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Exploring the Effect of Color Palette in Painterly Rendered Character Sequences

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Abstract

In this paper we explore the consequences of different color palettes on the user's experience of emotion as conveyed by facial expression. Artists have used colors and painting techniques to convey emotions in their paintings for many years. Researchers have also found that colors and line properties affect users' emotions. Motivated by previous studies, we hypothesized that painterly rendering with an appropriate color palette would augment the perception of emotions in a facial character sequence. To test this hypothesis, we made sequences of an animated character undergoing four basic facial expressions, using carefully designed color palettes to render them in a painterly style. A series of user studies examined the effect of the color palettes on the perceived emotional expressiveness of the character. The results supported our hypotheses, verifying the importance of visual style and color on viewers' experience of animated facial character's emotions. Similar to how lighting and music are used, animators can use painterly rendering with suitable colors as a tool to enhance the emotional content of character sequences in games and animations.

Categories and Subject Descriptors (according to ACM CCS): I.3.8 [Computer Graphics]: Applications—; I.3.m [Computer Graphics]: Miscellaneous—Painterly Animation

1. Introduction

The expressiveness of a character-based animation relies heavily on its success in conveying emotions to viewers. In order to achieve high levels of expressiveness, today's game character sequences not only rely on the animation techniques, but also on contextual elements such as lighting, background music and scene composition. These contextual elements are not only used to enhance the overall emotional tone of the sequence, but they can also draw the user's attention to specific regions of scene in order to influence the narrative. Painters accomplish much the same thing by using color, various brush strokes, and painting techniques to emphasize certain features of a scene while leaving out unnecessary details. Edward Munch, and Vincent Van Gogh are two exemplary artists who used colors to depict emotions in their work [dPG07]. The use of texture for inducing mood is also evident in different brush stroke styles used by artists [SBC06].

Intrigued by the emotional effects of art and paintings on users, recent research studies have examined the effect of visual style on users' perception and emotional responses. Past psychological studies demonstrated that there are links between rendering style and one's perception and feelings about a rendered object [DBHM03, HMH*03, Hev35]. Furthermore, some other studies investigated people's association between colors and emotion [Hev35, dPG07, VM94]. Finally, studies in human vision demonstrated that texture properties of a painting can guide the viewer's gaze through a portrait painting [DRE10].

Painterly rendering, a subset of Non-Photorealistic Rendering (NPR), is a computer graphics technique that simulates the work of illustrators and portrait artists and is commonly reported as an expressive style inspired by painting, drawing, technical illustration, and cartoons [HE04, Her01, LS95]. We believe that the expressiveness of emotional character sequences can be enhanced by merely changing the visual style of those sequences. We examine this hypothesis by applying painterly rendering to facial sequences of four basic (universal) emotions in a series of user studies. We used carefully designed color palettes to address this spe-

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cific question: Does the color palette of a painterly-rendered facial character sequence influence the perceived type and intensity of the expressed emotion(s) in that sequence?

A first step in our work involved matching colors appropriately to emotions. For this we relied on previous studies of color and texture [dPG07, DRE10, SBC06], with special emphasis on the work of da Pos and Green-Armytage [dPG07], who asked multiple professional designers to assign specific values from a color palette to a variety of facial expressions. These authors found overall consistency in color-emotion assignment for the six basic emotions. Specifically, designers mostly used desaturated colors for fear and sadness, and colors with higher saturation for anger, joy and surprise. Designers were also asked to decode colors chosen by other designers into the corresponding facial expressions. They found high percentage of correct decoding from colors back to facial expressions. Based on the finding of that study, we used combination of colors in yellow-orange range for the joy and surprise emotions, red and black range for the anger emotion, desaturated blue and later desaturated gray-brown colors for the fear emotion (See section 3.4 for the La*b* values of the color palettes). This allowed us to analyze our results across emotions by comparing the results for "congruent" animations (when the facial expressions matched the color values of da Pos and Green-Armytage) with those from "incongruent" emotions (when the facial expressions were mismatched to these colors). Based on this notion of congruent and incongruent color palettes, our general hypothesis is

Painterly rendering of a basic emotion with the congruent color palette in a facial character sequence will increase the perceived intensity for that emotion. Rendering the same character sequence with the incongruent palettes for that emotion will reduce the perceived intensity for that emotion.

