Camera	2	1.4%	Video's range	1	0.7%	Video's range	2	1.5%
Props	1	0.7%	Props	1	0.7%	Animation's quality	2	1.5%
The setting	1	0.7%		138			137	
Video's range	1	0.7%						
	141							

4.2.2 Results on the lighting designs' narrative effect

Story genres

After each video was watched, we asked the participants that "If this scene is a part of a story, what do you think is the genre of this story?" Table 17 shows the

participants' answers. Not including "No lighting", the lighting designs that the participants most associated with each story genres are listed as followed

Suspense/Thriller: "High-key Red", "High-key Blue" and "Low-key Green"

Sci-Fi: "High-key Yellow", "Low-key Yellow", and "Low-key Blue"

Romance: "High-key Red", "Low-key Red", and "High-key Blue"

Mystery: "Low-key Green", "High-key Green", and "Low-key Neutral"

Horror: "Low-key Red", "Low-key Purple" and "Low-key Blue"

Feel-Good: "Low-key Yellow", "High-key Yellow", "Low-key Neutral" and "High-key Green"

Fantasy: "Low-key Red", "Low-key Neutral", "Low-key Green" and "High-key Yellow"

Drama: "High-key Neutral", "Low-key Purple", and "Low-key Neutral"

Crime: "Low-key Blue", and "High-key Red"

Comedy: "High-key Purple", "High-key Green", "High-key Red" and "High-key Blue"

Adventure: "High-key Yellow", "High-key Green", and "Low-key Green"

Action: "High-key Green", "High-key Neutral", and "Low-key Red"

Table 17. Story genre results

		Lighting Design													Total
		No lighting	High-key Red	Low-key Red	High-key Blue	Low-key Blue	High-key Yellow	Low-key Yellow	High-key Purple	Low-key Purple	High-key Green	Low-key Green	High-key Neutral	Low-key Neutral	
Story Genre	Other	3	0	0	0	1	0	3	1	0	0	0	2	2	12
	Suspense/ Thriller	15	11	7	10	8	3	3	4	4	2	9	2	2	80
	Sci-Fi	4	0	2	0	3	4	4	0	1	0	2	0	0	20
	Romance	7	8	3	3	1	0	2	2	1	0	2	0	0	29
	Mystery	4	0	0	0	0	0	1	0	1	4	5	1	2	18
	Horror	6	3	12	3	11	1	4	0	11	2	8	2	7	70
	Feel-Good	37	5	0	4	0	7	10	5	0	7	1	4	7	87
	Fantasy	12	1	6	0	1	2	1	0	1	0	2	0	3	29
	Drama	61	3	4	7	3	9	3	9	11	8	5	19	10	152
	Crime	7	2	0	0	3	0	1	1	0	1	0	1	0	16
	Comedy	25	3	2	3	0	1	1	7	0	5	1	0	0	48
	Adventure	16	2	0	2	1	7	0	1	0	5	3	0	1	38
	Action	9	0	2	0	0	0	1	0	0	4	0	3	0	19
Total		206	38	38	32	32	34	34	30	30	38	38	34	34	618

Perceived story

After each video was shown we asked the participants an open ended question about what they think is the story of the scenes. Table 18 shows coded qualitative results of the perceived story. We also quoted the participants to show examples for each story theme. Explanation and examples of each story theme in the table are listed as follows:

Routine/regular activities

The data was coded with this code when it descripts the character doing everyday activity and not anything special. Examples of data from our study coded with this code are: “She was feeling hungry and waiting for the food she ordered and opening the door expecting the delivery boy”, “She probably heard someone knock at the door. It will probably be a friend or relative.” and “She is doing work on here pc.”

Positive scenario

We coded data with this code when it descripts positive story such as happy, good news, the character is having a good time or enjoying something. Some of the data that was coded with positive scenario are “The girl gets surprised with something pleasant, she must have been doing her routine work when she open that door she finds a surprise which makes her happy.” and “The character was checking her emails and she was surprised and delighted to find an email about a special gift from her friends.”. If, in some lighting design groups, there is no more than one *romantic* and *relax* code they will be included in positive scenario instead.

Negative scenario

Negative scenario is when the participants' answers descript negative story such as bad news, conflict, frustrating and bad or terrible event. Quotes for this code are "I think she saw something she did not want to see." and "I think she is at home checking her email or browsing the internet for news, and suddenly she comes across some bad news that she wasn't expecting, like family trouble or some world news problem."

Scary scenario

This code was used when the participants descript horror story, the character feel scared or saw something scary. Examples of the data coded with scary scenario are "I believe the character opened the door widely expecting someone she knew to be at the door and was scared when she saw no one was there and that there was no one in the vicinity." and "This clip definitely seems like a horror movie scene. Once again, the teenager hears something downstairs and goes to investigate."

The character is surprised

This code was used when the data descript the character as being surprised or seeing something that surprising or shocking. If, in some lighting design groups, there is no more than one *unexpected scenario* code it will be included with this code instead. An example of answers coded with this code is "It looks like at the end, she is surprised by something. Perhaps she was messaging with someone and something they said surprised her." It is to note that if the answer descripts "happy surprise" it will be code with *positive scenario* and not this code.

Unexpected scenario

This code was used when the participants mentioned the character experiencing unexpected event without being more specific beyond the word “unexpected”. For example, “The doorbell rings and she opens the door. She saw someone unexpected.” and “I think she found someone on internet which she was not expecting.”

The character is in danger

If the answer descripts the character in dangerous situation, being attacked by dangerous person or even get killed it is coded with this code. For example, “The red light seems that there is a dangerous situation.” and “She hears a knock at the door. She goes over to open it, and on the other side is someone who attacks or kidnaps her.”

The event happens during night/day time

The code was used when the answer specifically mentioned time of day.

The character is having interesting experience

The code was used when the answer descripts the character seeing something interesting or doing something interesting but it was not being specific beyond the word “interesting”. For example, “She might have seen an interesting photo of her friend on social network.” and “She might be browsing on the internet and found something interesting.”

Romantic scenario

This code is used when the answer descripts story related to love relationship, dating or the character’s love interest. Example of data coded with *romantic scenario* are “A love story, it’s like she is either trying to find something or stalking someone on

Facebook that is of her interest" and "She could be opening the door to a romantic dinner set up by her lover."

Suspense scenario

Our definition of suspense themed story is the same as how thriller and suspense films are descripted. Thriller and Suspense Film are types of films known to promote intense excitement, suspense, a high level of anticipation, ultra-heightened expectation, uncertainty, anxiety, and nerve-wracking tension. Thriller and suspense films are virtually synonymous and interchangeable categorizations, with similar characteristics and features (AMC filmsite, 2014). For example, "The door on her room was now closed and a trail of blood leading towards it. Sarah could not believe her eyes, blood marks like hands on the floor, like something or someone had been dragged inside her room." and "Suddenly she received an email, from an unknown address, she opened it, inside was a folder with pictures, she clicked on it, there were 23 photos, all of them of each victim of the killer, photos she had never seen before, photos not taken by the police."

