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THE EFFECT OF COLOR ON EMOTIONS IN ANIMATED FILMS

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IN ANIMATED FILMS

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This thesis is dedicated to my family, who have given me support and encouragement every step of the way.

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ABSTRACT

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Lighting color in animated films is usually chosen very carefully in order to portray a specific mood or emotion. Artists follow conventional techniques with color choices with the intention to create a greater emotional response in the viewer. This study examined the relationship between color variations in videos and emotional arousal as indicated by physiological response. Subjects wore a galvanic skin response (GSR) sensor and watched two different videos: one portraying love and one portraying sadness. The videos were watched multiple times, each with variations in the lighting color. No significant effects on emotion for either hue or saturation were observed from the GSR sensor data. It was concluded that the hue and saturation of lighting are not likely to cause a significant impact in the strength of emotions being portrayed in animated films to a degree in which it can be measured by electrodermal activity.

CHAPTER 1. INTRODUCTION

The purpose of this research is to determine the emotional impact that color brings to animated videos. The lighting and composition of an animated video are usually chosen very carefully by the artist in order to communicate the story or message. The lighting of the scene determines how the color is seen in the final image, which has a psychological effect on the viewer. There are standard practices and conventions used by artists in order to influence the viewer's emotions, such as filling a scene with blue light in order to make the viewer feel sad. While these effects of color on emotions have been studied extensively, little work has been done in the area of studying the physiological effects of color in animated films. This is important for artists to know because they make lighting decisions to best communicate their message to their audiences. This research will help to inform the decisions made by 3D artists so that they can be further conscious of the impact lighting design has on the emotions of the viewers.

1.1 Scope

This research addresses the changes in physiological arousal when the color properties of lights are altered in a 3D animated video. It is only concerned with the strength of the emotion and does not address changes in the perception of the emotion being portrayed.

1.2 Significance

Birn (2006) noted:

> When they are absorbed in the story and watching what happens to the characters, most of your audience will never consciously see your lighting as they watch a movie, but instead will feel it. Helping create a mood or tone that enhances the emotional experience of watching a films is the most important visual goal of cinematic lighting design" (p.11).

The lighting choices that are made in an animated movie become a vehicle to deliver the filmmaker's message to the audience. Not just the plot, but the subtleties of emotion and mood are conveyed by the choices that the lighting artists make when producing the film. Animated feature films are extremely expensive to create, costing some studios hundreds of millions of dollars (Chmielewski & Eller, 2010). On a large scale production, it is critical that every detail is perfect. With such large stakes, it becomes important that the movie is successful; lighting design plays a very critical role in this. If the traditional practices of conveying emotion through color truly elicit a significant emotional response, then it is important to know. It furthermore validates the currently accepted theories of the psychological effects of color in art and film.

1.3 Research Question

Does a change in the hue and saturation of lighting color impact the strength of the emotion being portrayed in a rendered animated video?

1.4 Assumptions

The following are the assumptions of this study:

- The scenes depicted contain material generally seen in an animated movie.
- All hardware and software used in the testing is functional.

- An environment free of distractions ensues the accuracy of the collected data.
- The Ishihara Color Test is an accurate test to determine if an individual is free from any visual defects that will impact their perception of color.
- All participants will be free from any visual defects that will impact their perception of color.
- All participants will answer questions truthfully.
- EDA is an acceptable substitute for emotional arousal and is measured using GSR.

1.5 Limitations

The following are the limitations of this study:

- The study will only cover changes made to light hue and saturation.
- The study will only cover changes made to light hue and saturation.
- Measurements of emotional arousal will only be taken from a GSR sensor.
- Research subjects will be limited to Purdue University students and faculty over the age of 18.
- The use of GSR to measure physiological responses as a proxy for emotional arousal is not a universally agreed upon measurement.

1.6 Delimitations

The following are the delimitations of this study:

- This study only deals with static properties of light. No changes to the color properties are made spatially or temporally.

- No devices other than a GSR sensor will be used to determine physiological responses or emotional arousal.
- Only the effects of the color of light will be tested. Any other property of film, such as audio, composition, or storytelling will not be addressed.
- No participants in the study may be under the age of 18.

1.7 Definitions

GSR - Galvanic Skin Response. A measurement of the conductivity of the skin which is used as a measurement of emotional arousal.

EDA - Electrodermal Activity. The unit measured by the GSR sensor.

1.8 Summary

This chapter provided the scope, significance, research question, assumptions, limitations, delimitations, definitions, and other background information for the research project. The next chapter provides a review of the literature relevant to lighting and emotion.

CHAPTER 2. REVIEW OF RELEVANT LITERATURE

This chapter summarizes the research in the fields of lighting and color, the human visual system, and emotional responses.

2.1 Lighting and Color

Lighting and color are two basic visual cues that give context to the story being presented. Good lighting design is both an artistic and narrative choice that immerse the audience in the setting of the fictional world. Both art theory and human psychology show evidence that lighting and color has a large impact on the perception of the viewer. This section addresses the impact of lighting and color in 3D environments.

2.1.1 Digital Lighting and Rendering

Jeremy Birn (2006) of Pixar Animation Studios writes a great deal about the importance of lighting and color in his book Digital Lighting and Rendering. In a film, the color choices used elicit certain emotions from the viewer. Often the associations occur at a subconscious level. By carefully selecting colors, filmmakers can cause a greater impact in their viewers (Birn, 2006).

Red is a color that causes alarm or apprehension. Yellow evokes happy emotions and gives the audience the expectation that the story will be taking an optimistic turn. In general, warmer colors capture attention more effectively than cooler colors, which is why they appear so often in advertisements. A warm color palette brings excitement and energy to the picture (Birn, 2006).

In contrast, cool colors let the viewer feel more relaxed. Outdoor scenes involving nature are dominated by cool colors and are thereby suitable for neutral backgrounds. Blue will convey sadness or coldness. Green is unique in the sense that it is the quintessential color of nature, yet green light can also make a place look eerie or portray illness (Birn, 2006).

While there are established conventions for using color, they also must be used carefully with their impact in mind. For example, giving the villain in a story red eyes is an instant visual cue that the character is bad, yet it is a clichéd technique that could perhaps upset the viewer. Using color in lighting is certainly a powerful tool, but it should not be the limit of creative expression for the story.

2.1.2 Projecting Tension in Virtual Environments through Lighting

Penn State University professor El-Nasr (2006) studied the effects of lighting on tension in virtual environments. There is a recent trend that uses techniques learned from the world of film and applies them to games to achieve similar effects. Games, like film, utilize lighting techniques such as light flickering or oversaturation to enrich the environment and to interact with the user. Unfortunately with the nature of games and other virtual environments, the user must be interacting with the world and are not passively viewing it as is the case in film. Certain lighting techniques that are common in games, though effective at creating tension, also pose a major distraction to the user. The goal of the author was to design a lighting system that dynamically changes to incite an appropriate amount of tension while still following proper lighting principles that do not negatively interfere with the user's experience (El-Nasr, 2006).

A study of lighting effects was done in order to identify the common lighting techniques used to cause tension that could be implemented in a game engine. Contrast was the defining element. High amounts of contrast between light and dark, contrasts in color scheme, and changes in contrast over time were linked to cause tension in the user. When the amount of contrast increased over time, it caused a high amount of tension in the viewer, and when the amount of contrast was decreased over time, it lowered tension. The author used these observations to create a custom lighting engine that modified the lighting properties of the current environment in order to create tension in the user (El-Nasr, 2006).

No formal study was conducted, but the initial tests of the lighting engine showed that using these lighting techniques led to the predicted increased tension in the user. Although no formal testing was done, these results were expected given their roots in established film techniques (El-Nasr, 2006).

2.1.3 Chroma Space: Affective Colors in Interactive 3D World

Mansilla, Puig, Perkins, and Ebrahimi (2010) explored the impact of color saturation on emotions in an interactive virtual environment. Color is seen as the most important factor in film to create an emotional response. To test this, a study was performed in a special installation called Chroma Space. It is a space equiped with a projection system, speakers, and an infrared camera to capture user motion. An individual can stand in front of the screen and navigate through the virtual environment using a series of arm gestures. A number of virtual worlds could be visited in Chroma Space with varying levels of color saturation (Mansilla et al., 2010).

To test the impact of saturation, subjects navigated through each of the four virtual worlds in Chroma Space either in full color or 20 percent color. After a brief time in each of the scenarios, the subjects were asked to give their feedback on how emotionally stimulating they found the experience. A t-test and matched pairs t-test were run to analyze the results. When the participants navigated through the desaturated environments, they experienced a significantly increased emotional arousal when the scene involved internal conflict. However in other scenes, the effect of the desaturation was not as drastic. The practical implications of the research indicate that an artistic choice of desaturated colors can cause a higher emotional response in the audience provided that the scene is appropriate (Mansilla et al., 2010).

2.1.4 Image-based Haptic Texture Rendering

In the study of haptics, a method was created to present height information based on the color information of an image by Li, Song, and Zhang (2010). For an image to be presented with depth information in a haptic environment, a height map must be generated. The authors take an approach inspired by color temperature and brightness to generate the height map. By generating the texture based on simple rules, like dark, cool colors receding and bright, warm colors advancing, an accurate height map representative of the original image can be generated. Though it is not the main aim of this paper, a clear correlation is present between basic color psychology and human perception of depth (Li, Song & Zhang, 2010).

2.1.5 Color Palette in Painterly Rendered Character Sequences

Seifi, DiPaola, and Enns (2012) used painterly rendering to see if the color used on a character's face changed the way their emotions were perceived. Specifically, they explored colors that were linked to certain emotions with the intent of those colors amplifying the portrayal of said emotion. The emotions studied were fear, anger, joy, and surprise (Seifi, DiPaola & Enns, 2012).

The design of their experiment was to show a variety of images to participants and to have them rate their perceived intensity of the emotion being portrayed by each image. A variety of facial expressions were rendered using a non-photorealistic rendering technique called painterly rendering, each with five variations in color palette including the base color. Additionally, each image had a "blurry" and "jaggy" variant of rendering. Results were expected to correspond to literature suggesting that certain colors enhanced the perception of certain emotions. The statistical analysis of the experiment used a within-subject ANOVA to compare the results. Results concluded that there was a significantly higher difference in perceived intensity of emotion portrayed when a facial expression was shown with an appropriately chosen color scheme. The method of rendering was not shown to have any impact (Seifi, DiPaola & Enns, 2012).

Overall, joy and surprise were found to be enhanced by a warm color palette, whereas fear and anger were enhanced by a cool color palette. There were a few incongruities with the results however. Fear rated higher in the original color palette than it did with a warmer color palette, and the participants ranked the fear images as a combination of different emotions. The authors conclude that while they have proven that color affects the perceived mood, the topic is complex and warrants additional research (Seifi, DiPaola & Enns, 2012).

2.2 Human Visual System

An understanding of the human visual system provides a framework for why certain visual elements are important and how they function. The research in this section addresses this in relation to video media.

2.2.1 Visual Attention in 3D Video Games

It is important to understand human visual attention when designing 3D environments. El-Nasr and Yan (2006) studied the patterns of visual attention in one of the most complicated settings, a 3D interactive environment. Because of the constantly changing nature of these environments, knowing what captures the eye was a question that warranted exploration. A study was performed that analyzed the visual attention patterns of individuals playing two different video games (El-Nasr & Yan, 2006).

Two different visual attention models were tested. First, a bottom-up visual model that predicted features that would draw attention, such as color, contrast, shape, and brightness. Second, a top-down visual model was explored that predicted that goal-oriented objects will draw attention, such as a door when the player is trying to escape. Two different games were played, one focused on action and another focused on exploration. Test participants had their eye movements tracked throughout the duration of the games. Video of the gameplay was then analyzed with the eye tracking data to see which visual attention model was being followed (El-Nasr & Yan, 2006).

Evidence for both models was found. Bottom-up features were found to impact the attention of the viewer. In some instances it even distracted the user from their goal in the game. Their eyes were drawn to objects that contrasted with the environment. Top-down visual attention patterns were also discovered. Some of the exploration in the games followed a pattern in which the brightness or color of the environment had little effect on the users, who were instead using a goal-oriented approach to the game. There was no conclusive support for one visual attention model over the other, rather both played a part in capturing viewer attention (El-Nasr & Yan, 2006).

2.2.2 Local versus Global Information and the Role of Color

Vogel, Schwaninger, Wallraven, and Blthoff (2007) explored human perception and categorization of images based on local information, global information, and color. Local information is defined as details that are specific to a small region of an image. Global information is the larger details of the entire image that are indicated by overall brightness and shape. A series of experiments was run to test the categorization of images when certain information is not present (Vogel et al., 2007).

To test this, the authors obtained a database of nature images that contained either coasts, rivers and lakes, forests, plains, or mountains. Test participants were asked to briefly view each image and categorize it based on the five options. Five experiments were done in total, each removing one or more details important to human categorization. Images were either scrambled, blurred, converted to gray scale, or a combination of these. Each yielded a different accuracy in respect to the first test. A series of ANOVA tests were run to compare the results (Vogel et al., 2007).

When only global or local information was present, the ability to categorize was lower, which suggests that humans use both local and global contextual cues to process images. The presence of color was significant, but only on a case by case scenario. Local information, global information, and color all play an important role in human visual processing (Vogel et al., 2007).

2.2.3 Affective Image Classification

Machajdik and Hanbury (2010) created a means of categorizing images based on their emotional connotations. Often images are classified by their contents rather than by their emotional context. The authors proposed that examining the images from the perspectives of both psychology and art theory would give an accurate analysis of the emotional context of an image (Machajdik & Hanbury, 2010).

Four major categories were examined per image: color, texture, composition, and content. Basic color information was considered such as hue, saturation, and brightness. There was also analysis of contrast and identification of large areas of color or brightness. Texture features examined were based on graininess and blurriness. Composition included level of detail, depth of field, lines, and adherence to the rule of thirds. Content provided consideration for the presence of human faces and skin (Machajdik & Hanbury, 2010).

A large number of photographs were analyzed by test participants on a web survey that evaluated the emotional content of the images. Following that, the images were analyzed in accordance with the aforementioned techniques. A cross validation statistical test was performed to compare the accuracy of the results in comparison to other popular image classification software. The results showed that the authors' method was the most effective method to date of categorizing images based on emotional content (Machajdik & Hanbury, 2010).

2.3 Emotional Responses

One of the ultimate goals of a movie is to convey a sense of emotion through the artistic choices made in each scene. There is a wealth of information that supports the idea that graphics enhance the emotional experience. This section addresses the emotional responses that can be elicited through movies and images.

2.3.1 The Kuleshov Effect: Recreating the Classic Experiment

The Kuleshov effect is a widely used example of how environmental context will alter our perception of emotion in film. Prince and Hensley (1992) revisit this classic experiment to bring up controversies and further explore it.

The Kuleshov effect is a phenomenon discovered by Lev Kuleshov whereby a shot can take on a different meaning based on the sequence of video that it is in. A man's facial expression might convey hunger, sadness, or desire by simply showing video of him with food, at a funeral, or with a woman. His theories, however, were based mainly on speculation and the original film used to conduct the experiment has been lost. The authors revisited the experiment by conducting their own and evaluating it with contemporary research methods (Prince & Hensley, 1992).