In order to investigate this hypothesis, we conducted a series of user studies with computer generated, painterly rendered, facial expression images and animated sequences, as described in section 3. However, to provide important background to these studies, we will first describe the related research in the literature. A general discussion of our results and anticipated future work will conclude the paper.

2. Related Work

Our work builds on past psychological studies on the association of colors and emotions [DBHM03, Hev35, dPG07, VM94]. The most relevant work to ours is a study by da Pos and Green-Armytage [dPG07] in the sense that they examine the association of colors to facial representations of six basic facial emotions [EF03]. Specifically, they asked European and Australian designers to choose first, a combination of three colors and then a single color that best fit each of the six basic facial expressions. They found considerable consensus among designers in their color-emotion association. For instance, a great percentage of the participants used red and black for anger. For the positive emotions of surprise and happiness, they mostly chose highly saturated yellow and orange hues. In contrast, colors for the negative emotions of fear and sadness were less saturated with gray as the commonly used color. For sadness, designers also used shades of blue, while there was less consensus on fear other than the overall gray hue. This study suggests that there may be specific colors associated with each emotion. We therefore used the findings of this study to design the color palettes for our studies, specifically assigning the consensus colors for each emotion from this study as the "congruent" color: black-red hues for anger, yellow-oranges hues for joy and surprise, and desaturated gray-brown for fear.

Other studies explored the association of colors to emotion spaces or colors to emotional qualities in a more general sense using emotion words. A study by Henver [Hev35] explored the affective value of different colors and shapes used in a painting. According to their results, blue is expressive of dignity, sadness, tenderness, and red is indicative of happiness, restlessness and agitation. Moreover, they realized that curves are perceived as conveying tenderness and greater sentimentality, in comparison to straight lines that are associated with sadness, seriousness, vigor, and robustness.Valdez and Mehrabian [VM94] proposed understanding the emotion-color association by decomposing colors according to a color space. They represented colors in terms of hue, saturation, and brightness components. Using Pleasure-Arousal-Dominance (PAD) space for emotions [Meh96], they suggested linear relationships between the Hue, Saturation, and Brightness components and the PAD dimensions. According to their results, color brightness has a strong positive correlation to pleasure and the saturation component is correlated with the arousal axis in the PAD space. Although informative, these studies use solid colors on small squares and ask subjects to choose from a list of emotion words/terms. The results suggest the association of the colors to those emotion words regardless of their manifestation. None of the abovementioned studies examine any perceptual effect of applying the colors to images or facial emotions.

Another study by Duke et al. [DBHM03] points to the importance of visual style on perceived properties of objects in an image. Specifically, they conducted a series of experiments on NPR images and showed that people's perception of an object in an image can be modified by simply changing the visual characteristics of the object. For instance, NPR can induce perception of safety, personality and can influence navigation and exploration behaviors. They concluded that psychological theories and studies can enhance the outputs of NPR applications; and moreover psychology and NPR can mutually benefit from such interaction [HMH*03].

In computer graphics area, Dipaola et al. [DiP07, DiP09] adapted general painterly rendering algorithms for portraiture painting of faces. The Painterly program has been developed based on the collected qualitative data from art books

and interviews with portrait painters. The qualitative data about how portrait artists achieve the final painting was then translated into a parametric model. The program combines general painterly algorithms with this parameterized knowledge of portraiture painting into a more sophisticated algorithm for faces. The Painterly system can differentiate areas of the input image including background, hair, face and eyes. This allows using sophisticated color palettes and painterly parameters (e.g brush and texture properties) for each area. Various color palette and brush properties result in different texture and visual effects in the output image. A series of recent eye tracking studiesdemonstrated the effects of textural variations on guiding users' gaze in portrait paintings. Such an effect has been used by artists as early as Rembrandt to attract viewer's gaze into emotionally loaded areas of portrait paintings such as eyes [DRE10] .

3. User Studies

In total we conducted two pilot studies and four main studies, which are described here in more details.