Adventurous scenario

This code is used when the character is descripted to be going on an adventure or doing something adventurous. For example, "The woman goes to her best friend(s) with what she saw on the internet and convinces them to go on an adventure with her to find answers."

Intense/Drama scenario

The code is used when the participants mentioned "drama" genre or descripted intensely emotional scenario such as "Sarah had not seen her father for about 5 years

now, they had a fall out. Today was her father's birthday, someone knocked the door, she opened it, it was her father. They hugged and she started crying."

Exciting scenario

If the answer descripted the character doing something exciting or feeling excited it will be coded with this code. For example, "The lady is very excited. Her friend from college has called to say that she is passing through town and wants to stop to say hello."

Expecting the character to call someone for advices

One of the answer we sometimes got from the participants is that they think the character will call her friend or someone to discuss something or ask for advices. Those answers are code with this code. Some of the examples are "It could be an email attachment from a friend showing her a video of something exciting or scary. She'll probably end up calling her friend to discuss what she saw." (In this case the answer was coded with exciting and scary scenario as well.) And "She will probably calls or messages a friend to talk to them about it and plot what they should do next."

Comedy scenario

The answer was coded with this code when it descript the character seeing or doing something funny or comedy related. For example, "I think she was going through someone's Instagram pics and came across something shocking yet funny" in this case the data was also coded with s*urprise*.

Disgusting scenario

Examples of this code are "I think she was watching something on her computer and then saw something disgusting." And "The whole feel of the area is eerie."

Supernatural creatures are involved

Supernatural creatures in this case are aliens, zombies or monsters. Mostly fictional creatures that are not real. An example of coded data is “The girl heard a loud sound coming from outside the door. She opens the door to investigate to see glowing alien figures standing in her hallway.”

Supernatural scenario

The code is used when the data involved supernatural or paranormal story such as “I think maybe she heard about people who go to a certain website and are soon after found dead or something of that nature and she didn't believe it so she was dared and decided to do it and found something awful.”

Table 18. Perceived story qualitative data

High-key Red			High-key Blue			High-key Yellow		
Name	**freq**	**%**	**Name**	**freq**	**%**	**Name**	**freq**	**%**
Routine/regular activities	7	29%	Positive scenario	11	39%	Positive scenario	5	25%
Positive scenario	7	29%	Suspense scenario	5	18%	Romantic scenario	4	20%
Scary scenario	6	25%	The character is surprised	4	14%	Routine/regular activities	3	15%
The character is surprised	2	8%	Routine/regular activities	3	11%	The character is surprised	3	15%
Unexpected scenario	2	8%	The event happens during night time	3	11%	Adventurous scenario	3	15%
	24	100%	The character is having interesting experience	2	7%	Scary scenario	2	10%
				28	100%		20	100%
High-key Purple			High-key Green			High-key Neutral		
Name	**freq**	**%**	**Name**	**freq**	**%**	**Name**	**freq**	**%**
Positive scenario	5	20%	Routine/regular activities	6	27%	Routine/regular activities	7	30%
Routine/regular activities	4	16%	Negative scenario	6	27%	Negative scenario	5	22%
Scary scenario	3	12%	Suspense scenario	4	18%	Scary scenario	3	13%
Negative scenario	3	12%	Positive scenario	3	14%	The character is surprised	3	13%
Intense/Drama scenario	2	8%	The character is surprised	3	14%	Positive scenario	3	13%
Exciting scenario	2	8%		22	100%	Expecting the character to call someone for advices	2	9%
Romantic scenario	2	8%					23	100%
Expecting the character to call someone for advices	2	8%						
Comedy scenario	2	8%						
	25	100%						

Table 18 Continued.

Low-key Red			Low-key Blue			Low-key Yellow		
Name	**freq**	**%**	**Name**	**freq**	**%**	**Name**	**freq**	**%**
Suspense scenario	7	23%	Scary scenario	6	23%	Routine/regular activities	5	22%
Scary scenario	5	17%	The character is in danger	4	15%	Scary scenario	4	17%
The character is in danger	3	10%	Negative scenario	4	15%	Positive scenario	3	13%
Routine/regular activities	3	10%	Routine/regular activities	3	12%	Negative scenario	3	13%
Negative scenario	3	10%	Positive scenario	3	12%	The event happens during night time	2	9%
Disgusting scenario	3	10%	Supernatural creatures are involved	2	8%	The character is in danger	2	9%
The character is having interesting experience	2	7%	The event happens during night time	2	8%	Romantic scenario	2	9%
Supernatural creatures are involved	2	7%	The character is surprised	2	8%	Exciting scenario	2	9%
Crime/violent scenario	2	7%		26	100%		23	100%
	30	100%						
Low-key Purple			Low-key Green			Low-key Neutral		
Name	**freq**	**%**	**Name**	**freq**	**%**	**Name**	**freq**	**%**
Negative scenario	6	22%	Routine/regular activities	6	32%	Routine/regular activities	6	29%
Scary scenario	4	15%	Scary scenario	4	21%	The character is surprised	5	24%
Suspense scenario	4	15%	Negative scenario	4	21%	Positive scenario	2	10%
The event happens during night time	3	11%	The character is surprised	3	16%	Supernatural scenario	2	10%
Routine/regular activities	3	11%	Suspense scenario	2	11%	Unexpected scenario	2	10%
The character is in danger	3	11%		19	100%	Negative scenario	2	10%
The character is surprised	2	7%				The character is in danger	2	10%
Supernatural scenario	2	7%					21	100%
	27	100%						

It is noteworthy that green lighting which was highly associated with most positive emotional effects from the PANAS-X scales, was also associated with negative story theme, suspense and scary scenario. This could mean that while green lighting triggers positive emotional effects the story perceived from the scene with green lighting are not necessary positive. Still, the result shows that 13% of the stories perceived from High-key Green lighting design is positive.

In additional to the above qualitative data, we asked the participants what they think the character see. Appendix D shows the participants' answers.

4.2.3 Cinematic lighting effects in movie scenes

When asked personal opinion, 97% of the participant agreed that cinematic lighting affects movie scenes. 71% of those participants think that cinematic lighting affects the mood and emotional effect of the scene, 13% think that cinematic lighting affects the story of the scene, 9% think that lighting affects character's expression, while the rest think that lighting can direct viewer attention (4%) and affects time of day (3%). Figure 20 shows the participants' answers.