The results they found were surprising. A modern recreation of Kuleshov's experiment showed that there was no attribution of emotion based on the film editing. They provide some explanations as to why they believe this was the case. An important point to address is that there is no clear description of what exactly Kuleshov's experiment was. It may have been more complex than reported. Additionally, the time period in which the experiments were run is an obvious factor. Kuleshov's audience was still captured by the novelty of film as a medium and standard narrative practices had not had time to become established (Prince & Hensley, 1992).

Nevertheless Kuleshov's work is still relevant. He created such a legacy in the world of film that Alfred Hitchcock has cited him as an inspiration for his methods. This research lends credence to the idea that the content of each individual shot is important for conveying emotion and that the visual cues cannot come entirely from the sequence of shots itself (Prince & Hensley, 1992).

2.3.2 Emotion Elicitation Using Film

Gross and Levenson (1995) were concerned with finding a defining list of films that would produce one of 10 different emotions. These emotions were amusement, anger, contempt, disgust, fear, happiness, interest, sadness, surprise, and tension. A five year study that involved nearly 500 participants and 250 films eventually resulted in a list of 16 films that were determined to be the best films to produce these emotions. Throughout the process, however, a significant amount of knowledge was gained about how films portray emotion (Gross & Levenson, 1995).

Emotions are best portrayed in film when they are very distinct. For an emotion to be strongly portrayed, it must be both intense and separate from other emotions. A film that evokes both anger and fear will not produce as strong of feelings for either than a film that only elicits one of the emotions. Also, prior viewing affects the viewer's emotional response. Having viewed a movie will cause a higher emotional response in subsequent viewings. The easiest emotions to portray were amusement, disgust, and sadness. Anger, contentment, and fear were the most difficult, with anger being the most difficult. (Gross & Levenson, 1995).

2.3.3 Emotive Captioning

Lee, Fels, and Udo (2007) studied ways in which closed captioning can be enhanced to better convey the emotions of the speakers. Among the various techniques tested, colorization of words was explored. The authors believed that emotions can be conveyed graphically to enhance the captioning experience for both deaf and hearing impaired individuals. Emotions have been shown to have a strong link to color in psychological studies. They also complicate speech, because the context and emotion with which a person speaks can change the meaning of the words entirely. Furthermore, emotion is one of the most commonly unaddressed issues in captioning (Lee, Fels & Udo 2007).

A study was conducted in which participants watched scenes from a film with the authors' new captioning techniques and answered a questionnaire about their experience. A cross tabulation analysis was used and it was determined that color had an overall positive response in regards to expressing emotion. Some users, however, reported that the colorized text was distracting from the overall experience (Lee, Fels & Udo 2007).

The implications of this are twofold. First is that cinematography does not always convey the emotion in the dialogue through visuals alone, and it is important to know the limitations. Secondly, though color can be a vehicle to convey emotion it is not always the best option in every scenario.

2.3.4 Adding Emotions to Pictures

In situations where illustrations are poorly or inappropriately colored, Hauff and Trieschnigg (2011) propose that the images can be automatically re-colored to portray the intended emotion. The innovation was inspired by the emergence of a large number of illustrated children's books becoming freely available in electronic format. Though accompanied by illustrations, some of the illustrations do not convey the appropriate emotions as described in the text. Since children are able to identify emotional context based on color, it is important for the image to appeal to the reader (Hauff & Trieschnigg, 2011).

For their technique, a number of color schemes were chosen that were labeled as happy, sad, or angry. The happy schemes contained mostly bright colors, while angry schemes contained harsh contrast between opposite colors and sad schemes were characteristically dark and desaturated. Through contextual clues in the text, the intended emotion for the illustration is identified and a color transformation is applied to the image (Hauff & Trieschnigg, 2011).

No study has been conducted yet, and the next step in the research would be to determine the effectiveness of the technique on the intended audience (Hauff & Trieschnigg, 2011).

2.3.5 Evaluation of Emotional Response to Non-Photorealistic Images

Mandryk, Mould, and Li (2011) studied the effect of non-photorealistic rendering on the portrayal of emotion. Non-photorealistic rendering (NPR) is a technique used to give a distinct stylization to a film or image, but there was no knowledge as to whether or not it was affecting the emotional response it was intended to provoke. Using a database of images, the authors performed a study where users evaluate a series of photos that had been processed with a number of different NPR algorithms (Mandryk, Mould & Li, 2011).

Overall, NPR rendering was shown to lower the emotional response in the user. Only line drawing and photo abstraction caused higher emotional arousal. Blurred images tended to most negatively impact the emotional response than other techniques, and got the most negative feedback as well. Due to the fact that NPR algorithms tend to be motivated from a scientifically oriented point of view, it is not surprising that the emotional response is negatively impacted by it. Further research is warranted to discover exactly why the rendering technique changes the emotional impact and what those low-level details are (Mandryk, Mould & Li, 2011).

2.3.6 Creating and Interpreting Abstract Visualizations of Emotion

Taylor and Mandryk (2012) created a system to represent emotion through abstract renderings. These visualizations are intended to be able to convey emotion in a computer environment where emotion is often difficult to express. By studying emotion and visual stimulus patterns, EmotiViz was created, a software that generates these emotive visualizations. EmotiViz generated five separate effects that represented different locations on the valence-arousal diagram. Happy is the emotion corresponding to a high valence and high arousal. Anger has high arousal but low valence. Sadness is the quadrant that has low valence and low arousal, and finally calm has high valence but low arousal. A neutral valence and neutral arousal state was the fifth effect chosen for the test (Taylor & Mandryk, 2012).

As each of the effects is procedurally generated by the computer program, the parameters can change in correspondence to amount of valence and arousal over time. The authors performed two studies in which the users viewed the visualizations generated by EmotiViz; one was to determine the differences between the emotions and the other was to determine a change in emotion. Chi squared tests were run and showed significance for both cases. Not only were the test subjects able to correctly match the visualization with its intended emotion, but they were also able to perceive a change in the emotions over time as the simulation parameters were changed. This study shows that even abstract, low level visual cues are enough to stimulate the human visual system and cause a link between patterns, color, and emotional expression (Taylor & Mandryk, 2012).

2.4 Conclusions

In conclusion lighting and color's effect on perception was explored. Intelligent color choices and composition decisions will convey messages subconsciously to the viewer and help emphasize emotions or moods in the story. The human visual system was examined for clues as to why certain visual cues draw the attention of the eye. Finally, emotional response in film was covered in order to see how emotions can be affected by visual techniques. When all are considered, it is evident that there are connections to lighting and emotion. However, there is a lack of support from the area of physiological responses.

2.5 Chapter Summary

This chapter summarizes the current research in the topics of lighting and color, the human visual system, and emotional responses. Each article and experiment was briefly discussed along with its contribution to the field.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

This chapter provides the framework and methodology to be used in the research study.

3.1 Study Design

In this study, a quantitative analysis was performed to determine the effect that lighting color has on emotional arousal as observed by physiological responses. The study performed was a mix of a crossover design and an incomplete block design that tested a large number of treatments across multiple subjects. The dependent variable in the study was electrodermal activity (EDA) as measured by a GSR sensor. The GSR sensor used in this study was the Affectiva Q Sensor. Higher EDA suggests a higher emotional involvement in the subject. There were 2 different videos that were shown, and there were 21 versions of each video with variations in the lighting hue and saturation. A total of 42 treatments were administered.

		Saturation						
		Red	Orange	Yellow	Green	Cyan	Blue	Purple
Hue	High	High Red	High Orange	High Yellow	High Green	High Cyan	High Blue	High Purple
	Medium	Medium Red	Medium Orange	Medium Yellow	Medium Green	Medium Cyan	Medium Blue	Medium Purple
	Low	Low Red	Low Orange	Low Yellow	Low Green	Low Cyan	Low Blue	Low Purple

Figure 3.1. The 21 possible treatments for both videos.

Each subject only viewed 5 treatments of each video, for a total of 10 viewings. In order to eliminate the effect of viewing order, a pre-determined set of treatments was applied to each subject. Subject 1 received treatments 1 through 5, subject 2 received treatments 2 through 6, and so on. Thus each video was viewed 5 times, and each video was viewed in all five possible orders. The viewing order was strictly controlled due to the fact that the order of viewing can have an effect on the emotional state of the viewer (Gross & Levenson, 1995).

Subject 1	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Subject2	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
Subject 3	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7
Subject 4	Treatment 4	Treatment 5	Treatment 6	Treatment 7	Treatment 8
Subject 5	Treatment 5	Treatment 6	Treatment 7	Treatment 8	Treatment 9
Subject 21	Treatment 21	Treatment 1	Treatment 2	Treatment 3	Treatment 4

Figure 3.2. Treatments for each subject.

Both videos shown were short clips, under 20 seconds long, and were designed to present a strong display of a single emotion. In order to test a similar range of emotions that one might see in an feature length animated film, a strong positive and strong negative emotion were chosen. The first video portrayed the emotion love, and the second video portrayed the emotion sadness.

GSR data were recorded along with data from a pre-test survey and a post-test survey. Survey data was not included in the statistical analysis.

3.1.1 Hypotheses

The hypotheses for this study are the following:

H_{01}: Changing the hue of lighting color does not impact the strength of the emotion portrayed in an animated video.

$H_{\alpha\,1}$: Changing the hue of lighting color has an impact on the strength of the emotion portrayed in an animated video.

H_{02}: Changing the saturation of lighting color does not impact the strength of the emotion portrayed in an animated video.

$H_{\alpha\ 2}$: Changing the saturation of lighting color has an impact on the strength of the emotion portrayed in an animated video.

3.2 Population & Sampling

The sampling approach used was convenience sampling. The study was advertised to the student population in the Computer Graphics Technology department at Purdue University. Test participants were incentivized by being eligible to win a raffle prize. Recruitment for the study was done via departmental mass email announcement. The sample size for this test required 21 subjects; a total of 27 subjects participated in the study. All participants were over the age of 18. Although no two people perceive colors in exactly the same way (Glassner, 1994), subjects who had any form of colorblindness would have skewed the results, and were excluded from the study.

3.2.1 Electrodermal Activity and the GSR Sensor

Electrodermal Activity (EDA) were the data that was collected in this study by the Affectiva Q Sensor. The Q Sensor works as follows: each quarter of a second, the Q Sensor sends an electrical signal from one electrode into the body and travels to the second electrode. The sensor then calculates the time taken for the signal to travel between electrodes. A lower time means that the subject is in a higher state of emotional arousal, and therefore results in a higher EDA value.

Though the validity of using GSR to measure emotion has previously been brought into question (Schlosberg, 1954), the concerns are only applicable when attempting to measure specific emotional states. Measuring only the amount of emotional involvement was the goal of this study, and is an appropriate use of the tool.

3.3 Testing Materials

The testing took place in the game research lab at Purdue University; a quiet room that was free from visual and audible distractions. The environment was kept consistent in order to eliminate some of the environmental factors that might potentially influence the physiological responses of the subject (Chiang, Liu, Lin, Wang, & Chou, 2012).

To measure emotional response, the Affectiva Q Sensor was used. The device is small and is attached to the wrist using a velcro strap.

The videos shown during the testing were produced with Autodesk Maya 2014, Adobe After Effects CS6, and Adobe Photoshop CS6, all of which are industry standard tools for animation production. In order to reduce render time, compositing techniques were used to produce 21 variations of each video. A lighting pass was produced for both videos using only white lights. The lighting pass then had hue and saturation shifts applied in the compositing package, which had the same effect as rendering with colored lights, but without having to render each scene 21 times. The videos were in 720p resolution and were displayed on a large television screen with QuickTime player.

LEGO bricks were also used in the study as a distractor task.

3.4 Testing Procedure

The testing took take place in a plain, quiet room free of any visual or audible distractions. After the subject was informed about the procedures of the experiment, they signed a consent form. The subject was assigned a tracking number which determined the treatments they were assigned. The GSR sensor was then securely attached to their wrist. Subjects were shown images from the Ishihara

Figure 3.3. There were 42 videos used in the study.

color test (Ishihara, 1917) in order to check for any form of color blindness. If an individual was unable to identify the numbers in the images, the study was ended.

A pre-test survey was then taken by the subject. The pre-test survey asked for some basic demographic information. After the pre-test survey, there was a brief period of rest where a baseline measurement was established for the Q Sensor readings, which was used to normalize data during analysis. The total resting time of the participant prior to the beginning of the test was about five minutes, which was necessary in order to establish a more accurate baseline (Ark, Dryer, & Lu, 1999).

After the calibration period, the testing began. The subject was asked to turn their attention to the television screen. The subject viewed an animated video portraying romantic love. After viewing the video, the subject was asked to turn their attention to a bucket of LEGO bricks placed in front of them. For approximately 45 seconds, the subject was asked to build something with the LEGOs. This served as a distractor task for the purpose of eliminating a carryover effect from video to video. After the distractor task was finished, the subject viewed the second video portraying love. This pattern continued until all five love videos were watched. Next, the same procedure was followed with five sadness videos.

When all 10 videos had been watched, the subject was asked to remove the Q Sensor from their wrist. Then a post-test survey was filled out by the subject. This survey was used to gather additional data to be used in the interpretation of the statistical analysis. Subjects were asked to identify the emotion they saw in the videos and then used a Likert scale to answer whether they saw the strength of the emotion differently in any of the videos. Finally, they were asked to rank the videos in order of strongest to weakest portrayal of the emotion. These questions were answered about both videos.

3.5 Summary

This chapter provided the framework and methodology to be used in the research study. The next chapter provides the data analysis and results of the study.

Post-Study Survey

Please answer the following questions:

First Video:

1. The emotion being portrayed in this video was:

2. I feel that the **strength** of this emotion was different in at least one video.

1 2 3 4 5

Strongly Disagree Strongly Agree

3. Rank the videos in order of strongest emotion to weakest emotion.

1 ___________________ (Emotion was strongest)
2 ___________________
3 ___________________
4 ___________________
5 ___________________ (Emotion was weakest)

Figure 3.4. At completion of the study, participants were asked, using the survey above, to provide descriptions and ratings of their emotional responses to the videos they watched during the study.

CHAPTER 4. DATA ANALYSIS

This chapter describes the data collected in the study. The data were analyzed using a generalized linear mixed model (GLIMMIX). After calculating the baseline as well as the mean EDA during each treatment, the data were normalized to each subject's baseline in order to make comparison between subjects possible.

4.1 Data Processing

Data were gathered over a period of three days. Twenty seven subjects participated in the study, all of whom were students at Purdue University. The design of the experiment called for 21 participants, however six subjects' data were removed from the study. Reasons for removal from the study were either due to a failure to pass the Ishihara Color Test or poor GSR sensor data collection. Upon successful completion of the study, subjects were given the opportunity to enter their name in a raffle for a gift card.

All data for each subject were normalized to their resting baseline in order to have meaningful comparison of the results (Wu, Liu, & Hao, 2010).

4.2 Demographic Results

The age of the participants ranged from 18 to 35, with 59.2% being male. A large majority of the participants listed the United States of America as their country of origin, though responses also included Canada, Puerto Rico, Taiwan, and China.

4.3 Study Results

Subjects first watched the video portraying love five times followed by the video portraying sadness five times. Each viewing of a video had one of 21 color variations in the lighting. The treatments were randomly assigned to each subject number which ensured that each of the 42 total videos would be watched five times.

For this study, the Q Sensor was set to a sampling rate of 4Hz. The data output was accurate to three decimal places. Figure 4.1 shows an example of the GSR data collected. After the data were gathered, the measurements that took place during the video viewings were isolated, and a mean EDA was calculated from that. A baseline value from each subject was gathered from a time where the subject was resting before the video viewings took place. The mean values were normalized according to their baseline in order to facilitate comparison between subjects.