Brief description of the studies. Two pilot studies were conducted in order to determine the appropriate intensity levels for the facial expressions and to help with the choice of rendering styles. Then, we examined the effect of cool vs. warm colors on facial expressions, which led to revising the color palettes. We designed the color palettes based on the work of da pos and Green-Armytage [dPG07] and examined them in two main studies on still images and moving sequences respectively. All the studies follow a common structure. The participants watched a number of still images or short character sequences in which a computer rendered 3D face expressed a facial emotion. After each image or video, the participants selected an intensity level for the emotions they saw conveyed in the facial expressions of the still image or animated sequence. To do this, they were able to set six different sliders, each one representing one of the universal emotions. The following includes the description and results of each study in detail (See table 1 for a summary). First we describe the set up common to all experiments.

Emotions. We examined four of the six basic expressions introduced by Paul Ekman as universally recognizable expressions: Anger, Fear, Surprise, Joy [EF03].

Intensity levels. The experiments included base expressions for each emotion set to one of three intensity levels: low, medium, high. Two of these intensities were used in each experiment.

Apparatus. The apparatus for our studies is a .NET windows application written in C#. The program receives the number of repetitions for each movie and generates a random ordering of the experiment movies and displays the first movie in the sequence. After watching each image or movie, the participant can choose the intensity perceived for each of the six basic expressions using the six sliders on the response form. The order of sliders are based on the order of presentation in Ekman's book [EF03]. The choices made by the participant along with the timing for those choices are saved in a text file.

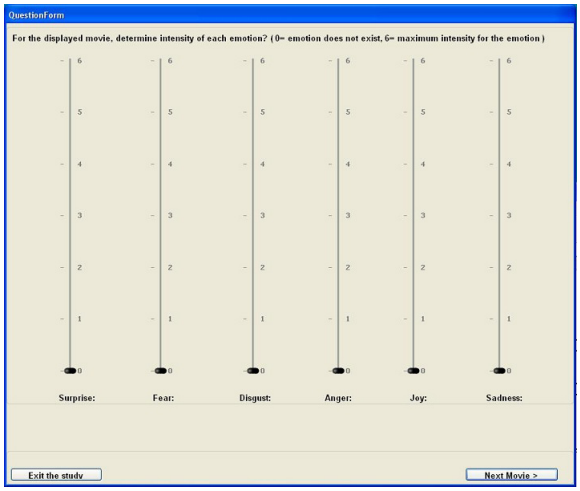

Figure 1: *Response form (right) with six sliders*

Movies. Each movie began with a computer rendered 3D head model in a neutral emotional position, seen in three-quarter view (facing 45 degree to the left of the screen). The head then turned to face the viewer and became animated from the neutral emotional posture to one of the four emotional expressions.This expression was held for one second before the face stopped moving. These 3D animated sequences were authored using the iFace facial animation system [ADP09] which allowed precise configuration of facial expressions based on Paul Ekmans' definition of the expressions and MPEG4 standard for facial animation. We chose the most representative face from the available head models for iFace although the model is still not as realistic as the state-of-the-art head models. We rendered the animation frames from iFace in the Painterly system [DiP07, DiP09]. All movies were made from these painted frames using a frame rate of 24 fps.

Variables. Since we were interested in capturing any changes in the emotion perceived as a result of painterly rendering, we asked users to rate the intensity they perceived for each of six universal expressions (joy, sadness, anger, disgust, surprise, and fear). These ratings formed the basis for our measurements. As a result, all of the studies have six dependent variables representing the perceived intensity of the six basic expressions. All of the dependent variables thus consist of values ranging from zero to six. The default value is zero, which means that the subject did not observe the expression in the movie. Subjects could set the intensity by moving each slider up and down after watching each movie.

Procedure. During each testing session, the investigator first provided the participant with a brief description of the study. Non-painterly "base" animation versions of all six emotion sequences were shown to participants as context. The investigator also stated the type and intensity of those baseline facial expression movies (e.g. "this movie displays fear in extreme intensity"). The participant could watch these sample movies as many times as he/she wanted. The investigator also mentioned that the experiment movies could display just a single expression or a mixed facial expression (a combination of two or more basic facial expressions). The participant was instructed to move one or more than one slider, based on their perception of the expressions. The participants watched the images or movies in random order, with no time pressure placed on participants. Participants were left alone in a small office to complete the study.