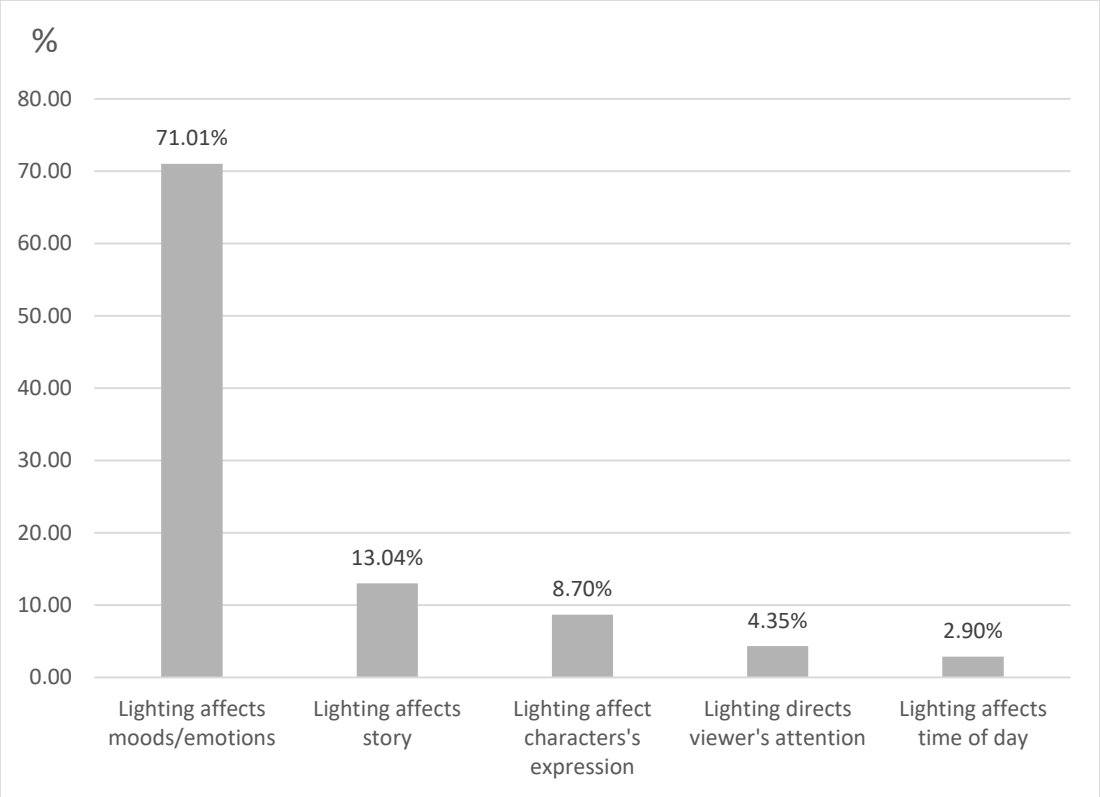

Figure 20. Effects of cinematic lighting in movie scenes

5. DISCUSSION AND LIGHTING RECOMMENDATIONS

5.1 Discussion

The study provided evidence regarding cinematic lighting's effects to viewers' emotions and perceived story. Cinematic lighting affects viewers' emotions, more strongly so in low-key lighting style. The results also show that the perceived stories are different for each lighting designs, proving the cinematic lighting's effects on storytelling.

5.1.1 Emotional effects

Results from table 16 shows that when the scene does not have cinematic lighting design, story, character's expression and overall content are what most affect viewers' emotions. For the scene with lighting designs, lighting and story are the biggest factors which affect viewers' emotions. Lighting is even bigger factor than story factor in low-key lighting scenes.

Result from lighting style's emotional effect shows that the effect was not present in a monolithic manner meaning that not every lighting styles effects emotions in every scales. The significant emotional effect was only found in low-key lighting style compared to no lighting and was only present in negative affect and negative emotions.

This could mean that, the dramatic nature of low-key lighting makes it affect emotions more strongly, but because low-key lighting often indicate negativity, the effect was only present on negative scales.

In additional, the scenes without cinematic lighting have the weakest negative affect and basic negative emotion scales. High-key lighting style provided less positive and basic positive emotion effects compared to no lighting group, which mean that high-key lighting style does not always provide strong positive and positive emotion effects.

Results from light color's emotional effect show that lighting color as well does not affect emotions in a monolithic manner. The effect of color on emotions was present in Positive &Negative Affect, Basic Positive Emotion but not on Basic negative Emotion Scales. Results from table 2 demonstrates that yellow and green light color provided the highest positive affect regardless of lighting style while "High-key Neutral", "Low-key Purple", and "Low-key Red" have the most negative affect in that order. This demonstrates that high-key lighting style, in this case "High-key Neutral", has higher negative affect than low-key lighting style.

It is also noteworthy that interaction between the color of light and lighting style was present only for positive affect, negative affect, and basic positive emotion scales.

The results from PANAS-X basic positive emotion scales are discussed as follows: High-key lighting with green and yellow lighting color provided the highest means in joviality scale. Yellow lighting in both high-key and low-key lighting style have statistically high joviality effect. The result confirmed existing theory that yellow and green lighting is often associated with happiness (Birn, 2013; Calahan, 1996; Kaya & Epps, 2004).

"High-key Green", "Low-key Green", "Low-key Neutral" and "High-key Blue" are lighting design with the highest self-assurance affect. "High-key Green", "Low-key

Green", "Low-key Yellow", and "Low-key Blue" lighting designs are lighting design with highest attentiveness affect. From these results, green seem to be the lighting color associated with most basic positive emotions followed by yellow light color. This is surprising because in past works (Birn, 2013; Calahan, 1996) though green lighting is also mentioned as a positive color, yellow lighting seems to be associated with positive emotions the most.

On the other hand, the results from PANAS-X basic negative emotion scales revealed that fear is most associated with "Low-key Red", "Low-key Purple", "Low-key Neutral", and "High-key Red" lighting design in order. Hostility is most associated with "Low-key Green", "High-key Red", "High-key Green", and "Low-key Red" lighting design. As we anticipated based on past work (Birn, 2013; Calahan, 1996; Rangaswamy, 2000), red lighting can trigger alarm, anger, and fear. On the guilt affect scale, "High-key Neutral", "High-key Red", "Low-key Blue", and "High-key Green" lighting design provided the highest mean.

"Low-key Blue", "High-key Blue", and "High-key Neutral" lighting design have the highest sadness affect, supporting Birn (2013) and Calahan's (1996) theory that blue lighting can take on sad feeling. It is interesting that while green lighting has strong effects on positive emotions, it is also highly associated with some negative emotions such as hostility and guilt. This supports Birn's (2013) and Calahan's (1996) theory that while green is generally a positive color, a symbol of nature and money which triggers the feelings of security, constancy, normalcy, balance, civility, and calmness, green lighting can also looks eerie, chemical and represents sickness.

Additionally, PANAS-X scale also provided us with other effective states as follows: Shyness is most associated with “Low-key Neutral”, “High-key Neutral”, and “High-key red” lighting design. Fatigue is most associated with neutral and yellow light color in both lighting styles. Serenity is most associated with “High-key Green”, “High-key Yellow”, “Low-key Yellow” and “Low-Key Neutral” lighting design. Lastly, the lighting designs with the highest surprise affect are “High-key Yellow”, “High-key Green”, “Low-key Yellow”, and “Low-key Green”.

5.1.2 Storytelling effects

The results from the study’s qualitative data shown in table 18 clearly demonstrates stories that the participants perceived from scenes with different lighting design. Positive scenario was most perceived when the scenes were lit with “High-key Red”, “High-key Blue”, “The results comfirm and “High-key Purple”. The results confirmed the theory that positive scenes are often lit with high-key lighting style (Rangaswamy, 2000) but while majority of the high-key indicated positive story high-key neutral and high-green lighting were associated with negative story theme. It is noteworthy that while green lighting is associated with most positive emotions, positive scenario is not the most perceived story from the scenes with green lighting.