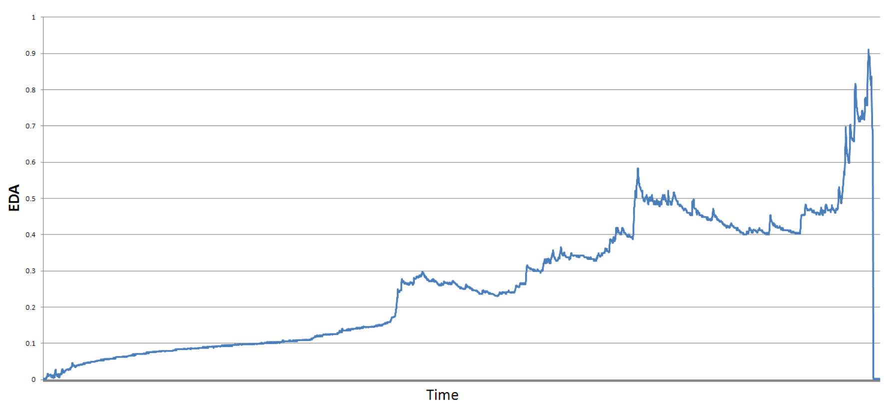

Figure 4.1. A subject's GSR results during the test.

A generalized linear mixed model was used to check for significance (alpha = 0.05) between treatments. The results showed no significant effect of the treatments on the EDA of the subjects.

Neither hue nor saturation of the lighting color showed a significant effect on the EDA of the subject. Furthermore, there was no interaction effect observed between variables. The only factor in the test that showed a significant effect on the

Love

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
hue	6	62.3	1.44	0.2133
sat	2	65.64	0.79	0.4602
hue*sat	12	59.96	1.34	0.2198
period	4	57.3	17.17	<.0001

Sadness

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
hue	6	64.2	1.18	0.3268
sat	2	67.85	0.34	0.7128
hue*sat	12	62.16	1.00	0.4584
period	4	59.13	5.10	0.0013

Figure 4.2. Results of the GLIMMIX tests for the love video (left) and sadness video (right).

EDA was the viewing order, shown as **period** in Figure 4.2. This was consistent with the expectations set by Gross and Levenson (1995).

Although no significant relationship was observed, the data still showed some general trends. For both videos, hue had a stronger correlation with a change in EDA than saturation (refer to p-values in Figure 4.2). Figure 4.3 shows the normalized average EDA caused by each treatment. Figure 4.4 shows the same results, averaged by hue, and Figure 4.5 shows the same results, averaged by saturation. Differences between treatments were less profound in the love video than in the sadness video. Higher saturations produced higher EDA on average for both videos.

4.3.1 Survey Results

The results of the post-survey displayed some clear trends. For each video, subjects were asked to identify the emotion being portrayed in the video. The responses are seen in Figure 4.6. Nearly every participant correctly identified the emotion present in both videos.

Subjects were also asked to asked to rate their agreement with the statement "I feel that the strength of this emotion was different in at least one video." on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Responses can be seen in Figure 4.7. Subjects responded with a median value of 4 for both videos.

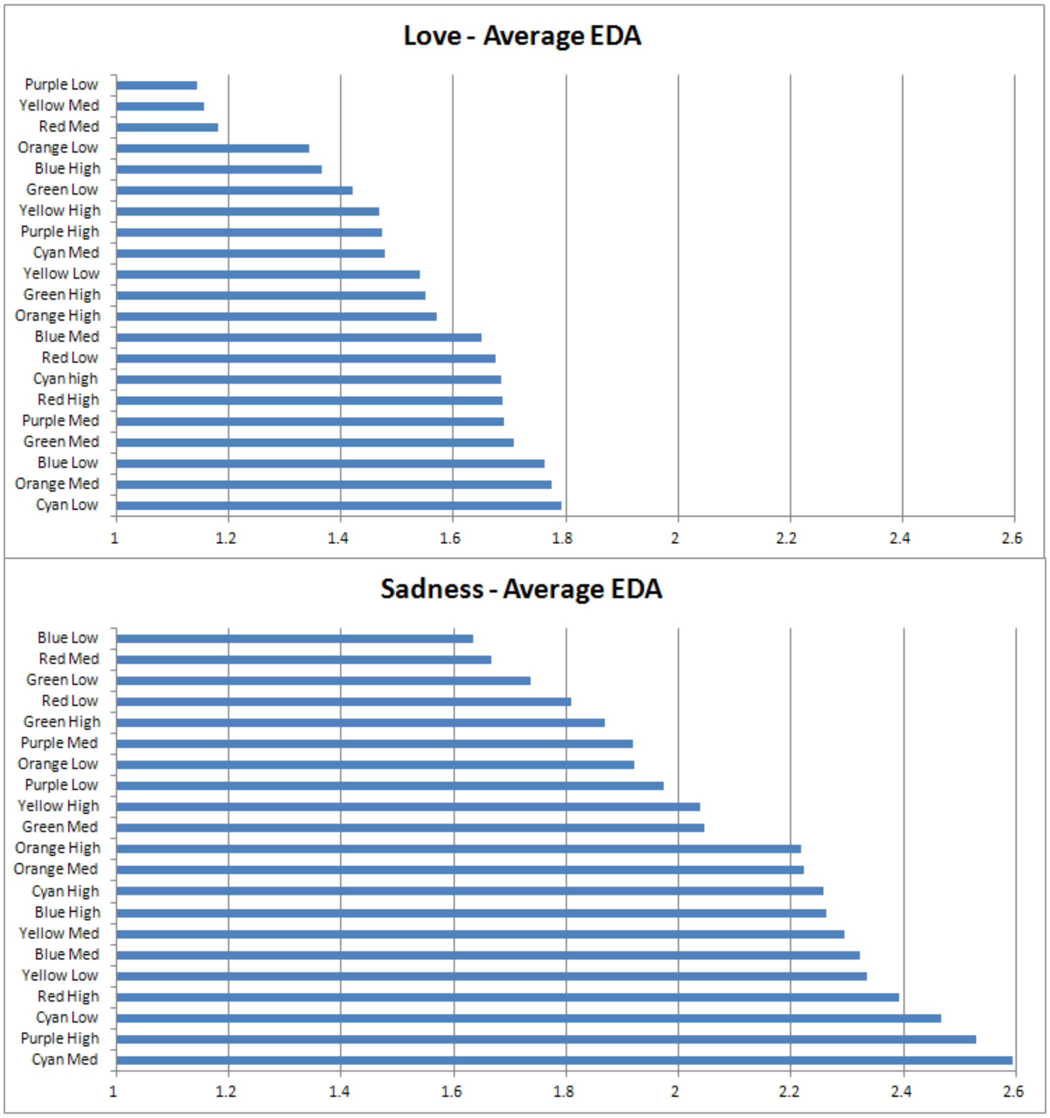

Figure 4.3. Average EDA (normalized) per treatment.

The final survey questions asked subjects to rank the videos they saw in order of the strongest to weakest portrayal of emotion. Figure 4.8 shows a count of the treatments that were ranked as having the strongest portrayal as well as the weakest portrayal of emotion in the love video. Figure 4.9 also shows a count of the treatments that were ranked as having the strongest portrayal and the weakest portrayal of emotion in the sadness video.

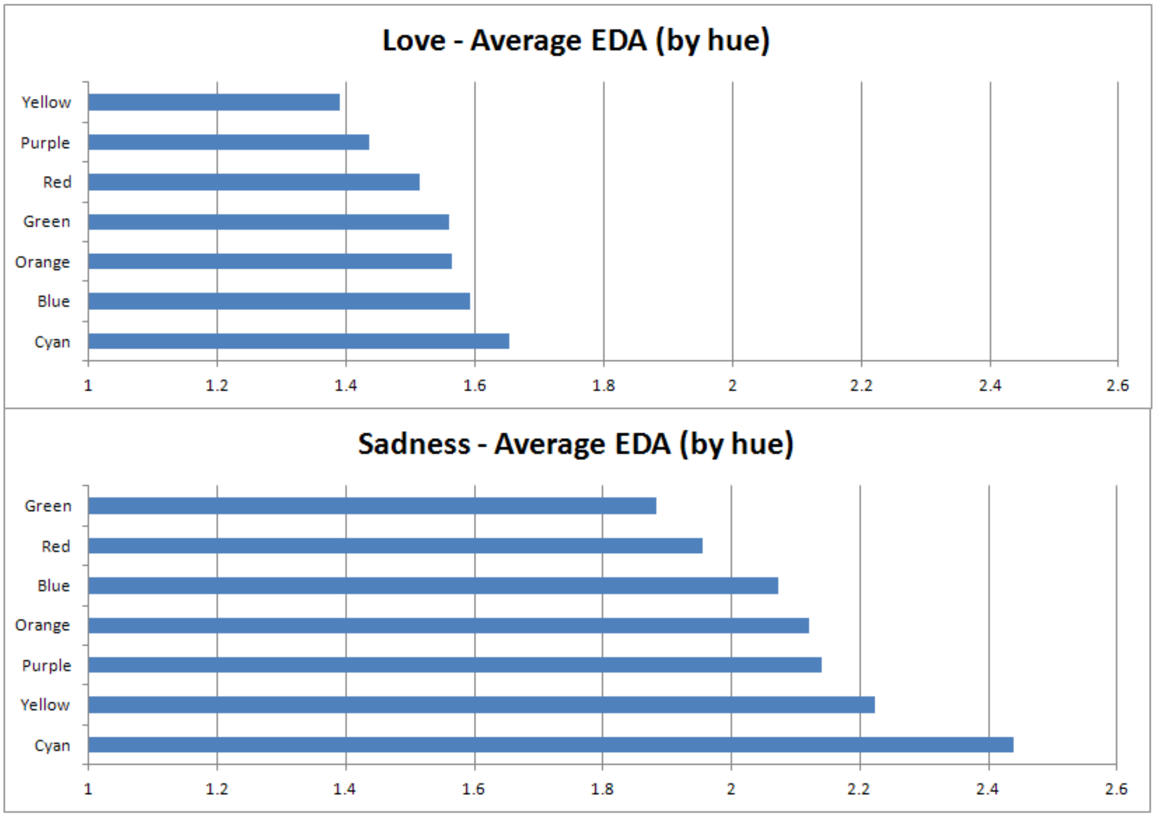

Figure 4.4. Average EDA (normalized) per hue.

To visualize the effects of hue and saturation separately, the same data from the previous charts was averaged together both for hue (Figure 4.10 and Figure 4.11) and saturation (Figure 4.12 and Figure 4.13). Red, yellow, and green hues were reported as portraying love the strongest, and blue hues were reported as portraying love the weakest (Figure 4.10). Medium and low saturations showed love the strongest, and high saturations had a lesser effect (Figure 4.12). In the sadness video, results showed that blue was reported as portraying sadness the strongest, and purple as the weakest (Figure 4.11). There was no clear correspondence between saturation and strength of emotion in the sadness video (Figure 4.13).

A visual analysis of the GSR data and the survey data showed no strong correspondence between the two.

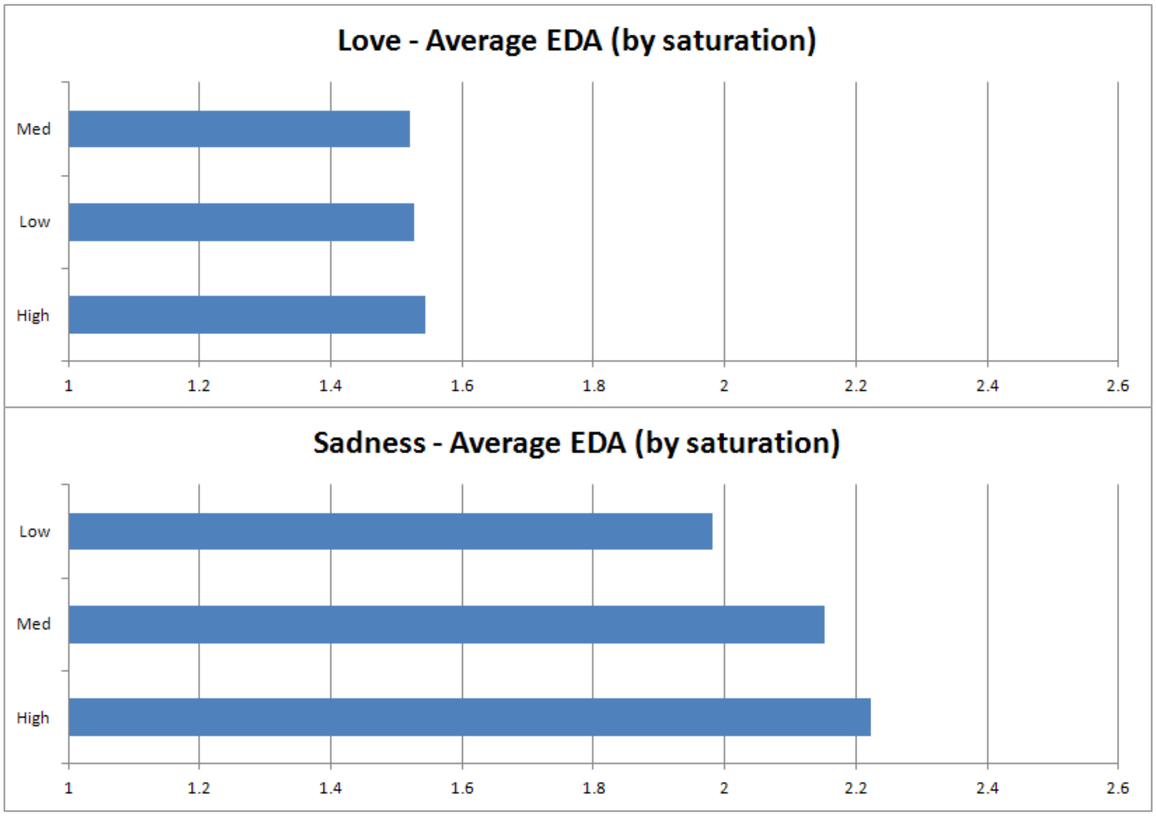

Figure 4.5. Average EDA (normalized) per saturation.

4.4 Summary

This chapter has described the data collected in the study as well as the analysis of the data. The next chapter will provide a discussion of the results as well as recommendations for future work.

Subject Number	Emotion being portrayed (Love)	Emotion being portrayed (Sadness)
1	affection	sadness
2	romantic	sadness
3	Romantic, subtle, love, crush	sad, memory
4	love	sadness
5	love	sadness
6	flirty, romantic	somber, melancholy
7	love	sadness
8	love, concerns	sad
9	love	death, sadness
10	attraction, love	sadness, pain, depression
11	Love	depression, sadness
12	Hesitating, a sense of not caring, hope	Sadness, melancholy
13	lightheartedness, youth	sorrow
14	awkward romantic tension	sadness
15	Affection	Sadness
16	Desire	sad
17	Flirty, love	Sadness
18	Love, desire	Sadness, sorrow
19	romance, flirtatiousness	sadness, grief
20	Love, uncertainty, confidence	Sadness, acceptance
21	Love	Sadness

Figure 4.6. Post-survey results to Question 1.