Table 1: *Summary of all studies*

Study	Movies	Intensity	Brush Type
Calibration Studies	Original CG movies	Low/Medium/ High	Jaggy
Warm-Cool Studies	Original CG movies and painted movies in 3 palettes	Medium/ High	Jaggy
Study on Still Images	Painted movies in 5 palettes	Medium/ High	Jaggy
Study on Moving Images	Painted movies in 4 palettes	Medium/ High	Jaggy/ blurry

The following sections describe the details of the studies:

3.1. Calibration Studies

The first calibration study investigated the sensitivity of the subjects to three selected intensity level for each emotion: low, medium, and high. Each of 13 graduate students (9 female, 4 male, age=23-30) watched the CG versions of the facial expressions in a unique random order and responded by using the slider to indicate the perceived intensity levels for each expression. The mean and standard deviation of the intensity ratings for each movie indicated that the subjects could correctly identify the non-painted facial expressions and were adequately sensitive to the changes in the intensity for all the expressions. The only exception was the fear expression, for which the low-intensity version was sometimes confused with surprise.

The purpose of the second pilot study was to examine users' perception of the non painterly, standard Computer Graphics (CG) animated movies compared to the painted movies in the original palette. 14 graduate students (6 female, 8 male) participated in a 15 minutes user study. According to the results, the effect of the rendering style (CG vs. painted) on the users' perception was negligible. This means that the computer graphic version and the painted version in the original color palette were not perceived as significantly different from one another with regard to the type and intensity of the expressions. Again, only the fear and surprise movies resulted in secondary ratings of surprise and fear, respectively, in both CG and painted movies.

3.2. Warm-Cool Color Palette Studies

Since artists often use these cool and warm color palettes in their work to set an emotional tone [DiP09], we began by examining the effect of cool and warm color palettes on the perception of animated facial expressions. Four different movie types were used: original CG movie, painted in original color palette, painted in cool color palette, and painted in warm color palette. Based on our general hypothesis, the warm color palette in these studies was predicted to be congruent with joy and surprise whereas the cool color palette should be congruent to fear and anger. The result of these studies suggested some color trends for the emotions. Ratings (of the perceived emotion intensity) for both cool and warm palettes were significantly higher than the original color palette in case of anger, joy, and surprise emotions. Although this result supported our hypothesis about the effect of colors, the mean ratings for cool and warm palettes were not significantly different from each other. Additionally, the effect of colors did not hold for fear emotion. Reflecting on the study design, we think that the warm and cool color groupings are higher level constructs which were not appropriately captured in our controlled study. Warm and cool for colors are defined by artists relative to other colors. For example purple is considered cool compared to red but is warm compared to green or blue. Thus, we decided to find the association of primary colors to facial expressions instead of using higher level constructs such as cool and warm palettes with more fuzzy definitions.

Two important conclusions were drawn from the Calibration and Warm-Cool studies: 1) Precise facial configurations based on Ekman's guidelines are necessary to avoid confusion in distinguishing the emotions. Confusion was greatest between fear and surprise expressions. 2) The cool and warm color palettes inspired by the artists did not influence perceived emotions, perhaps because they are higher level constructs. The effect of color on facial expressions needs to be examined with more primary color concepts to address the complex relationship of colors and emotions. We did not draw any further conclusions from these studies. These initial results mainly informed our design for the following studies.

3.3. da Pos and Green-Armytage Color Palette Study: Still Images

Because of the failure of the Warm-Cool palette to have an influence on perceived emotional intensity, we turned next to the color palette of da Pos and Green-Armytage [dPG07]. We designed five color palettes based on this study. Three of the color palettes were designed to enhance the four basic emotions of Anger, Fear, Joy and Surprise (Figure 2). In particular, we designed the dark-red color palette for the anger emotion and the cool-light color palette for the fear emotions. For joy and surprise we designed one color palette, yellow-orange color palette. The two other color palettes were added for exploratory purposes. Cool-dark color palette was added to balance the effect of brightness. Also, the natural color palette is considered as a baseline for our analysis as it uses the same colors as the original 3D frame. Figure 2 shows the color palettes with the corresponding emotions as captions.