Contrarily, Negative story was most perceived when the scenes were lit with “Low-key Purple” lighting design and also often perceived in the scene lit with “Low-key Green”, “Low-key Blue”, “High-key Neutral”, and “High-key Green”. Scary or horror story is often perceived when the scenes were lit with the low-key lighting style with the exception of “Low-key Neutral” design. Also often perceived in “High-key

Red", "High-key Purple" and "High-key Neutral". The lighting design where the scary scenario is most perceived is "Low-key Blue". The participants also frequently perceived that the character is in harm or dangerous situation when they saw the scenes lit with "Low-key Blue" and "Low-key Red" lighting design. Suspense scenario is another commonly perceived story. It is most perceived when the scenes were lit with "Low-key Red" lighting design. Also often perceived with "High-key Blue", "Low-key Purple", and "High-key Green" lighting design. The results support existing theories which states that red lighting is associated with blood, violence and danger (Birn, 2013; Calahan, 1996).

Romantic scenario was often perceived when the scenes lit with "High-key Yellow" lighting and slightly perceived with "High-key Purple" and "Low-key Yellow" lighting design.

The existing work states that that low-key lighting indicates danger (Rangaswamy, 2000), but our Results show that, it is true only for Low-key blue and Low-key red. From the results, low-key lighting style often makes the viewer interpret scary or horror story. Though many of the designs with high-key lighting associated with positive story, "High-key Green" and "High-key Neutral" are more associated with negative story.

5.1.3 Cinematic lighting effects in movie scenes

Results from subsection 4.3 confirmed that cinematic lighting affects movie scenes. Figure 20 shows the majority of the viewer think that lighting affects moods and emotions. The result supports the theories that lighting affects moods, directs viewer's

attention (Birn, 2013; Calahan, 1996; Lowell, 1999; Rangaswamy, 2000), affects time of day, and revealing character personality and situation (Calahan, 1996; Lowell, 1999). Additionally, the participants also think that lighting affects story.

5.2 Lighting design recommendations

When designing cinematic lighting for a scene, story is the first thing to consider. Before a 3D animated scene can be lit the lighting artist must understand the story the scene is telling and the moods needed to be perceived. Every scene has different story and cinematic lighting needed to be designed specifically for each scene. Most of the time when the project is not an individual work, lighting design in 3D animated project requires communication between lighting artist, director and art director (Calahan, 1996). After the story of each scene is analyzed the next step is to design cinematic lighting that will enhance the story and emotional impact of the scene.

Based on the results from our study, we developed lighting design recommendations that can help lighting artists achieved specific emotional and narrative effects. Though it is still to remember that lighting is a form of art, the purpose of these recommendations is to provide guidelines for lighting design. They are not rules lighting artists should limited themselves to. There is also practicality of the scene that needed to be considered. Lighting artists are encouraged to adapt and adjust from these recommendations to design lighting that will work best for the scene and one that they are satisfied with.

5.2.1 Lighting design to enhance emotional impact

The following recommendations are based on the results from our study. Lighting designs that were proven to best trigger specific emotions are listed along with the lighting designs that are not recommended. The recommended lighting designs are the ones that provided highest effects for each specific emotion from our study, while the lighting designs that provided statistically significant different effects from the recommended lighting designs were not recommended. They are listed in table 19 next to each specific emotional effects. If the *not recommended lighting designs* were not listed, that means the emotional effect was not statistically significant different between lighting designs for that specific emotion.

To use this recommendations, simply look for the emotional effect in the table 19 that is closest to the effect you want to trigger. For example, lighting designs recommended for joviality effect can be used when you want to trigger joyful or lively emotion. Section 4.2.1 provided detailed definition of each effect. Additionally, for simplicity's sake we will refer to cinematic lighting designs used in this study by lighting style-light and color. For example, "High-key Red" mean a lighting design with High-key lighting style and red light color.

Table 19. Recommended lighting designs to enhance specific emotional effects

Emotional effect	Recommended lighting designs	Not recommended lighting designs
Positive Affect	High-key Green, Low-key Green, Low-key Yellow, High-key Yellow	High-key Neutral, Low-key Purple, High-key red, High-key Purple, Low-key red
Negative Affect	High-key Neutral, Low-key Purple, Low-key Red	High-key Yellow
Joviality	High-key Green, High-key yellow, Low-key Yellow	Low-key Purple, High-key Neutral, Low-key red
Self-Assurance	High-key Green, Low-key Green, High-key Blue	High-key Neutral, Low-key Purple
Attentiveness	High-key Green, Low-key Green, Low-key Yellow, Low-key Blue	High-key Neutral, High-key Purple, Low-key Purple, High-key Red, Low-key Red, Low-key Neutral
Fear	Low-key Red, Low-key Purple, Low-key Neutral, High-key Red	High-key Blue, High-key Yellow
Hostility	Low-key Green, High-key Red, High-key Green, Low-key Red	N/A
Guilt	High-key Neutral, High-key Red, Low-key Blue, High-key Green	N/A
Sadness	Low-key Blue, High-key Blue, High-key Neutral	N/A
Shyness	Low-key Neutral, High-key Neutral, High-key red	N/A
Fatigue	Low-key Neutral, High-key Yellow, Low-key Yellow, High-key Neutral	N/A
Serenity	High-key Green, High-key yellow, Low-key Yellow, Low-Key Neutral	Low-key Purple, Low-key Blue, Low-key Red, High-key Red
Surprise	High-key Yellow, High-key Green, Low-key Yellow, Low-key Green	N/A

5.2.2 Lighting design to enhance story

The following recommendations are created by combining the qualitative results from table 17 and the result from table 18. The recommended lighting designs are the design that the participants most associated with each story theme. From the results on table 18 we listed the lighting designs with their top two most perceived story. If the story theme is not one of any lighting design top two, we will list two lighting designs that most associated with the story instead. We the added the story themes and lighting designs from table 17.

Please note that some lighting designs are recommended for more than one story theme. The reason we got repeated results is because other than lighting, we did not add any specific elements to specify the story theme (i.e. the character was not smiling or frowning) to give to participants full freedom to perceive story. The repetitive do not make the recommendations less effective. When design lighting in the scene, the lighting along with the other story elements should effectively tell the story.

To use this recommendations, look for the story theme in table 20 that most defines the story of your scene. Recommended lightings designs are listed next to each story theme. Section 4.2.2 explains most of the story themes more in details.