Subject Number	Q2 (Love)	Q2 (Sadness)
1	4	2
2	5	3
3	4	4
4	3	3
5	5	5
6	4	2
7	4	5
8	4	5
9	5	5
10	4	3
11	2	5
12	3	3
13	3	4
14	2	4
15	4	3
16	4	4
17	4	5
18	3	4
19	4	4
20	4	4
21	2	4

Figure 4.7. Post-survey results to Question 2.

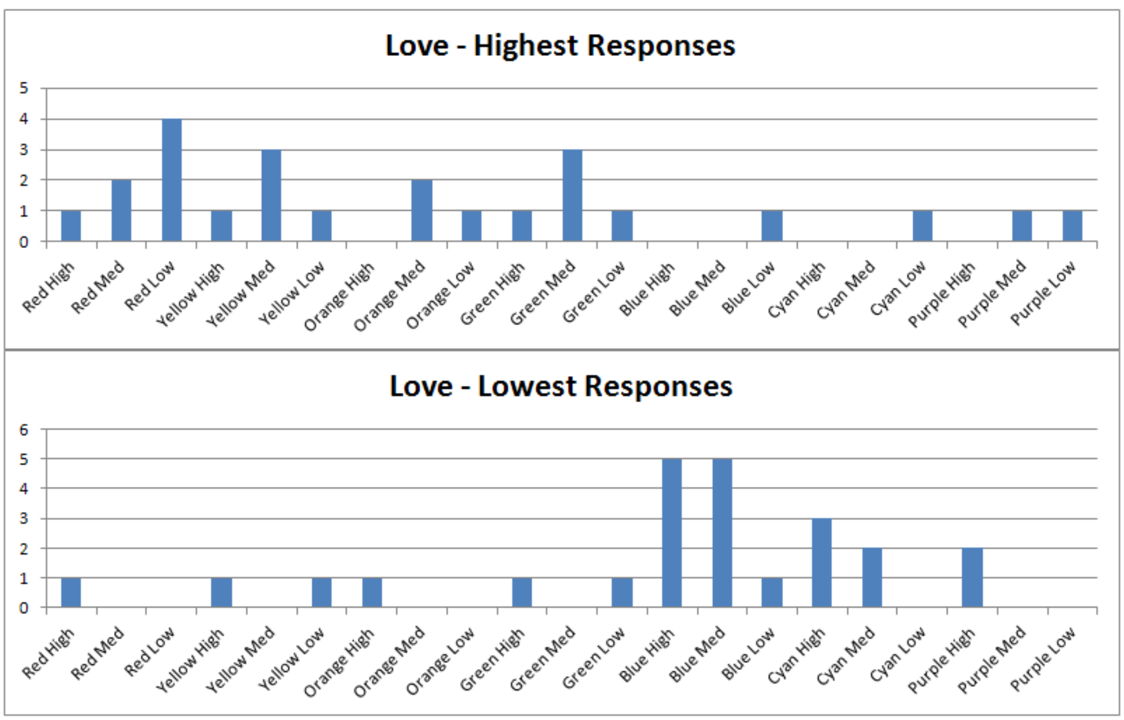

Figure 4.8. Treatments that were ranked in the post-survey as the strongest and weakest displays of emotion for the love video

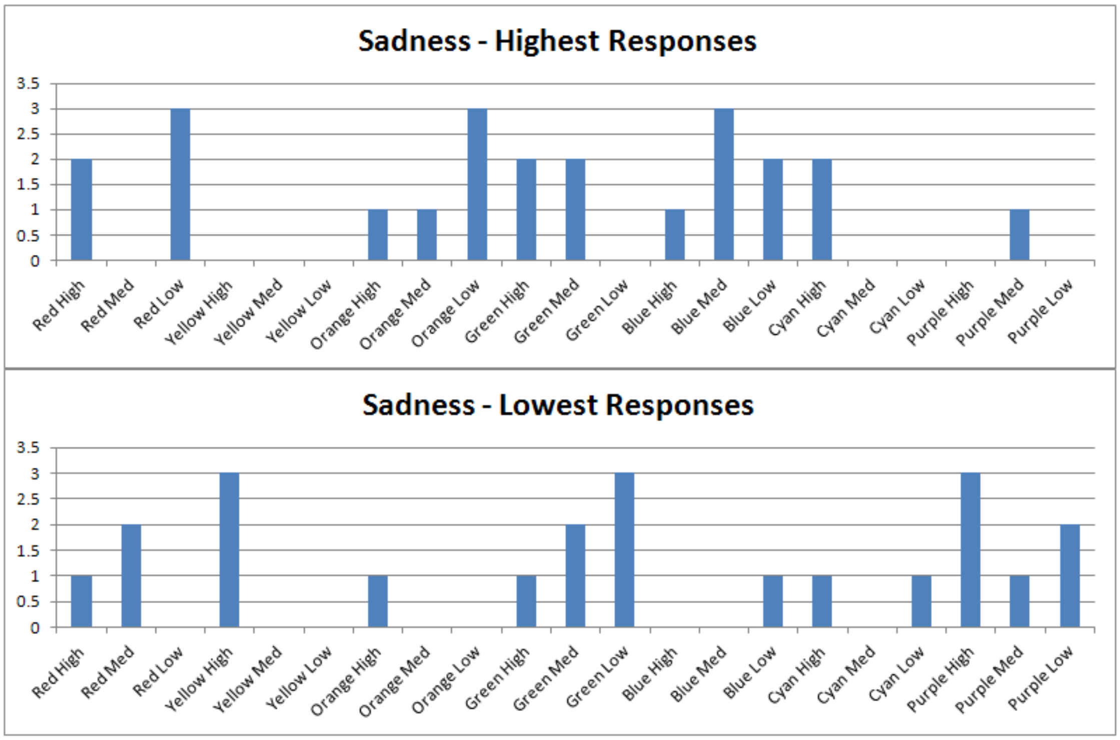

Figure 4.9. Treatments that were ranked in the post-survey as the strongest and weakest displays of emotion for the sadness video

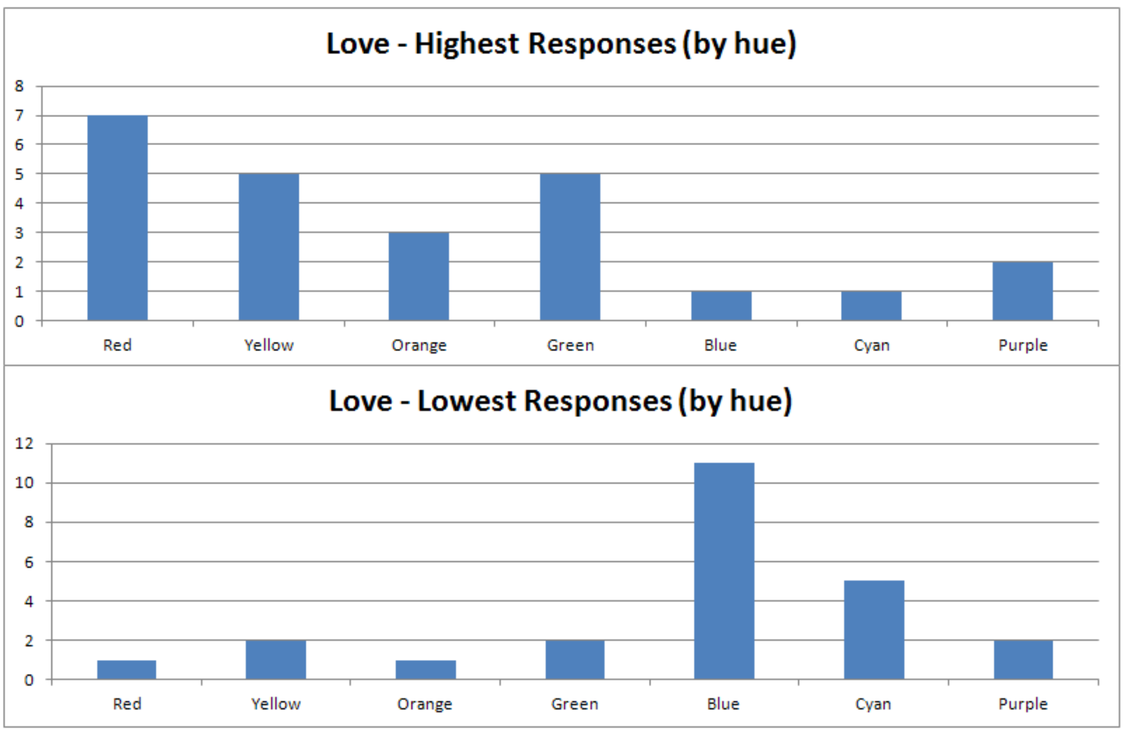

Figure 4.10. Hues that were ranked in the post-survey as the strongest and weakest displays of emotion for the love video

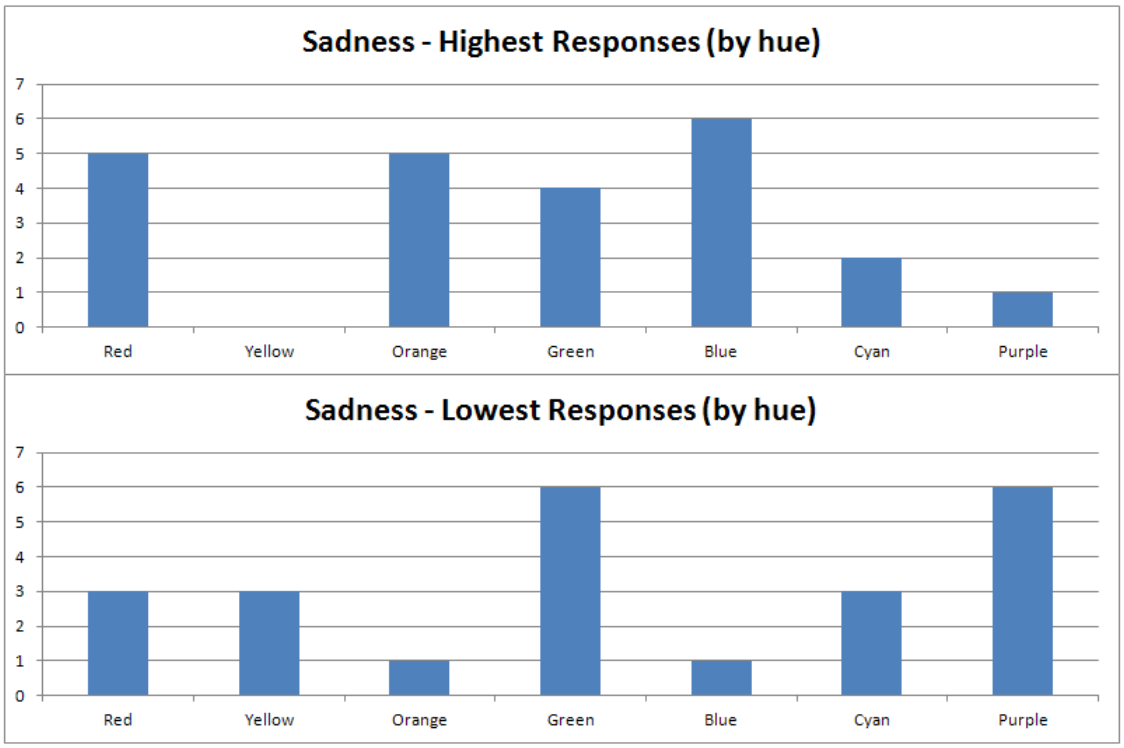

Figure 4.11. Hues that were ranked in the post-survey as the strongest and weakest displays of emotion for the sadness video

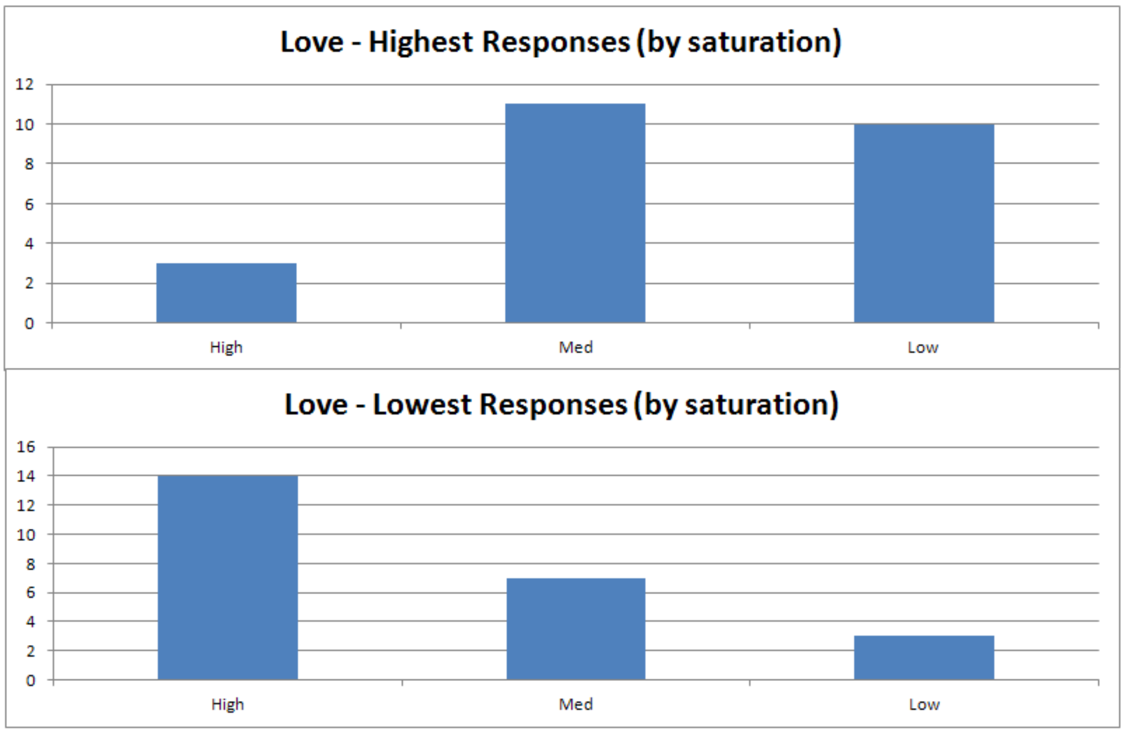

Figure 4.12. Saturations that were ranked in the post-survey as the strongest and weakest displays of emotion for the love video

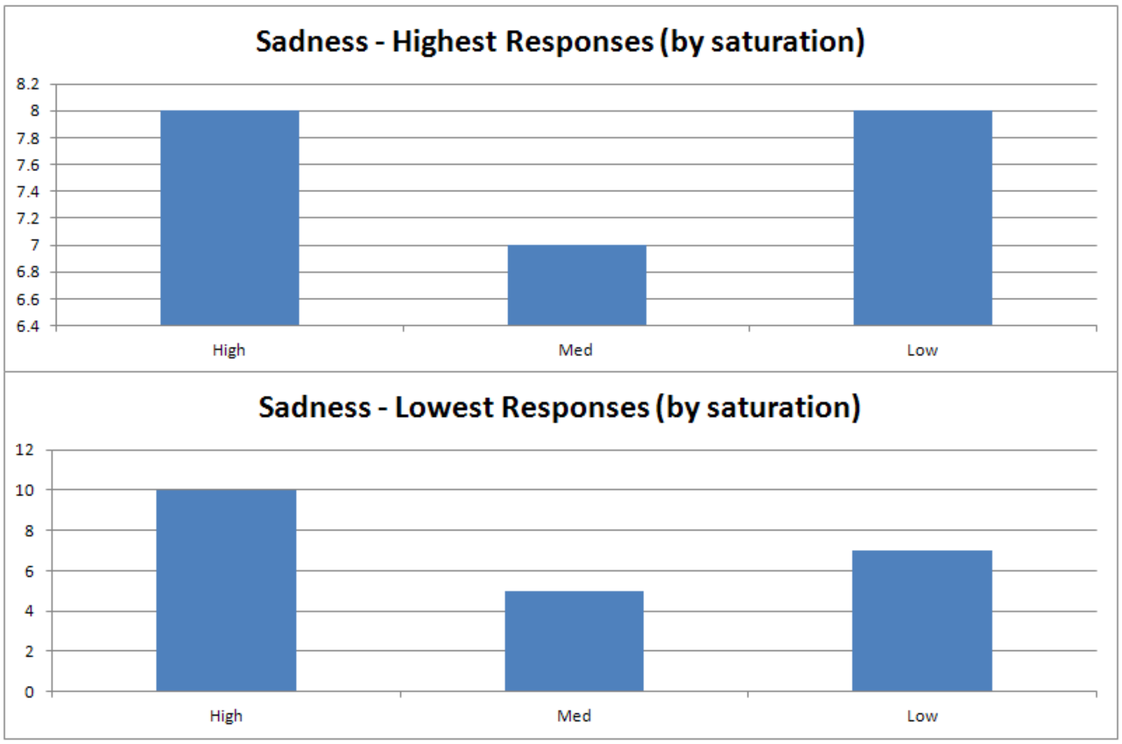

Figure 4.13. Saturations that were ranked in the post-survey as the strongest and weakest displays of emotion for the sadness video

CHAPTER 5. DISCUSSION AND FUTURE WORK

This chapter provides a discussion of the results of the data analysis as well as recommendations for future work.