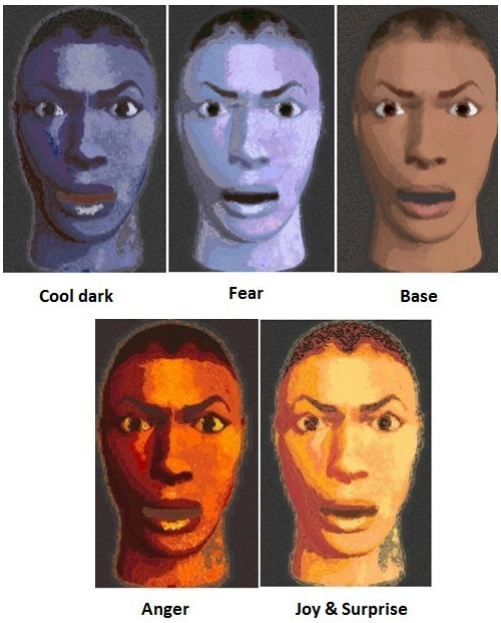

Figure 2: *Five color palettes for the study on still images*

Materials and procedure. Materials for the study were still images of the same four universal expressions used in the previous study, but this time rendered at medium and high intensity levels. The image for each of the facial expressions was extracted from the corresponding facial expression sequence and was painted by the Painterly program in all the five color palettes (see Figure 2), totalling to 40 images (4*5*2=40). We did not include the original CG movies based on the results of the second pilot study (see section 3.1). During a 30 minutes testing session, participants watched all 40 images for three times in random order and chose the intensity perceived for each facial expression on a Likert scale of 0 to 6 (zero being the neutral position and six the highest intensity for the emotion).

Participants. 15 graduate students(6 female, 9 male, age=23-30) voluntarily participated in a 30 minutes study.

Analysis and results. The average slider value entered by a subject over three repetitions of a movie formed the basic measure (continuous values between zero and six). For each emotion, the movies include one congruent, one neutral and three incongruent color mappings. The results were analysed with a within-subject ANOVA involving the three factors of emotion type (4 basic emotions), congruency (3 levels: congruent, incongruent, and neutral), and intensity level (medium and high). The primary finding was a significant main effect of congruency ($F(2,28) = 8.86$, $p = .001$). The results of Bonferroni's post-hoc test showed that for all four emotions, the mean rating for the congruent color palette to the emotion ($M=3.74$, $SD=0.19$) was significantly higher than the mean intensity rating for the incongruent color palettes ($M=3.24$, $SD=0.18$). This result indicates that an appropriate color palette increases the intensity of the emotions perceived by the viewer.

A finding of secondary importance was a significant interaction of emotion by congruency, with an F ratio of $F(6,84) = 2.83$, $p = .015$. This indicated that the patterns of mean ratings for congruency were not the same magnitude for all emotions. Figure 3 illustrates the emotion by congruency interaction. Notably, for the two positive emotions (joy and surprise), the use of incongruent colors weakened the perceived intensity of the emotions relative to baseline, whereas for the two negative emotions (anger and fear) congruent colors heighted the perceived emotional intensity relative to baseline levels.

Note that we did not systematically analyze the ratings for the secondary emotions for the simple reason that those ratings were too infrequent to warrant a quantitative analysis. However, we briefly refer to these details in section 4.

3.4. da Pos and Green-Armytage Color Palette Study: Moving Images

The final study using moving sequences had a similar design to the previous study of still images. However, the color palettes were adjusted to align even more closely with the colors proposed in da Pos and Green-Armytage's paper. They reported the average color chosen by designers for each of the six facial expressions in the La*b* system. We calculated the average color of the neutral-pose face painted in each color palette and ensured that our palettes correspond to the proposed colors in the paper. Tables 2 and 3 shows both the average values for the face with our color palettes and the average values provided in the da Pos and Green-Armytage's paper in the La*b* color system. Figure 4 displays the color palettes used for the final study.