Table 20. Recommended lighting designs to enhance narrative effects

Story theme	Recommended lighting designs
Positive	High-key Yellow, Low-key Yellow, High-key Blue, High-key Red, High-key Purple
Negative	Low-key Purple, Low-key Green, Low-key Blue, High-key Neutral, High-key Green,
Scary	Low-key Red, Low-key Purple, Low-key Blue, Low-key Yellow, Low-key Green
Romantic	High-key Yellow, High-key Purple, High-key Red
Suspense	Low-key Red, Low-key Purple, High-key Blue, High-key Green
Dangerous	Low-key Blue, Low-key Red,
Exciting	High-key Purple, Low-key Yellow
Supernatural	Low-key Neutral, Low-key Purple
Sci-Fi	High-key Yellow, Low-key Yellow, Low-key Blue
Mystery	Low-key Green, High-key Green, Low-key Neutral
Fantasy	Low-key Red, Low-key Neutral, Low-key Green, High-key Yellow
Drama	High-key Purple, High-key Neutral, Low-key Purple
Crime	Low-key Blue, High-key Red,
Comedy	High-key Purple, High-key Green, High-key Red
Adventure	High-key Yellow, High-key Green, Low-key Green
Action	High-key Green, High-key Neutral, Low-key Red

6. CONCLUSION

6.1 Conclusion

There has been a number of work done regarding cinematic lighting but a study was not conducted to test those theories. In this thesis, we created twenty-six videos of animated scenes using high-key and low key lighting style and six different light colors. A perception study was conducted to investigate the effects of cinematic lighting in 3D animated scenes on viewers' emotions and perception of the narrative.

Using both quantitative and qualitative data analysis, we investigated and present detailed results on how different lighting designs affect specific emotions and story theme. Results show that the significant emotional effect was only found in low-key lighting style compared to no lighting and was only present in negative affect and negative emotions. The effect of lighting color on emotions was present in Positive &Negative Affect, Basic Positive Emotion but not on Basic negative Emotion Scales. Interaction between the color of light and lighting style was present for positive affect, negative affect, and basic positive emotion scales. We also confirmed some of the existing lighting theories.

Based on the findings, we developed lighting design recommendations to consider when design lighting for 3D animated scenes. The recommendations suggest best lighting designs to achieve specific emotional effects and enhance particular story theme.

6.2 Study limitations

1. Longer animated and higher quality animated scenes could be created.
2. In this study we did not try mixing more than one color together in one scene, in real lighting design light colors are sometimes mixed.
3. Because of the limitation of time & resources, we have each participant looked at 6 videos. Number of participant and animated scenes could be increased, to shorten the study time and have them watch less videos and repeated scenes.
4. Also, the results may affected by the participants' learned associations. Meaning that previous lighting in the past animated movies that they have seen may have affected their reaction.
5. The starting state of the participants, such as the mood they were in right before they started the study may affected the results.
6. The qualitative data analysis is lacking intercoder reliability. The coding and analysis was done by one person.

6.3 Future work

There is a lot of potential for future work on cinematic lighting and emotions. Especially when interactive technologies are advancing rapidly. It would be interesting to see lighting becomes so interactive that it could changes in real time based on the emotions detected from the viewer. This could potentially be developed for gaming, Virtue Reality or any type of interactive software.

Moreover, this study only focus on two lighting styles and six light colors. There are many more techniques and theories of lighting that could be tested and investigated.

Mixing more than one light color together in one scene may result differently. The other well-known lighting goals such as creating depth, directing viewer's eyes and maintaining continuity were not focused in this study and should be further explored.

The participants' demographics such as age and gender were also not analyzed. Analyses factoring these variables could be done in future works.

REFERENCES

Adenuga, O. A. (2016). *Adapting Cinematic and Theatrical Lighting to Virtual Reality Storytelling.* (Master's thesis), Texas A&M University. Retrieved from http://hdl.handle.net/1969.1/158599

Alvarez, J. M. G., & Lora, A. M. (2014). Mery Project. Retrieved from http://www.meryproject.com/

Autodesk Maya. (2016) [Computer Software]: Autodesk, Inc.

Birn, J. (2013). *[Digital] lighting and rendering* (2nd ed.). Berkeley: New Riders.

Bjorke, K. (2004). *Image-based lighting* : NVidia.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49-59.

Calahan, S. (1996). Storytelling through lighting: a computer graphics perspective. *SIGGRAPH course notes.* Retrieved from http://media.siggraph.org/education/cgsource/Archive/ConfereceCourses/S96/course30.pdf

Ekman, P. E., & Davidson, R. J. (1994). *The nature of emotion: Fundamental questions*: Oxford University Press.

El-Nasr, M. S., & Horswill, I. (2004). Automating lighting design for interactive entertainment. *Computers in Entertainment (CIE), 2*(2), 15-15.

Garcia, J. M. (2005). *Creating effective computer generated scene lighting using traditional film lighting techniques.* (Master's Thesis), Texas A&M University. Retrieved from http://hdl.handle.net/1969.1/3229

Hemphill, M. (1996). A note on adults' color-emotion associations. *J Genet Psychol, 157*(3), 275-280. doi:10.1080/00221325.1996.9914865

HSL and HSV (2017). *Wikipedia, The Free Encyclopedia.* Retrieved from https://en.wikipedia.org/w/index.php?title=HSL_and_HSV&oldid=765756890

Kahrs, J. (1996). Pixel Cinematography: Lighting for Computer Graphics. *SIGGRAPH course notes.* Retrieved from http://media.siggraph.org/education/cgsource/Archive/ConfereceCourses/S96/course30.pdf

Kaya, N., & Epps, H. H. (2004). Relationship between color and emotion: A study of college students. *College Student J, 38*(3), 396.

Lowell, R. (1999). *Matters of Light & Depth: Creating Memorable Images for Video, Film, & Stills through Lighting*. New York City, NY: Lowel-Light Manufacturing, Inc.

Millerson, G. (1999). *Lighting for television and film* (3rd ed.). Oxford ; Boston Focal Press.

Oxford Dictionaries. (2014). Affect or effect: a visual guide. Retrieved from http://blog.oxforddictionaries.com/2014/04/affect-vs-effect-quick-visual-guide/

Paolacci, G., Chandler, J., & Ipeirotis, P. (2010). Running experiments on Amazon Mechanical Turk. *Judgment and Decision Making, 5*(5), 411-419.

Plantinga, C. (2012). Art moods and human moods in narrative cinema. *New Literary History*, *43*(3), 455-475.

Rangaswamy, S. (2000). Visual Storytelling through Lighting. Retrieved from http://www.ibrarian.net/navon/paper/Visual_Storytelling_through_Lighting.pdf?paperid=5015888

Schaefer, D., & Salvato, L. (1984). *Masters of light : conversations with contemporary cinematographers*. Berkeley: University of California Press.

Laerd Statistics. (2015). *Statistical tutorials and software guides.* Retrieved from https://statistics.laerd.com/

Tanenbaum, J., & Tomizu, A. (2007). *Affective interaction design and narrative presentation.* Paper presented at the AAAI 2007 Fall Symposium on Intelligent Narrative Technologies.

AMC filmsite. (2014). *Thriller - Suspense Films.* Retrieved from http://www.filmsite.org/thrillerfilms.html

Vacek, D., & Tousek, D. (2006). Challenge #21: The Bedroom. *Lighting Challenges Forum.* Retrieved from http://www.3drender.com/challenges/

Valdez, P., & Mehrabian, A. (1994). Effects of color on emotions. *Journal of Experimental Psychology: General*, *123*(4), 394.