5.1 General Findings

No significant relationship was observed between hue or saturation of lighting color and electrodermal activity.

H_{01}: Changing the hue of lighting color does not impact the strength of the emotion portrayed in an animated video.

FAIL TO REJECT

H_{02}: Changing the saturation of lighting color does not impact the strength of the emotion portrayed in an animated video.

FAIL TO REJECT

There is not enough evidence to conclude that changing the hue or saturation of lighting color significantly impacts the strength of the emotion being portrayed in an animated video to a degree in which it can be measured by EDA. However, post-survey results suggest that the hue of the lighting color is not entirely unimportant.

No hard statistical analysis was performed on the survey results, but the results were displayed graphically in order to analyze the data visually (see Figures 4.10 through 4.13). Figure 4.10 and Figure 4.11 both show that the subjects had clear preferences for certain colors. Subjects generally chose red, yellow, and green hues as portraying love the strongest, and blue as portraying love the weakest. Subjects also chose blue and orange as portraying sadness strongest.

An implication of these results is that EDA might not be sensitive enough to measure something as subtle as human emotional response to art. Although EDA can be used as a possible correlate of emotional response, it is just one way to measure it. Because of the inconclusive data recorded by the GSR compared with the clear responses received in the post-survey, it can be concluded that emotion in films, particularly in short films, could be too nuanced to be able to be captured by EDA. Furthermore, watching a movie is a very passive activity; this type of activity might not be active enough to be measured by a GSR sensor.

5.2 Developing a Model for Lighting Color Choice

Given the results of the post-survey, a case can be made for the development of a model for lighting color choices. The data collected shows guidelines for lighting color choice for an artist intending to portray love or sadness in a short animated video. Given a specific set of inputs, an artist can use this model to make more informed decisions on lighting color. With the collection of more empirical data, this model will become more robust and cover a larger spectrum of conditions. In this study, love and sadness were tested in short video clips. More data should be gathered on different emotions in order to further develop this model. The data gathered in this study establishes the start of such a model.

One application of this model would be data visualizations that can quickly and clearly communicate the effects of different color choices for the intended emotion. Shown here in Figures 5.1 through 5.4 are infographics that convey the survey data in a more accessible and intuitive form.

5.3 Limitations

This study did not contain every emotion that could be conveyed using film; to do so would be an incredibly difficult, if not impossible, task. Instead, it was limited to just one positive emotion and one negative emotion. Additionally, there

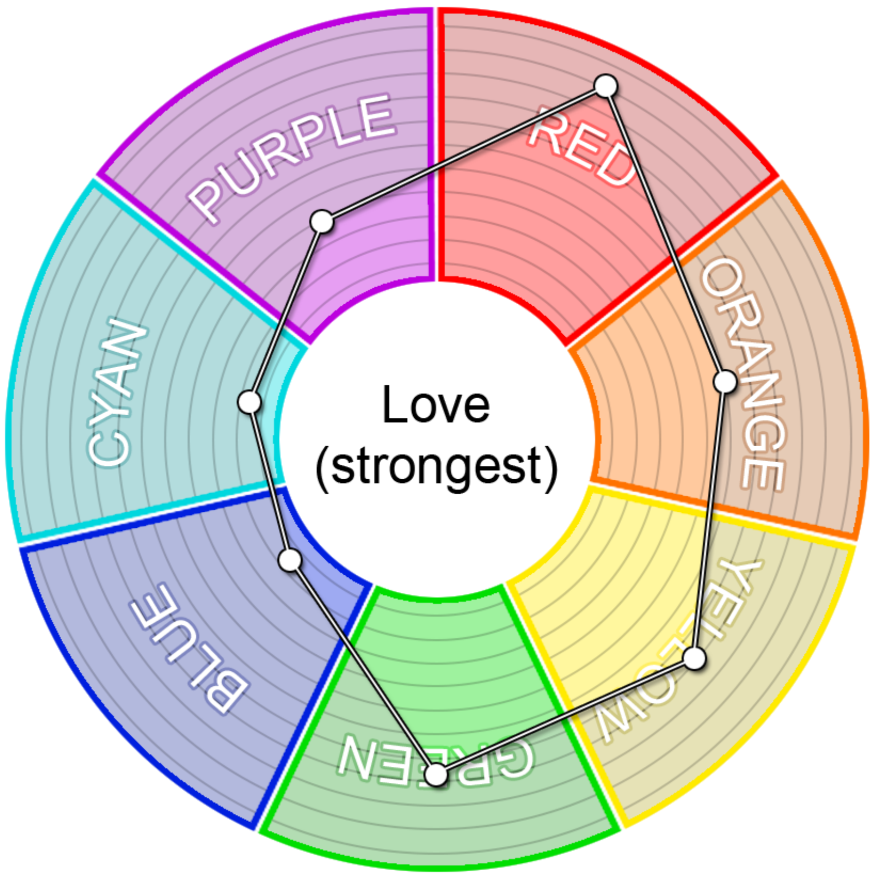

Figure 5.1. Data visualization of survey responses for love, these hues showed the strongest response.

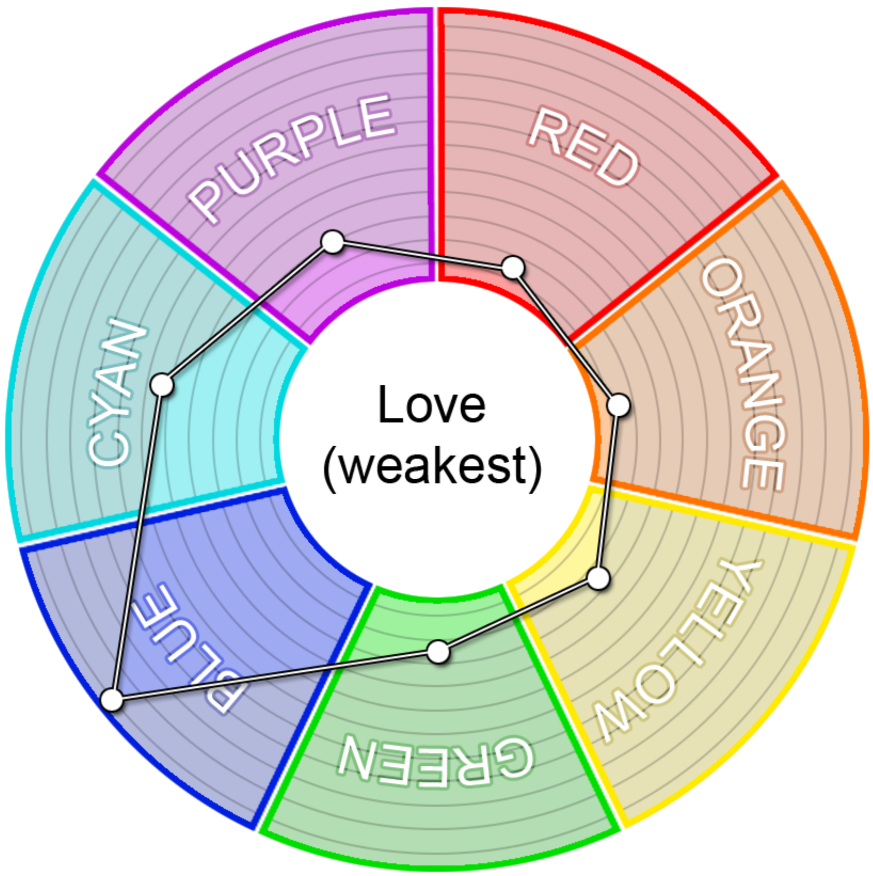

Figure 5.2. Data visualization of survey responses for love, these hues showed the weakest response.

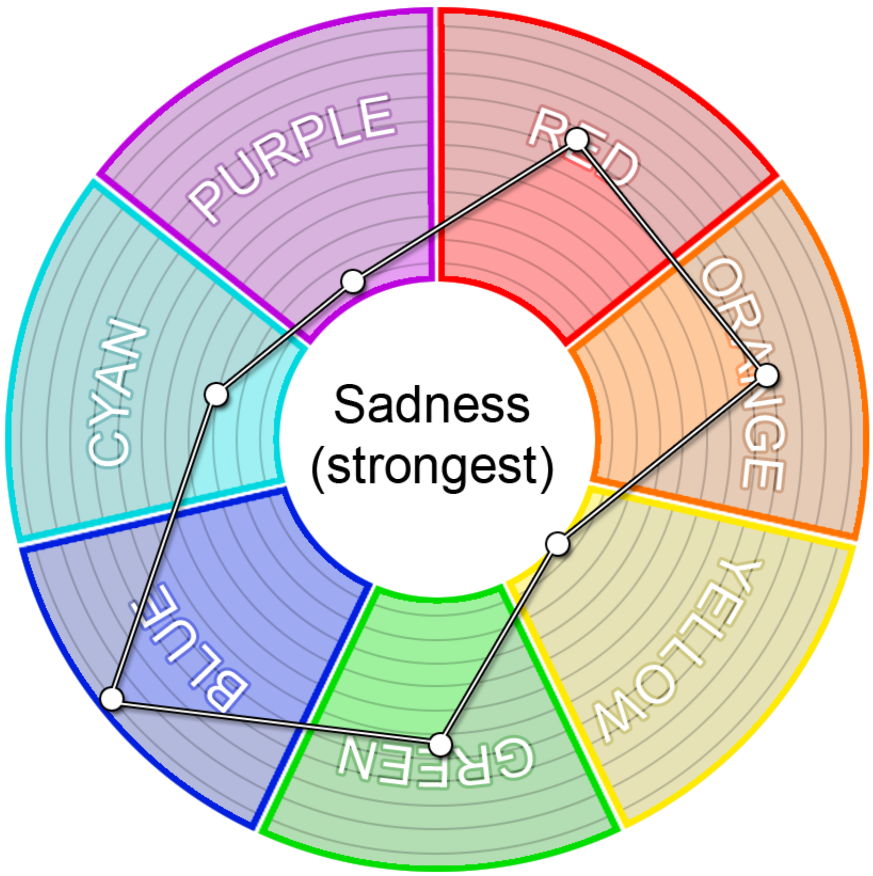

Figure 5.3. Data visualization of survey responses for sadness, these hues showed the strongest response.

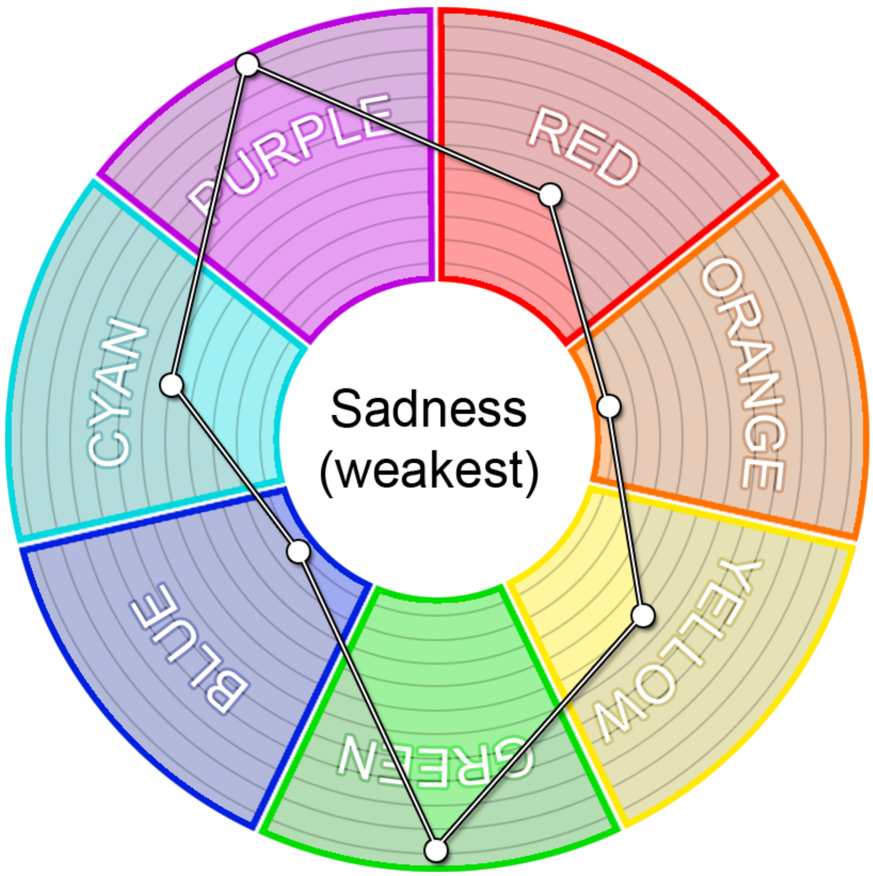

Figure 5.4. Data visualization of survey responses for sadness, these hues showed the weakest response.

are nearly infinite combinations of hue and saturation, and only 21 combinations were used in this study.

Due to time constraints, subjects were only able to be tested for a time period of 30 minutes. The schedule of classes at Purdue University generally starts and ends classes on the hour and half hour, so a 30 minute time period for the study was needed to ensure the availability of participants. Although every effort was made to ensure a significant resting period for the GSR data, it would have been ideal to have each subject go through a 15 minute resting period with the Q Sensor attached. As a result, the resting baselines of the subjects could probably be more accurately measured.

Both videos used in the study were short and had no context as part of a larger story. Emotional high points and low points in animated films are part of an overall story, where the viewer is more likely to have an attachment or emotional investment in the characters. It is possible that the lack of context in the videos that were used did not provoke as strong of an emotional reaction as would have been caused were it part of a larger story.