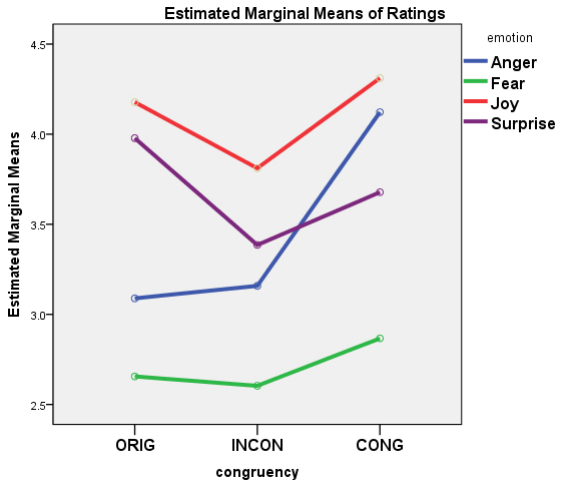

Figure 3: *Mean ratings for original (ORIG), incongruent (INCON), and congruent (CONG) palettes in the study on still images*

Table 2: *Average colors in the da Pos and Green-Armytage's study*

	L	a	b
Anger	30	22	10
Fear	50	8	10
Surprise	60	15	30
Joy	60	17	42

Table 3: *Average colors of faces with our designed palettes*

	L	a	b
Anger	36	40	41
Fear	53	7	12
Surprise/Joy	64	23	47

Figure 4: *Color palettes for the final study on moving sequences*

To explore the possible role of texture in conjunction with color, we combined our analysis of color-emotion congruence with one of brush texture. Specifically, we compared two different brush types. According to previous studies of affect in art literature [DBHM03, HMH*03, Hev35, SBC06], harsh angles and jaggy lines convey vigour, power, fury and agitation while smooth curves are associated with serenity, laziness, and tender sentimentality. Thus, we used two slightly different brush types: jaggy and blurry, created by different settings for the size and curvature of the brush. Figure 5 shows an example of these brush styles.

As a result, the study on moving images has an additional set of movies with blurry strokes. However, the jaggy brush stroke is similar to the brush stroke in the previous study on still images.

Participants. 22 undergraduate students (17 female, 5 male, age=18-30) participated in the study for course credit.

Movies and Procedure. 64 movies were shown (in random order) to each participant in three repetitions, resulting in 192 ratings. The set of movies displayed a female head model expressing four chosen emotions (4) in the medium and high intensities (2), painted with four color palettes (4) and two brush styles (2) (4*2*4*2=64). The experiment took approximately 45 minutes for each participant to complete with a procedure similar to the previous studies.

We tried to prevent the participants from noting the hypothesis of the study and mitigate any undesired effect on their responses. At the beginning of the study, the investigator asked the participants to rate movies just based on their impression since the movies can include obvious (color) as well as more subtle variations. In this regard, using two different brush types helped with increasing the variability of movies.

Analysis and results. The test of repeated measure (within-subject) ANOVA was taken with four factors of emotion (4 levels), intensity (2 levels), brush style (2 levels) and congruency (3 levels). The level for statistical significance was at .05. The results indicated an interaction effect of emotion* congruency with an F ratio of F(6,126) = 7.8, p= .000. This result indicates that the effects of the original, congruent, and incongruent palettes were different for the four emotions used. According to Figure 6, the anger movies have higher ratings for the congruent color palette (M=3.13, SD=0.25) in comparison to the original color palette (M=2.63, SD=0.23) and the incongruent color palette (M=2.53, SD=0.22). Similarly for joy movies, congruent color palette (M=3.85, SD=0.17) has higher rating than the incongruent color palette (M=3.66, SD=0.22) and original color palette (M= 3.56, SD=0.22).

In contrast to the findings of the still study with this color palette, the data for the fear movies indicate higher ratings for the original (M=2.36, SD=0.15) and then the incongruent (M=2.04, SD=0.18) color palettes compared to the con-

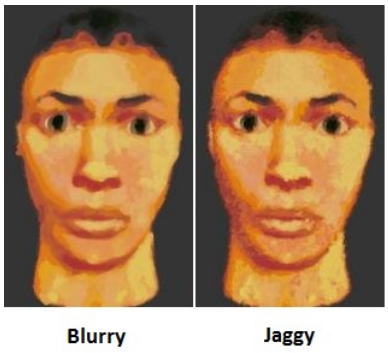

Figure 5: *Blurry and Jaggy brush styles*

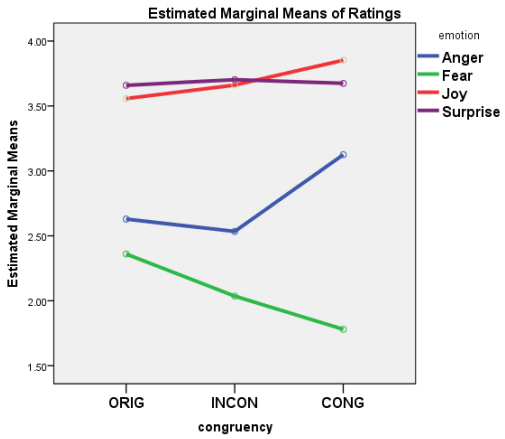

Figure 6: *Mean ratings for original (ORIG), incongruent (INCON), and congruent (CONG) palettes in the study on moving images*