VERBI Software. (2016). MAXQDA 12 Getting Started Guide. Retrieved from http://www.maxqda.com/wp/wp-content/uploads/sites/2/Getting-Started-Guide-MAXQDA12-en.pdf

Watson, D., & Clark, L. A. (1994). The PANAS-X: Manual for the positive and negative affect schedule (expanded form). *Unpublished manuscript, University of Iowa, Iowa City*.

APPENDIX A

Pre-study survey questions

1. What is your age?

- ❑ 18-24 years old
- ❑ 25-34 years old
- ❑ 35-44 years old
- ❑ 45-54 years old
- ❑ 55-64 years old
- ❑ 65-74 years old
- ❑ 75 years or older

2. What is your gender?

- ❑ Female
- ❑ Male

3. How are you feeling right now? Please rate ALL three following scales.(SAM scale (Bradley & Lang, 1994))

3.1 Rate your pleasant level (Happy VS Unhappy)

(Participants rated their pleasant level using SAM scale (Bradley & Lang, 1994))

3.2 Rate your excitement level (Calm VS Excited)

(Participants rated their excitement level using SAM scale (Bradley & Lang, 1994))

3.3 Rate your dominance level (Controlled VS In-control)

(Participants rated their dominance level using SAM scale (Bradley & Lang, 1994))

Questionnaire after viewing each video

PANAS-X (Watson & Clark, 1994)

1. How did this video make your feel?

Read each item and then mark the appropriate answer in the space next to that word.

*1 or leave blank = not applicable

1 very slightly or not at all	2 a little	3 moderately	4 quite a bit	5 extremely
_____ cheerful	_____ sad	_____ active	_____ angry at self	
_____ disgusted	_____ calm	_____ guilty	_____ enthusiastic	
_____ attentive	_____ afraid	_____ joyful	_____ downhearted	
_____ bashful	_____ tired	_____ nervous	_____ sheepish	
_____ sluggish	_____ amazed	_____ lonely	_____ distressed	
_____ daring	_____ shaky	_____ sleepy	_____ blameworthy	
_____ surprised	_____ happy	_____ excited	_____ determined	
_____ strong	_____ timid	_____ hostile	_____ frightened	
_____ scornful	_____ alone	_____ proud	_____ astonished	
_____ relaxed	_____ alert	_____ jittery	_____ interested	
_____ irritable	_____ upset	_____ lively	_____ loathing	
_____ delighted	_____ angry	_____ ashamed	_____ confident	
_____ inspired	_____ bold	_____ at ease	_____ energetic	
_____ fearless	_____ blue	_____ scared	_____ concentrating	
_____ disgusted with self	_____ shy	_____ drowsy	_____ dissatisfied with self	

Figure 21. PANAS-X scale (Watson & Clark, 1994)

2. From the first question, what do you think made you feel that way?

3. Consider the lighting in this scene. What do you think the character saw on the screen (or after she opened the door)? Please rate each option in the scale of 1-5.

a) Something joyful

b) Something scary

c) Something sad

d) Something frustrating

e) Something disgusting

f) Other (please specify) :_____

4. Consider the lighting in this scene. What do you think the story of this scene is? In the answer, please also explain what do you think happened before this scene and what will happen after? Please be as specific as you can.

6. If this shot is a part of a story, what do you think is the genre of this story?

a) Action

b) Adventure

c) Comedy

d) Crime

e) Drama

f) Fantasy

g) Feel-good

h) Horror

i) Mystery

j) Romance

k) Sci-Fi

l) Suspense/thriller

m) Other (please specify: _____)

Post-study survey questions

1. How are you feeling right now? Please rate ALL three following scales.

(Figure A.1.-A.3. show all three SAM scale (Bradley & Lang, 1994).)

2. Compare image A with the image B. What are the differences that you see between the two images?

3. How would you describe your 3D animation background?

- ❏ My job (or school major) is directly related to 3D animation. I have an advanced knowledge of animation production.
- ❏ I create 3D animation as my hobby. I know about the overall animation production.
- ❏ I've heard of animation production and know a few things about the production process.
- ❏ I am a fan of 3D animated films. I can tell the differences in quality between each film.
- ❏ I watch 3D animated films sometimes but don't know much about them.
- ❏ I know nothing about 3D animation. I rarely (or never) watch them.

4. What is the most emotional film you have ever watched? What are the elements that you think make that movie or any other movies in general emotional?

5. In your opinion, do you think cinematic lighting can affect a movie's scenes? If yes, how do you think the lighting can affect the scene?

6. How did you feel about the entire experiment? Please give us a short feedback.

APPENDIX B

Study procedures

The procedures that will be followed for the study are as follows:

1. The participants read and acknowledge the information sheet.
2. Those who participate in person will be asked to sign a consent form if they decide to continue the study.
3. The participants will be asked to fill a pre-study questionnaire about their basic demographics (age and gender) and how are they feeling (Using SAM scales).
4. The participants will be asked to look at each of the 6 video clips one by one, in random order.
5. We will show a neutralizing image for 5 seconds before each video. Figure 22 is a neutralizing image sample. Looking at a neutralizing image will delete the after effects from focusing on the last video so it won't affect the participants when they start looking at the next video.
6. After looking at each video for up to 5 seconds they will be asked to fill in a questionnaire. (The video will still be shown while they are filling the questionnaire.)
7. The participants will move on to the next video after they are finished with the questionnaire.

8. After the participants finished looking at and answer questionnaires for all 6 videos, they will be asked to answer a post-survey questionnaire and comparing across all the videos that they have seen.
9. For those who participate in person, a few questions in the post-survey will be replaced with a short audio interview.
10. Participants will be debriefed at the end of the study.

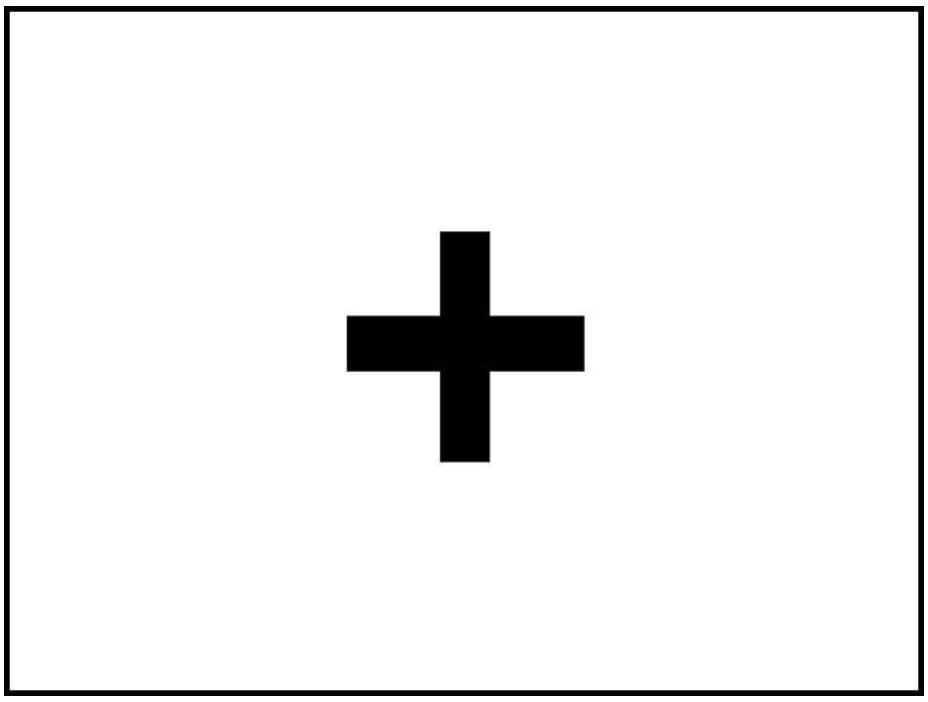

Figure 22. Neutralizing image

The study is expected to take approximately 60 minutes. Table 2 shows the estimated time for the activities.