5.4 Conclusion and Future Work

No statistically significant relationship was observed between lighting hue and saturation on EDA in either video used in this study. The results of this study suggest that scenes in animated films need not be constrained to certain colors in order to cause an emotional response. The fact that no significant relationship was observed, however, does not necessarily prove that lighting color plays no role in emotional response. Lighting color is only one item in a long list of artistic choices that go into making an animated film. Nevertheless, this study provides strong evidence against the assumption that lighting color alone can cause a significant emotional response detectable by a GSR sensor.

Other devices exist which have the potential to measure human emotional response more sensitively than the GSR sensor. There is precedence in the use of a fMRI machine to measure emotional response in relation to computer generated imagery (Montag et al., 2012). One possible extension of this study would be an examination of different physiological measurements that would be most appropriate for measuring human emotional response to film.

A strong case can be made for the development of a model that will aid in lighting color choice. Gathering subject data not only about different emotions, but also different lengths of videos or different environments can lead to the formation of a reference for artists which assists in lighting color choices.

There are a number of other related areas that are recommended for further research as well. A study on the interaction between lighting color and other artistic choices made in an animated film, such as framing or sound design, could show that lighting color works with other factors to portray emotion more effectively. Further studies using a larger number of emotions than just love and sadness should be pursued; the question remains open as to whether lighting color has a significant effect on emotions depending on the emotion being portrayed. Finally, studies involving much longer videos would provide story context that was not present in this study. This could lead to stronger emotional responses in which significant responses are observed.

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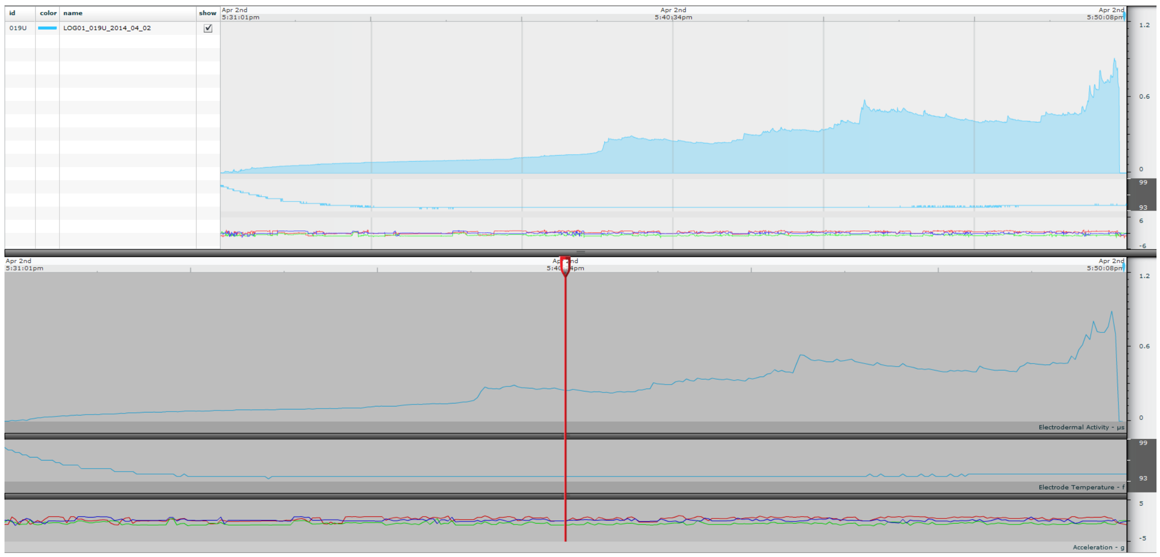
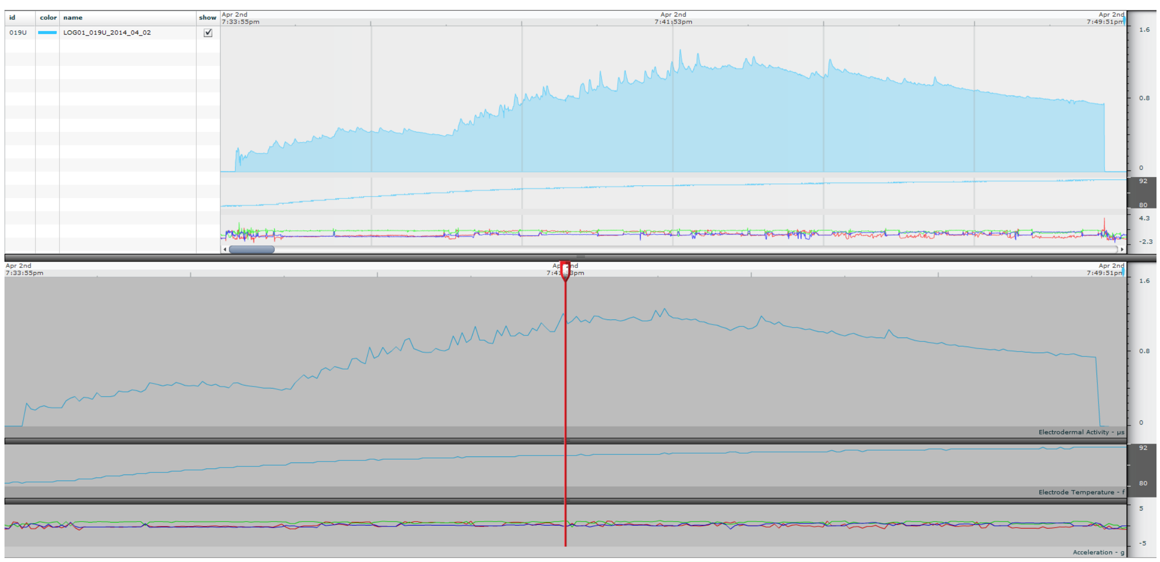
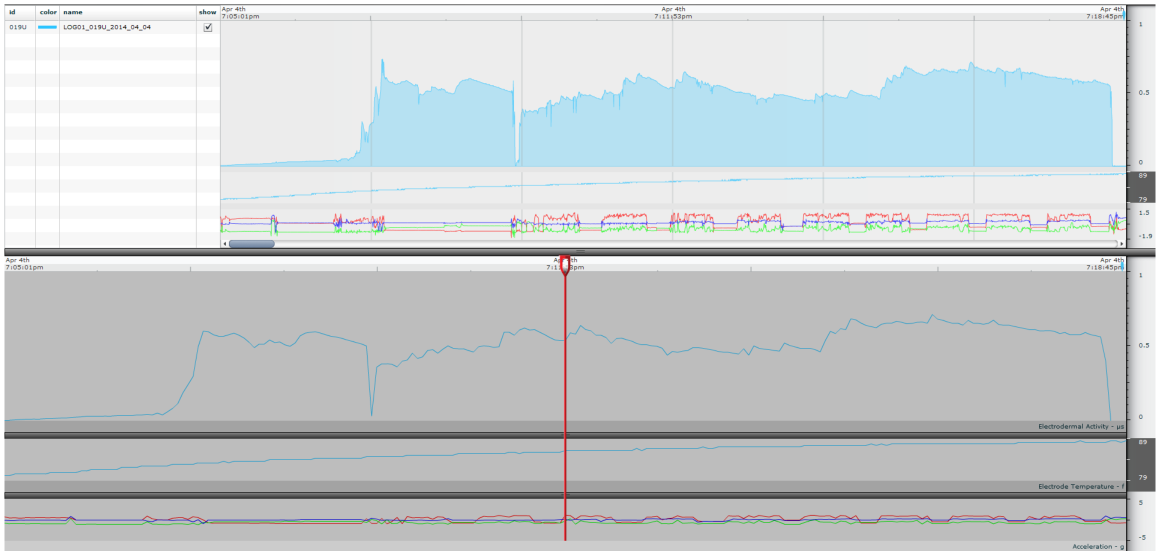
APPENDIX