gruent color palette (M=1.78, SD=0.24). The pattern of the ratings for the surprise movies were almost constant for all color palettes, with the following values for the original (M=3.66, SD=0.21), congruent (M=3.67, SD=0.15), and incongruent (M=3.70, SD=0.19) color palettes. While the results of the ANOVA test showed higher order interactions as well, the above interaction was the most relevant in terms of answering our research question and hypothesis.

Results did not indicate any significant difference between ratings of the jaggy and blurry brush styles. However, the texture effect used in this study was very subtle (see 5). A focused study on the effect of brush can explore this factor better.

Unexpected Results. Unexpectedly, for the fear movies, the congruent palette was rated the least fearful and the original palette the most fearful. Looking at the color combinations chosen by designers in da Pos and Green-Armytage's study [dPG07], one will find them more varied for the fear emotion compared to the more consistent color associations for anger, joy, and even surprise. This can point to various opinions among people about the congruent color for fear.

Furthermore, the constant pattern in the ratings for the surprise movies was not anticipated in our hypothesis. A possible explanation for such pattern can be differences between the facial configuration chosen for the surprise in our studies and the study by da Pos and Green-Armytage [dPG07]. Although both facial configurations are based on the Ekman's book [EF03], they represent two variations of the surprise emotion. While the surprise in da Pos and Green-Armytage's paper displays a joyful or pleasant surprise, the surprise in our movies was more of a shocked or unpleasant surprise. The similarity between the color combinations chosen for the joy and surprise expressions in da Pos and Green-Armytage's study [dPG07] can also be due to the pleasant surprise chosen in that study.

To better understand the results, we analyzed the ratings for jaggy brush movies separately. Results showed a similar pattern of ratings as the one in figure 6. This suggests that the differences in rating between still images and moving sequences are not due to the change in brush stroke.

4. Discussion and Conclusion

We conducted a series of user studies to investigate the effect of color palette on users' perception of an emotion in animated character sequences. Our first two attempts to do so (Warm-Cool Color Palette Studies) while suggesting some trends for specific emotions, did not lead to a consistent effect of heightening the intensity of perceived emotions. We think warm and cool palettes are defined by artists about the relative relationship between colors. Thus, they can represent higher level cognitive concepts with more complex associations to emotions. As a result, we focused on the direct association of colors to emotions in the follow up experiments.

In general, the results of the studies using da Pos and Green-Armytage's [dPG07] color palettes were much more consistent, for both still images and moving sequences, in creating a heightened emotional experience through the use of colors. These results indicate that specific colors paired with specific emotions can both enhance and weaken the emotions perceived in an animated facial sequence. In the study using still images, user ratings for all the four emotions (anger, joy, fear and surprise) were heightened by the use of a congruent color palette when compared with an incongruent palette. For the study using moving sequences, where we adjusted the color palettes more specifically to match the average colors indicated by da Pos and Green-Armytage [dPG07], we found that using congruent colors for anger and joy elevated the intensity of the emotion perceived. However, in that study, surprise and fear were not influenced as greatly. These studies give evidence about the

effect of carefully-designed color palettes on the emotional content of an animated sequence. However, the results also suggest that colors and emotions may be even more complicated than we had first assumed. Hence, further research is needed to develop a model for the color-emotion associations.

As an additional point, interestingly in all studies, participants rated the fear movies as a mix of fear, surprise and sadness with much lower intensity for surprise and sadness. The intensity of the latter emotions did not change with the intensity of the fear perceived but was slightly different according to the color palette. for example, the anger and joy/surprise color palettes had higher surprise ratings while the cool-dark and fear color palettes showed higher sadness rating. Similarly, ratings for surprise movies indicated fear as a secondary emotion. These ratings can be partially due to similarity between surprise and fear expressions but can also points to potential effect of colors on the type of facial emotion perceived. See figure 7 from the study on still images as an example. The original sequence displayed the fear expression but the participants also perceived surprise and sadness emotions in the sequence.