Table 21. Estimated activity time

Activity		Time
Reading information sheet		5 minutes
Pre-study questionnaire		2 minutes
Per video	Neutralizing image	5 seconds (For 6 videos, 30 secs in total)
	Observing video clip	5 seconds (For 6 videos, 35 secs in total)
	Answering a questionnaire	6 minutes (For 6 videos, 36 minutes in total)
For 6 videos		30 secs + 35 secs + 36 mins = ~37 mins
Post-study questionnaire		11 minutes
Buffer time		5 minutes
Estimated total study time		(5 mins + 2 mins+ ~37 mins + 11 mins + 5 mins) = ~ 60 minutes

APPENDIX C

Table 22. Descriptive statistic for emotional effects of light colors

Effects	Light Color	N	Mean	Std. Deviation	Std. Error
Positive Affect	No light color	206	19.74	8.77	0.61
	Red	76	17.64	7.79	0.89
	Blue	64	19.44	8.87	1.11
	Yellow	68	19.79	10.08	1.22
	Purple	60	16.40	7.16	0.92
	Green	76	23.36	8.59	0.98
	Neutral	68	17.09	5.43	0.66
	Total	618	19.29	8.54	0.34
Negative Affect	No light color	206	11.39	3.10	0.22
	Red	76	13.67	5.97	0.69
	Blue	64	12.17	3.85	0.48
	Yellow	68	11.04	2.40	0.29
	Purple	60	12.77	4.12	0.53
	Green	76	12.51	3.46	0.40
	Neutral	68	13.69	5.05	0.61
	Total	618	12.24	4.05	0.16
Basic Negative Emotion Scales	No light color	206	6.69	1.77	0.12
	Red	76	7.65	2.77	0.32
	Blue	64	7.04	1.64	0.20
	Yellow	68	6.52	1.49	0.18
	Purple	60	6.96	1.50	0.19
	Green	76	7.22	1.69	0.19
	Neutral	68	7.42	2.50	0.30
	Total	618	7.00	1.97	0.08
Basic Positive Emotion Scales	No light color	206	12.06	5.69	0.40
	Red	76	10.74	4.97	0.57
	Blue	64	11.46	5.86	0.73
	Yellow	68	12.06	6.05	0.73
	Purple	60	9.67	4.59	0.59
	Green	76	14.41	5.61	0.64
	Neutral	68	10.18	3.67	0.45
	Total	618	11.69	5.50	0.22

APPENDIX D

Coded results of the question "What do you think the character see?"

Table 23. Descriptive statistics for each lighting design group

		N	Mean	Std. Deviation	Std. Error
Story_Joyful	No lighting	206	2.03	1.7	0.12
	High-key Red	38	1.5	1.59	0.26
	Low-key Red	38	0.95	1.59	0.26
	High-key Blue	32	1.56	1.7	0.3
	Low-key Blue	32	0.66	1.31	0.23
	High-key Yellow	34	2.5	2.15	0.37
	Low-key Yellow	34	2	2.22	0.38
	High-key Purple	30	2.1	2.12	0.39
	Low-key Purple	30	0.67	1.35	0.25
	High-key Green	38	1.68	1.74	0.28
	Low-key Green	38	0.92	1.42	0.23
	High-key Neutral	34	1.12	1.32	0.23
	Low-key Neutral	34	1.56	1.44	0.25
	Total	618	1.63	1.76	0.07
Story_Scary	No lighting	206	0.69	1.19	0.08
	High-key Red	38	1.55	1.74	0.28
	Low-key Red	38	2.97	1.72	0.28
	High-key Blue	32	0.66	1.15	0.2
	Low-key Blue	32	2.31	1.73	0.31
	High-key Yellow	34	0.32	0.88	0.15
	Low-key Yellow	34	0.88	1.55	0.27
	High-key Purple	30	0.53	1.11	0.2
	Low-key Purple	30	2.13	1.96	0.36
	High-key Green	38	1.45	1.59	0.26
	Low-key Green	38	2.5	1.56	0.25
	High-key Neutral	34	1.35	1.63	0.28
	Low-key Neutral	34	1.71	1.77	0.3
	Total	618	1.27	1.63	0.07
Story_Sad	No lighting	206	0.46	1.02	0.07
	High-key Red	38	0.74	1.18	0.19
	Low-key Red	38	0.55	1.06	0.17
	High-key Blue	32	0.53	1.11	0.2
	Low-key Blue	32	0.84	1.19	0.21
	High-key Yellow	34	0.18	0.72	0.12
	Low-key Yellow	34	0.26	0.71	0.12
	High-key Purple	30	0.33	0.71	0.13
	Low-key Purple	30	0.5	0.94	0.17
	High-key Green	38	0.74	1.03	0.17
	Low-key Green	38	0.55	1.01	0.16
	High-key Neutral	34	1	1.33	0.23
	Low-key Neutral	34	0.79	0.95	0.16
	Total	618	0.55	1.03	0.04

Table 23 Continued.

		N	Mean	Std. Deviation	Std. Error
Story_Frustrating	No lighting				
	High-key Red	38	0.76	1.34	0.22
	Low-key Red	38	0.74	1.41	0.23
	High-key Blue	32	0.03	0.18	0.03
	Low-key Blue	32	0.25	0.8	0.14
	High-key Yellow	34	0.26	0.9	0.15
	Low-key Yellow	34	0.32	1.04	0.18
	High-key Purple	30	0.43	1.04	0.19
	Low-key Purple	30	0.63	1	0.18
	High-key Green	38	0.84	1.41	0.23
	Low-key Green	38	0.92	1.53	0.25
	High-key Neutral	34	0.97	1.22	0.21
	Low-key Neutral	34	0.82	1.17	0.2
	Total	618	0.54	1.13	0.05
Story_Disgusting	No lighting	206	0.4	0.9	0.06
	High-key Red	38	0.79	1.47	0.24
	Low-key Red	38	0.68	1.07	0.17
	High-key Blue	32	0.16	0.45	0.08
	Low-key Blue	32	0.66	1.1	0.19
	High-key Yellow	34	0.24	0.65	0.11
	Low-key Yellow	34	0.56	1.16	0.2
	High-key Purple	30	0.2	0.61	0.11
	Low-key Purple	30	0.77	1.17	0.21
	High-key Green	38	0.66	0.88	0.14
	Low-key Green	38	0.87	1.21	0.2
	High-key Neutral	34	1.12	1.53	0.26
	Low-key Neutral	34	0.97	1.22	0.21
	Total	618	0.57	1.06	0.04