APPENDIX: GSR Graphs For Each Subject



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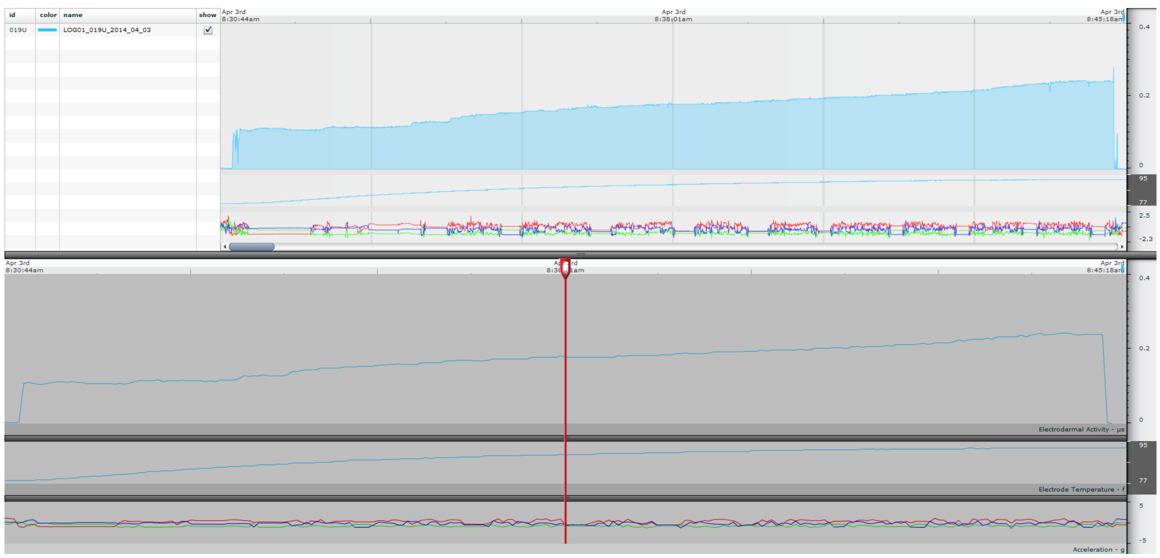
Electrodermal Activity - µs
Electrode Temperature - F
Acceleration - g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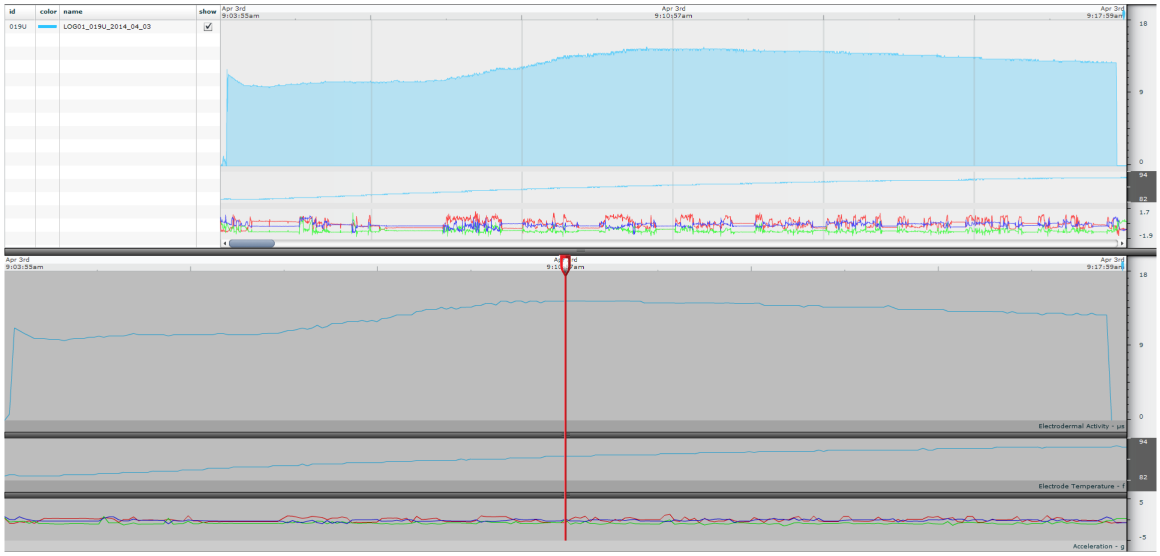
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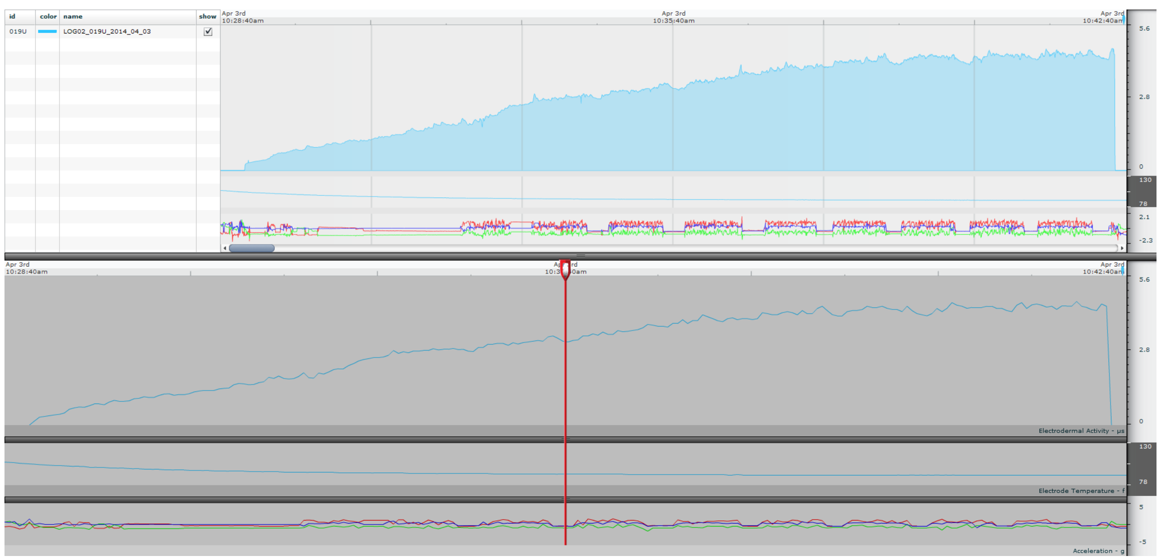
Acceleration - g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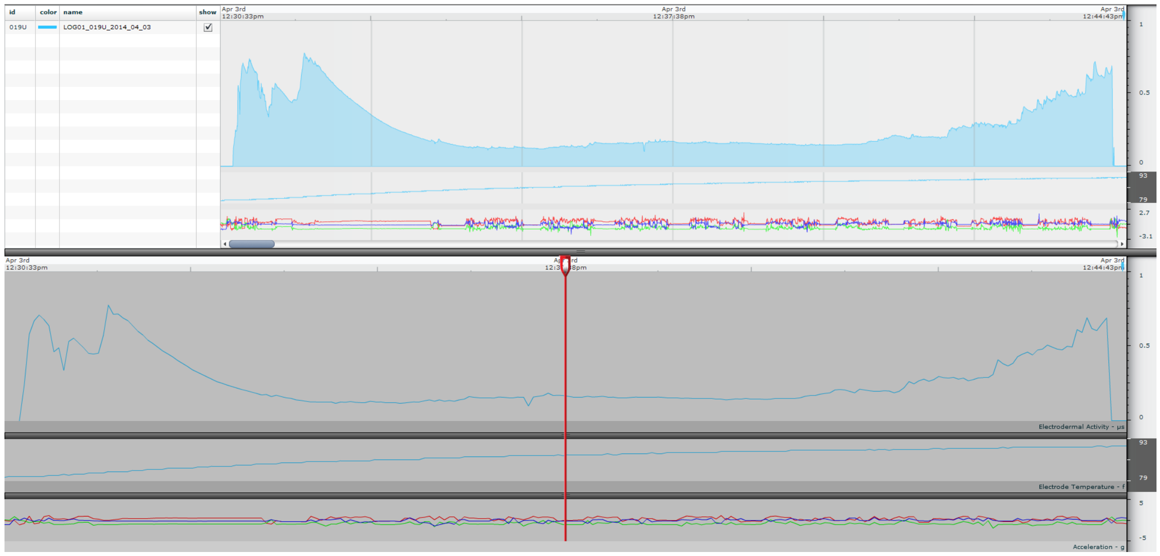
Acceleration - g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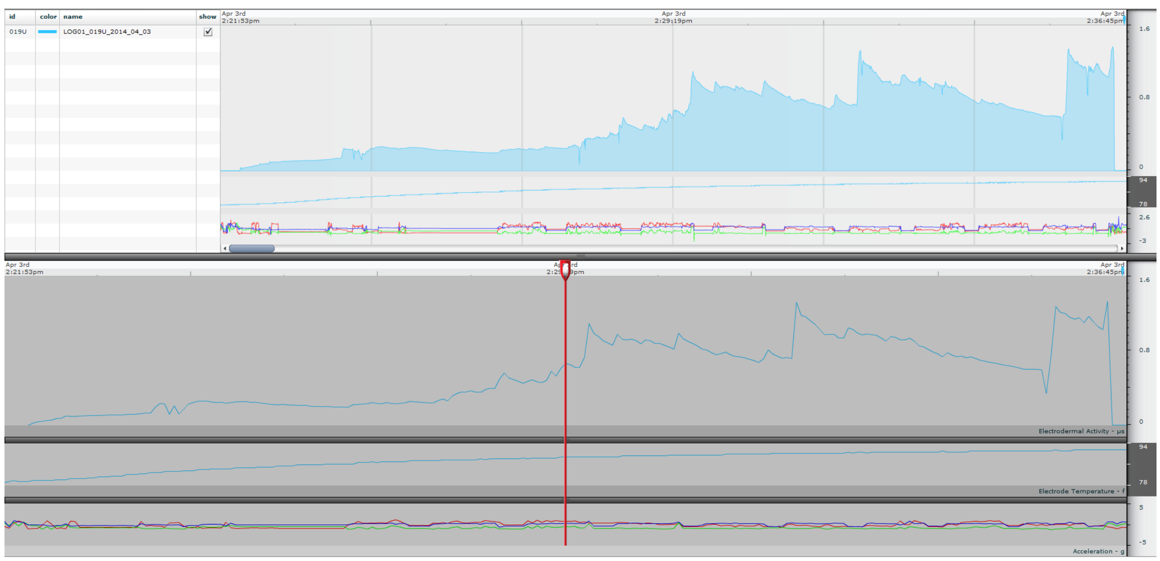
Electrode Temperature - f
Acceleration - g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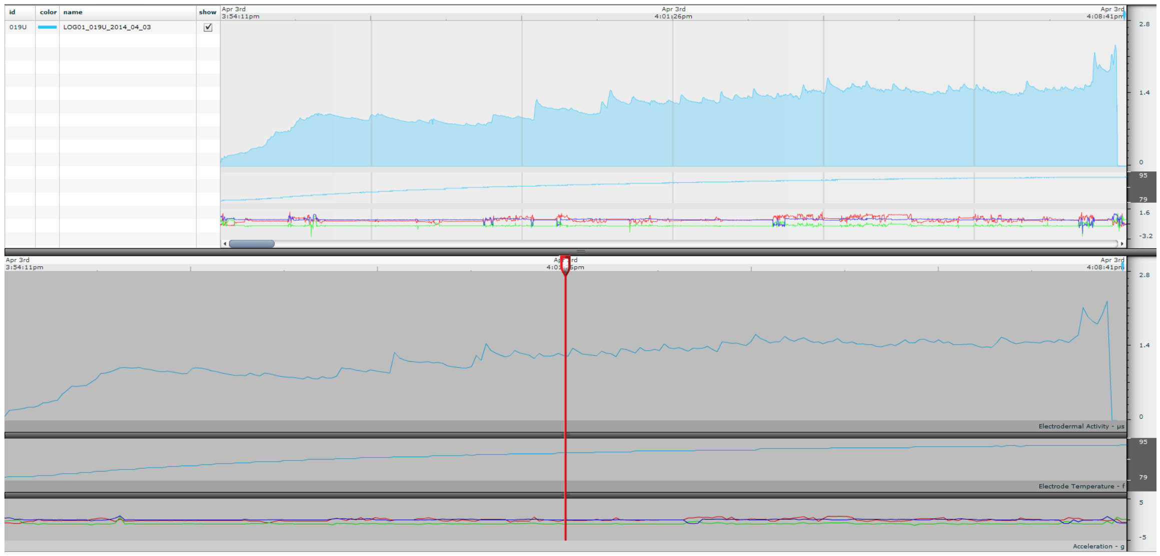
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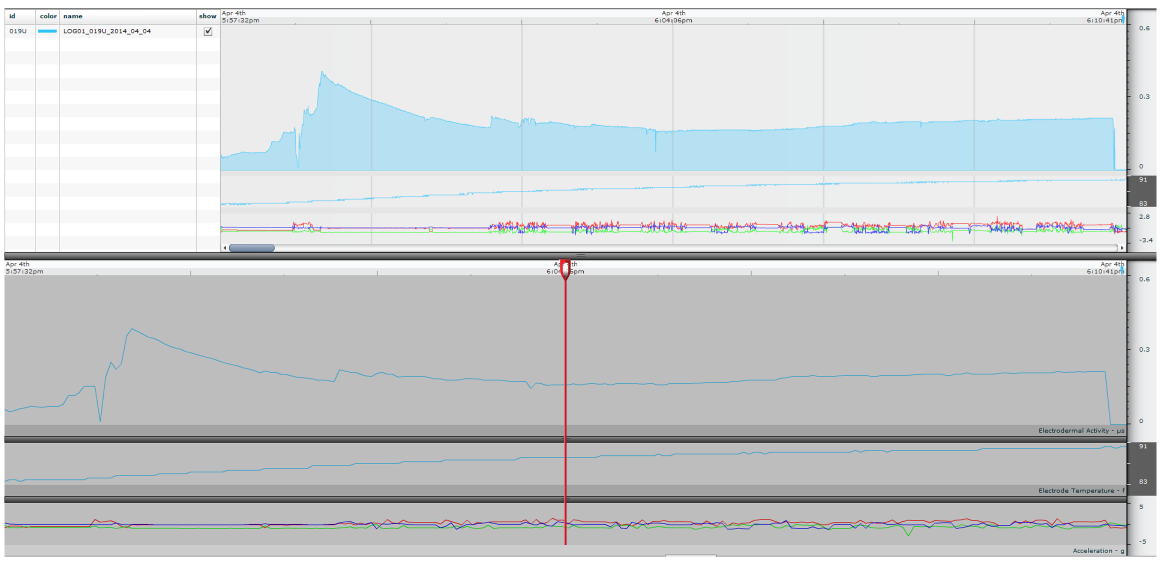
1.4
0
95
79
1.6
-3.2
5
-5
Electrodermal Activity - μs
Electrode Temperature - F
Acceleration - g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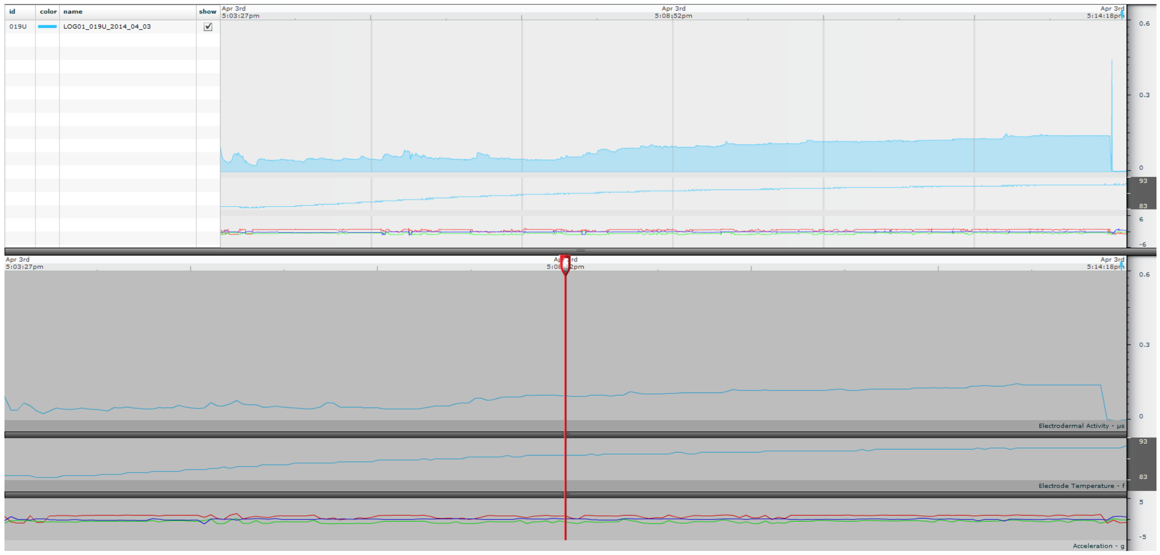
Electrodermal Activity - μs
Electrode Temperature - F
Acceleration - g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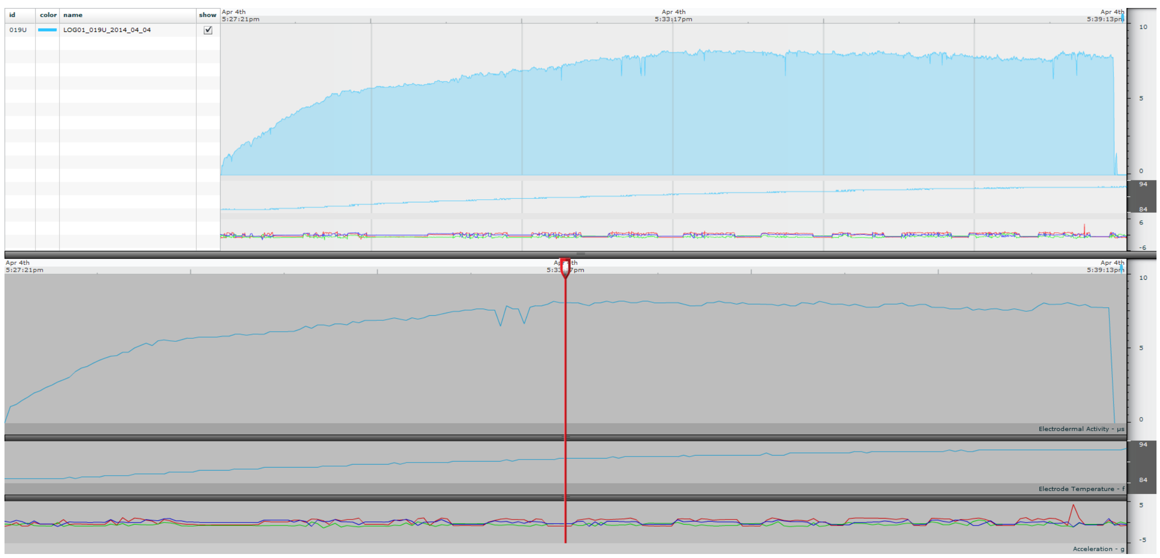
Electrode Temperature - f
Acceleration - g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Electrode Temperature - f
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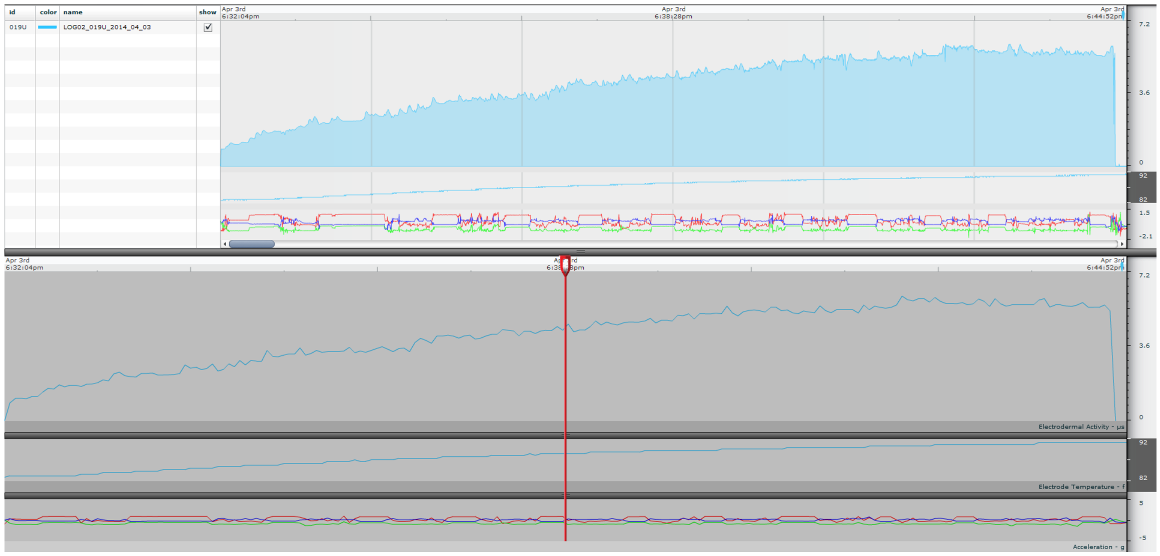