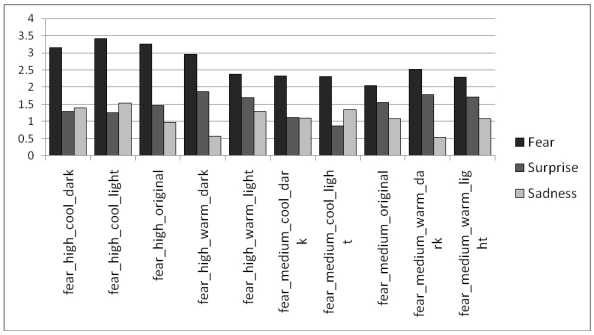

Figure 7: *Mean ratings for fear images- note surprise and sadness as additional emotions and their change based on color palette. Color palettes on x axis are as follows: cool-dark, cool-light (congruent to fear), original (base), warm-dark (congruent to anger), warm-light (congruent to joy and surprise)*

In contrast to most previous studies which looked at the association between single colors and facial expressions, we used painterly rendering to apply a range of colors to facial expressions in an automated and visually plausible way. As pointed in the study by da Pos and Green-Armytage [dPG07], no single color can be mapped to a facial emotion, thus they suggested a range of colors for each expression. Also, triple color combinations chosen by designers in their study reflected more consistency compared to single colors. The effect of different color combination effects have been known and utilized by artists and designers for many years. The current studies suggest that painterly algorithms can incorporate such knowledge from the art and design domains and acheive more expressive results. Thus, these studies support the idea of knowledge-based painterly rendering which utilizes the knowledge about the scene and its emotional content together with the knowledge of the painterly techniques and their affective content in order to make more expressive painterly output [SDA11].

5. Applications and Future Work

As mentioned before, the main application of knowledege-based painterly rendering is in animation and movie industries. These industries usually use a variety of techniques such as music and lighting to boost or flavor the emotional impact of a scene. Movie and animation sequences usually require carefully composed soundtracks to involve viewers in the story effectively [Coh01]. The number, color, direction, and the quality of a scene's lightings also have direct impact on viewers' emotional gain from the movie or animation sequence [Bir05]. These techniques have been used for many years as effective tools for adding to the emotional impact of movie and animation sequences. The proposed technique provides the animators with an additional tool to intensify or flavor the emotional content of a scene.

We anticipate a number of extensions to this work, one of which is conducting a similar study on a longer list of facial expressions, using the appropriate color palettes. Also, the affective impact of using different textures on the viewer's perception needs to be investigated in more detail. Moreover, similar studies on a range of head models including more realistic faces can investigate the generalizability of the current results.

One of the limitations of this study was considering only the six basic expressions. While this method of measurement helps in limiting the scope of the study and avoids the inclusion of many undesired factors in the results, we could not fully capture other possible effects of colors on the quality of the emotions. We think that colors might cause slight variations in the type of an emotion. In other words, colors can change the emotion perceived to a nearby emotion in the same family of emotions (see Ekman's description of the emotion families [EF03]). We tried to partially capture these effects by allowing for multiple ratings (see section 4 for the discussion on secondary ratings). However, repeating the study with measures that better capture the quality of the emotions is useful and leads to better insight.

Finally, NPR can be used as a tool to study visual perception as it allows researchers to systematically change the rendering parameters of an image and study their effects on users'perceptions. These studies are more difficult, if not impossible, by using real face images or even CG images. For instance, in the current work, we used NPR to build on previous understanding about emotion perception by changing the color palette and texture parameters. Based on Ekman's

work [EF03], we know that facial configuration plays an important role in perception of an emotion. Also, past studies have shown strong associations between colors and emotional interpretations. The results of our studies demonstrate that facial color also contributes to users' perception of emotions by increasing or decreasing the perceived intensisty of the emotion. Thus, as identified by Halper et al. [HMH*03], NPR and psychology can mutually benefit from interaction.

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