APPENDIX E

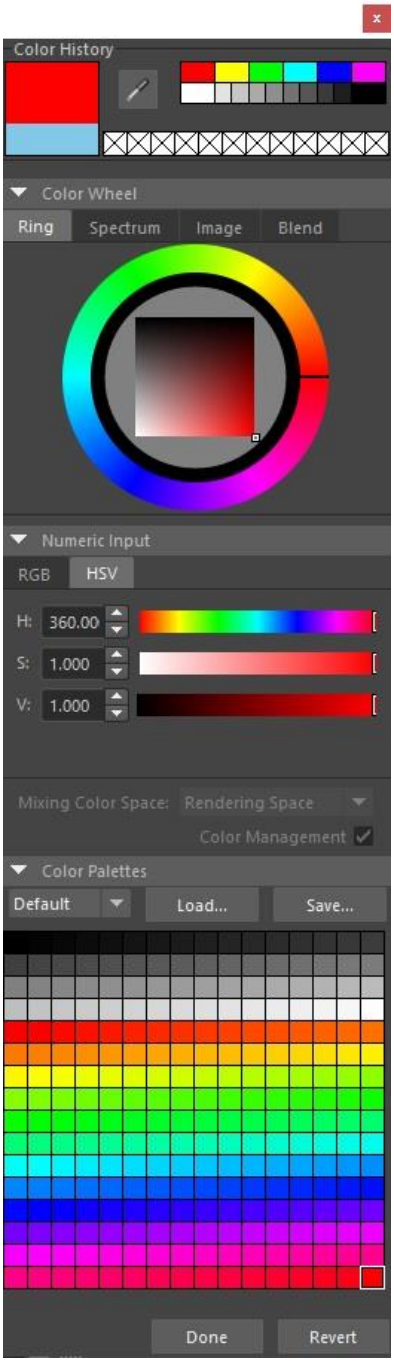

Figure 23. Color chooser in Autodesk Maya, screenshot by the author (Autodesk Maya, 2016)

APPENDIX F

Participants' demographics

There were 72 participants in total. 40% of them are male while 60% of them are female. Average time the participants used to complete the study is 38 minutes. The following figures show the percentages of their age range and animation background.

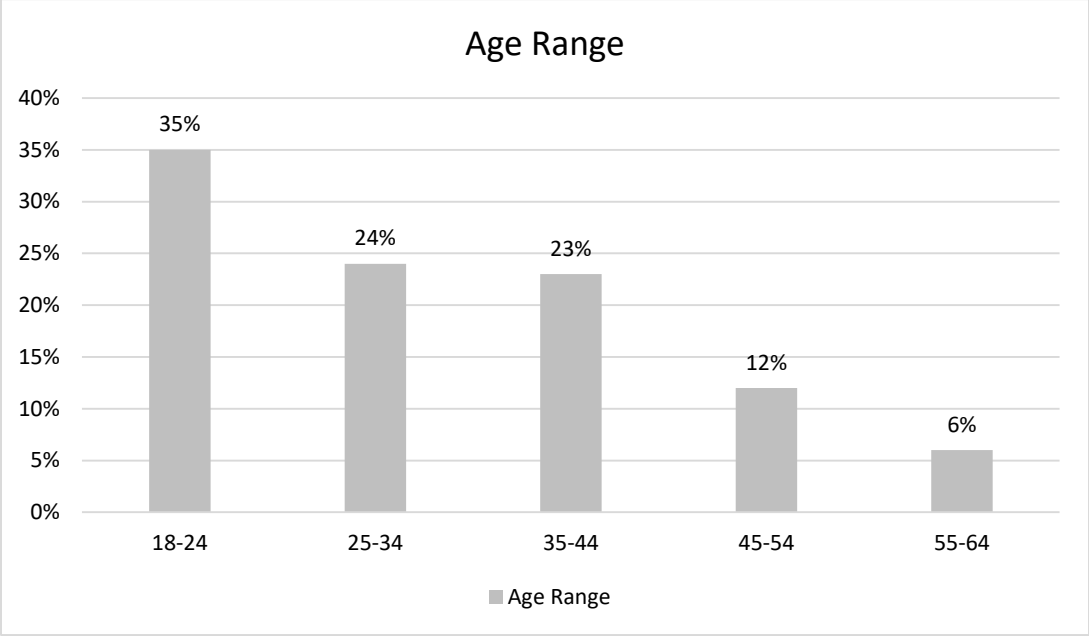

Figure 24. Participants' age range

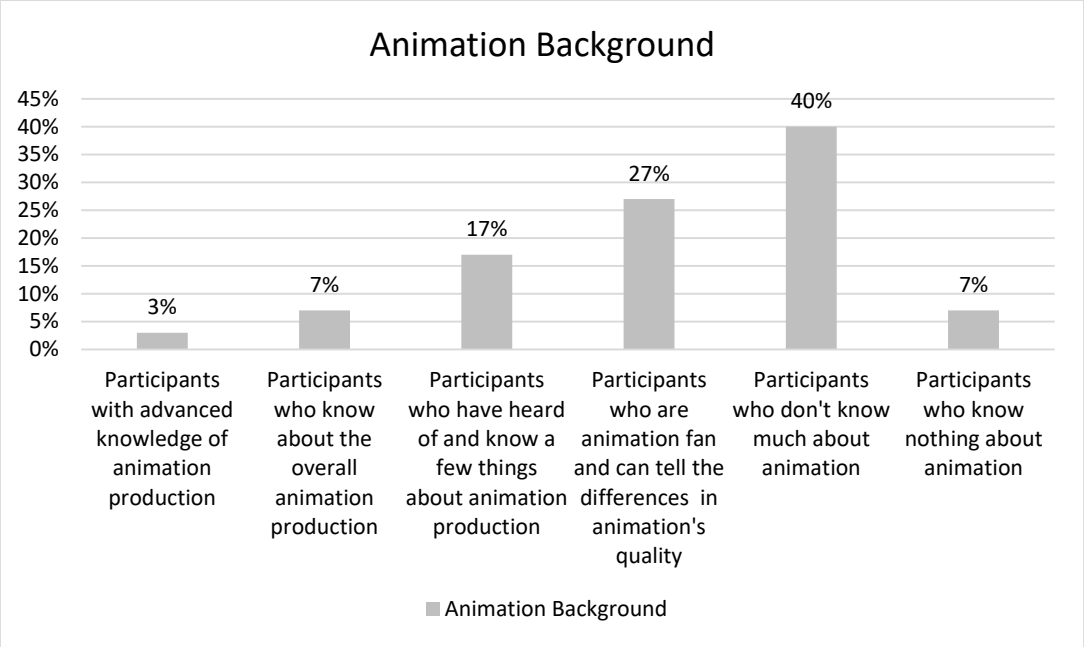

Figure 25. Participnats' animation background