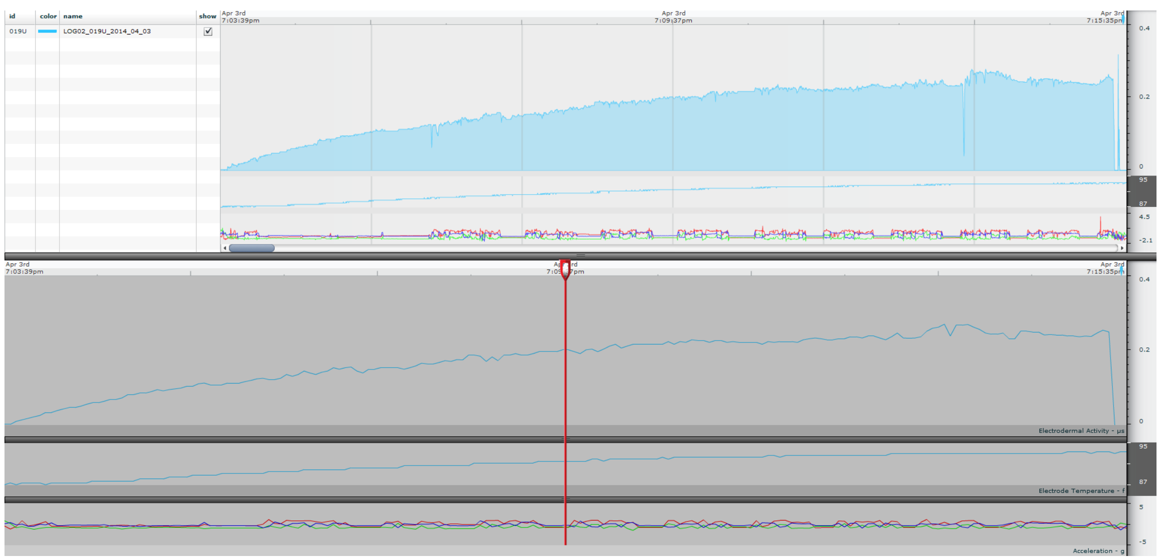

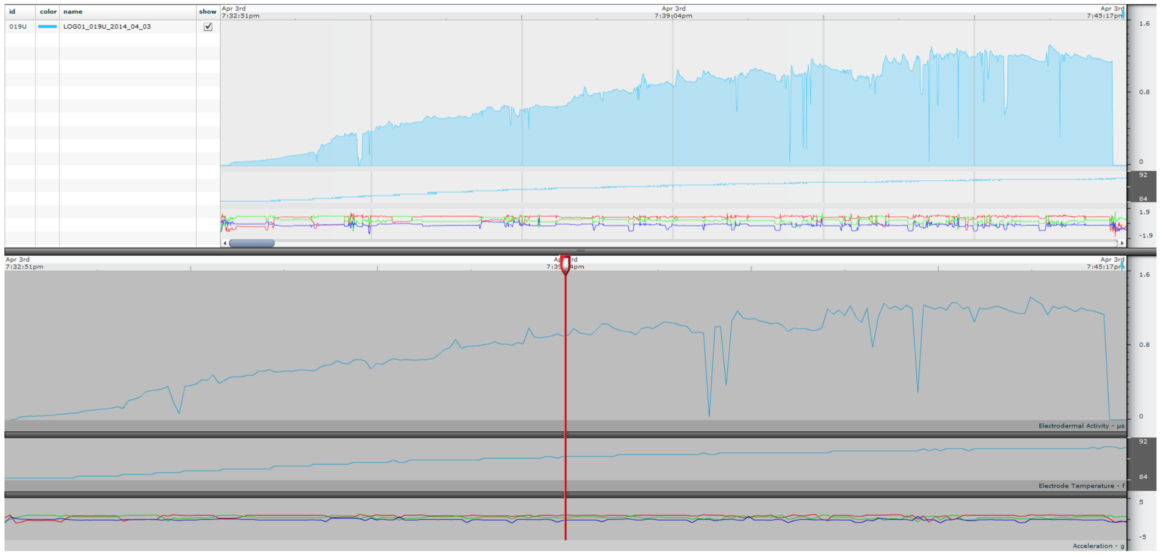

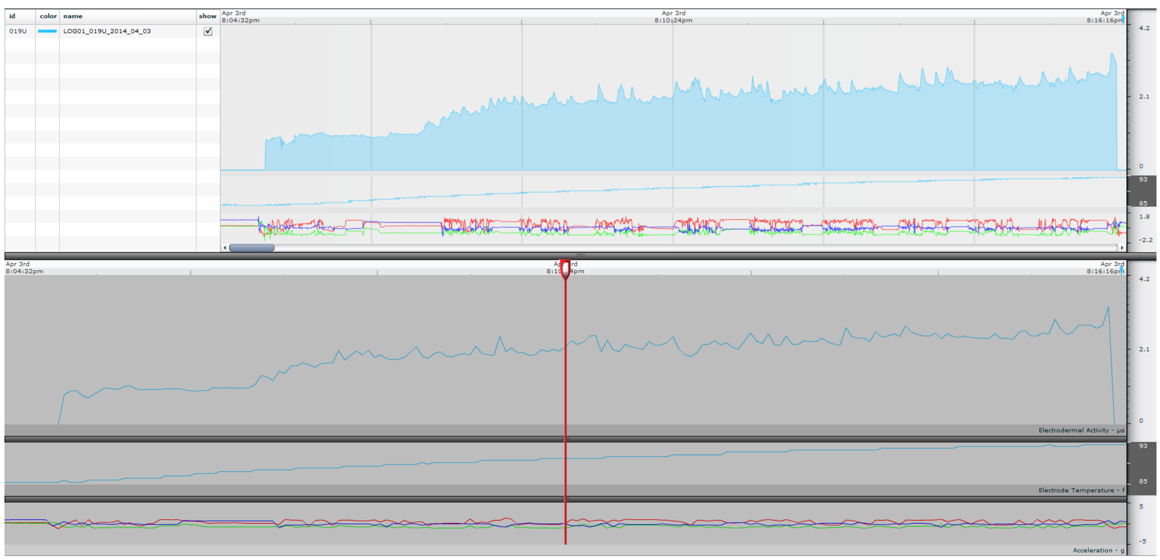

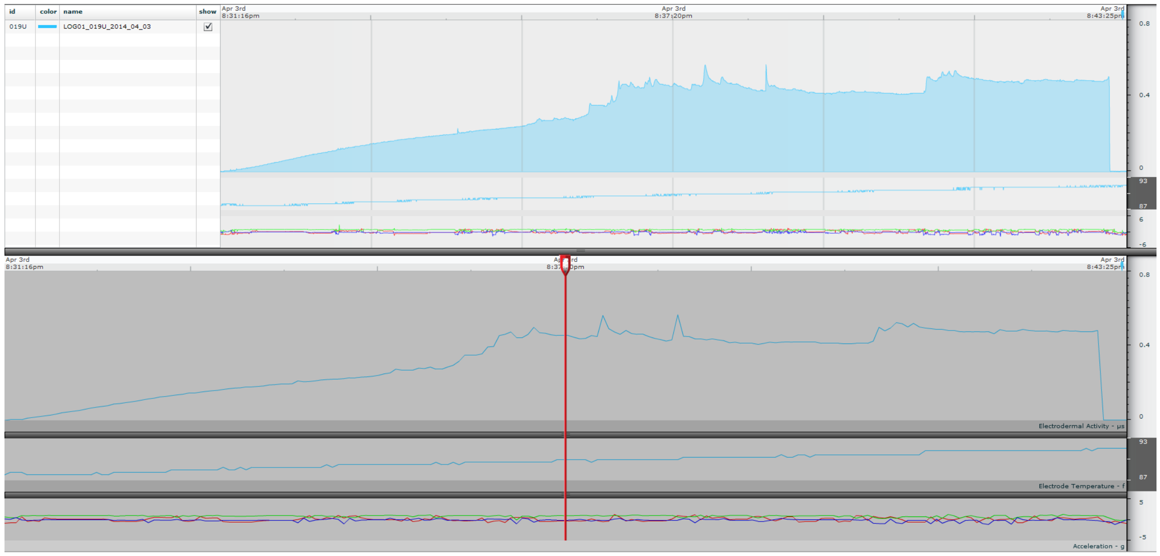
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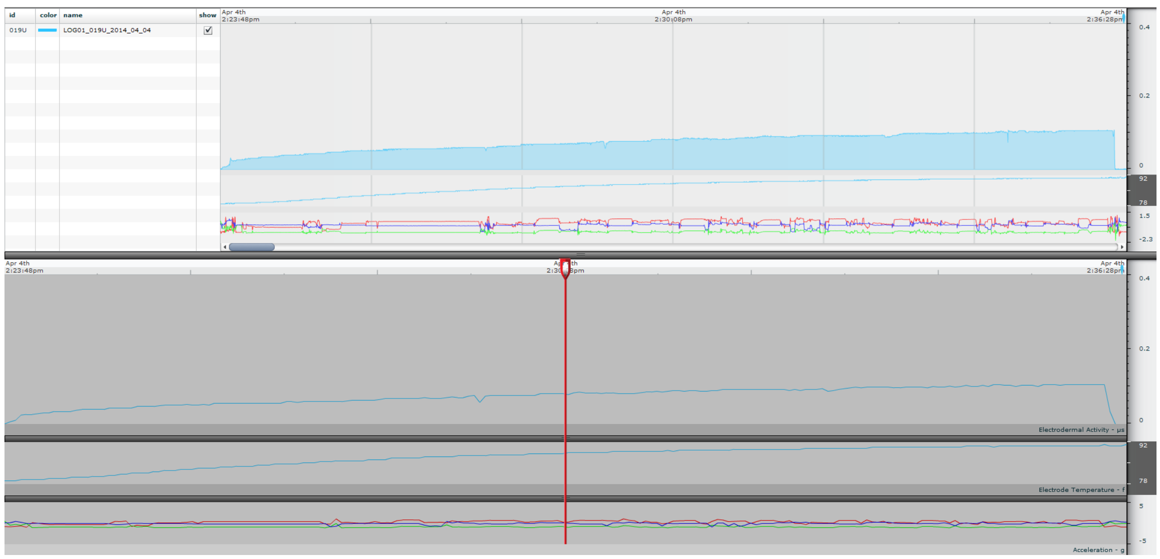
Electrodermal Activity - µs
Electrode Temperature - F
Acceleration - g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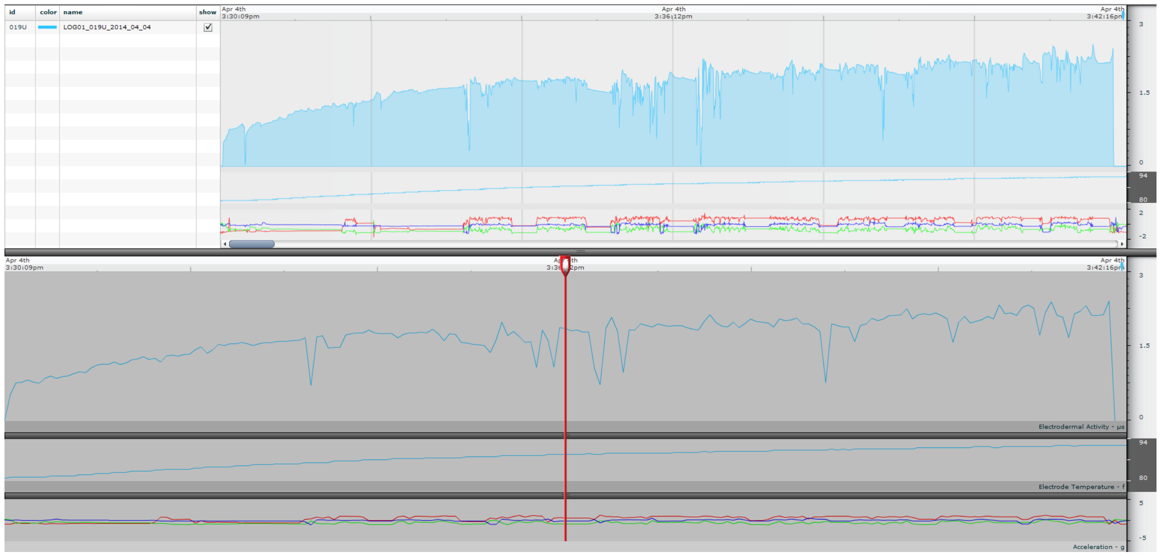
Electrodermal Activity - µs
Electrode Temperature - F
Acceleration - g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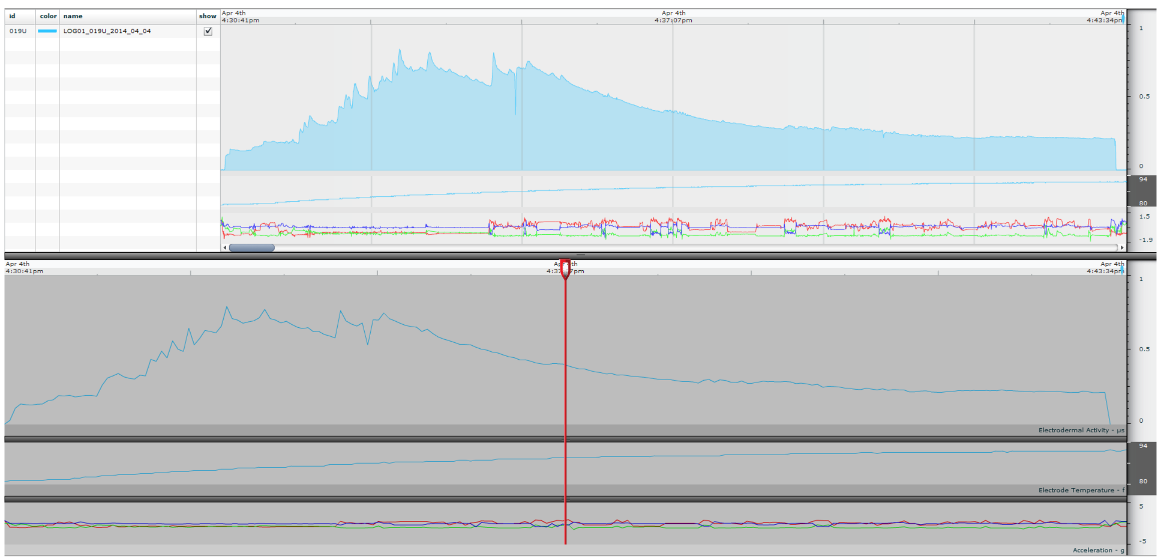
Electrodermal Activity - µs
Electrode Temperature - F
Acceleration - g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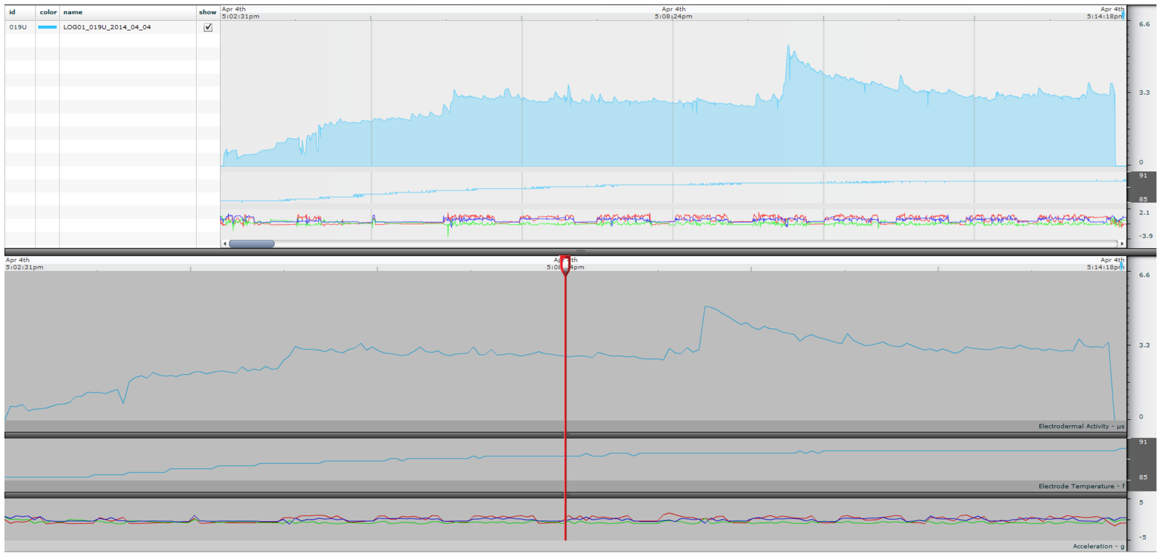
Electrodermal Activity - µs
Electrode Temperature - F
Acceleration - g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Apr 4th
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Apr 4th
5:14:18pm
6.6
3.3
0
91
85
2.1
-3.9
Electrodermal Activity - μs
Electrode Temperature - f
5
-5
Acceleration - g