Emotion-Color Associations in the Context of the Face

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Abstract

Facial expressions of emotion contain important information that is perceived and used by observers to understand others' emotional state. While there has been considerable research into perceptions of facial musculature and emotion, less work has been conducted to understand perceptions of facial coloration and emotion. The current research examined emotion-color associations in the context of the face. Across four experiments, participants were asked to manipulate the color of face, or shape, stimuli along two color axes (i.e., red-green, yellow-blue) for six target emotions (i.e., anger, disgust, fear, happiness, sadness, surprise). The results yielded a pattern that is consistent with physiological and psychological models of emotion.

Keywords: Emotion, Color, Face, Association

Outward expressions of emotion convey information about an individual's internal physiological and psychological state. Perceptual expectations regarding emotion are generated and reinforced through continued interactions with others. Specifically, perceivable characteristics of emotion are detected and stored as information, which is later used to effectively predict and understand others' emotion (Jack, Garrod, & Schyns, 2013; Yuille & Kersten, 2006). These expectations therefore reflect deeply engrained emotion-perception associations. By studying these associations, we can understand how emotion information is transmitted and interpreted as social information.

An important, yet understudied property of emotion expression is facial coloration. While a substantial amount of research on emotion expression has been dedicated to investigating facial musculature (Ekman, 1993), very little empirical work has been conducted to examine the role of facial coloration changes in emotion communication. However, facial coloration reflects physiological and psychological processes that are biologically and socially relevant. For example, facial color has been shown to influence perceptions of health (Stephen, Coetzee, Law Smith, & Perrett, 2009; Young, Thorstenson, & Pazda, 2016), attractiveness (Jones, Little, Burt, & Perrett, 2004; Thorstenson, Pazda, Elliot, & Perrett, 2016), and personality (Stephen, Oldham, Perrett, & Barton, 2012). Further, because the expression of emotion cues is an important component of emotion communication (Keltner & Haidt, 1999), we should expect to find cognitive and perceptual mechanisms that facilitate detecting such cues to emotion in others (Phelps, Ling, & Carrasco, 2006). In line with this, there is evidence that trichromatic color vision in humans is well suited, even optimized, for detecting subtle skin color changes resulting from physiological processes (Changizi, Zhang, & Shimojo, 2006; Lefevre, Ewbank, Calder, Hagen, & Perrett, 2013; Re, Whitehead, Xiao, & Perrett, 2011; Tan & Stephen, 2013). This suggests that skin color plays an important role in social communication. The current research aims to investigate observers' emotion-color associations that are presumed to represent a deep knowledge of the link between emotion expression and color in the social environment.

There is extant research that examines color associations in general, and emotion-color associations specifically (Adams & Osgood, 1973), and it is clear that color is a key perceptual feature in emotion language (Sutton & Altarriba, 2016). However, much of this work is limited in the generalizability of the findings. Specifically, much of the research relies on self-reported associations to color words or stimuli that lack context specificity. However, constraining color associations to a particular context is essential. For instance, red may carry positive connotations in affiliative contexts, but may carry negative connotations in achievement contexts (Elliot & Maier, 2014). In our experiments, we constrain the context of color associations to the domain of emotion and face perception. By doing so, we hope to elicit emotion-color associations that are specific to facial emotion expressions. Further, color association research often relies on discrete color categories (e.g., red, blue, etc.). However, color is not only categorical, but varies continuously. We can gain a much richer understanding of emotion-color associations by conceptualizing color as continuous (e.g., how much color?), as well as categorical (e.g., which color?). Finally, much of the past research fails to ground color associations in a theoretical framework (but see Palmer & Schloss, 2010, for a theoretical framework for color preferences). Here, we offer a physiologically plausible model for emotion-relevant color expectations.

We expect that emotion-color associations on the face will reflect the actual co-occurrence of emotion, underlying physiological reactivity, and perceived changes in skin color.

Contemporary models of emotion grounded in the approach-avoidance distinction (see Elliot, Eder, & Harmon-Jones, 2013) offer conceptual frameworks from which we can derive hypotheses about the relation between emotion, physiology, and color expression. For instance, the biopsychosocial model (BPS; Blascovich & Mendes, 2000) of challenge and threat holds that particular psychological states reliably predict specific patterns of cardiovascular activity, including peripheral vasculature. Within this model, challenge (i.e., an approach-oriented state occurring when an individual experiences sufficient resources to meet situational demands) elicits dilated arteries, facilitating blood flow to the periphery (i.e., vasodilation), which includes facial skin areas. Conversely, threat (i.e., an avoidance-oriented state occurring when an individual experiences insufficient resources to meet situational demands) elicits constricted arteries, inhibiting blood flow to peripheral areas (i.e., vasoconstriction).

Skin color is primarily determined by three chromophores: melanin, dietary carotenoids, and hemoglobin (Edwards & Duntley, 1939). Of these, only hemoglobin can change rapidly enough to accompany transient, vascular emotion responses and produce noticeable changes in skin color. There are two dimensions by which hemoglobin can alter skin reflectance and thus color appearance: hemoglobin oxygen saturation and hemoglobin skin concentration (Zonios, Bykowski, & Kollias, 2001). Hemoglobin oxygenation and concentration can independently alter skin appearance along the orthogonal color-opponent dimensions, red-green, and blue-yellow, respectively (Changizi et al., 2006). From these dimensions, we can predict how vascular emotion responses would be expected to influence skin color appearance. Emotions that involve reducing circulation of blood to the periphery (i.e., vasoconstriction) will slow cutaneous blood flow. This will make the skin appear bluer and greener because of accumulating blood volume and deoxygenation of the blood cells (Changizi & Shimojo, 2011). Conversely, emotions that involve flushing the periphery with rapid circulation of oxygenated blood (i.e., vasodilation) will result in redder and yellower skin appearance.

The notion of embodiment (Niedenthal et al., 2005) suggests that physiological states interact with information processing systems to influence perception and cognition regarding emotion. Hemoglobin concentration is concretely related to the temperature of the skin; vasoconstriction (predicting bluer and greener skin appearance) will lower skin temperature, while vasodilation (predicting redder and yellower skin appearance) will raise skin temperature (Changizi & Shimojo, 2011). Colors are also abstractly associated with temperature; blue and green hues are considered ‘cold’ colors, while red and yellow hues are considered ‘warm’ colors (Kay & Regier, 2003). Therefore, it is possible that there is correspondence between how blood flow (and accordingly skin color) is modified with emotion, and perception and cognition related to emotion. We expected that emotion-color associations would follow these patterns when measured using facial stimuli.

In the present study, we examined emotion-color associations in four experiments.[1] In Experiment 1, we sought to assess whether participants held different color associations for discrete emotion terms. To this end, participants manipulated the color of faces along two color-opponent axes (i.e., red-green and yellow-blue) simultaneously to match the target emotions (i.e., anger, disgust, fear, happiness, sadness, surprise, and neutral). Next, we sought to assess the unique influence of each of the color axes independently. In Experiments 2a and 2b, participants performed the task used in Experiment 1, but manipulated color along only one of the color axes -- redness and yellowness, respectively. Finally, we wanted to address whether the pattern of facial color changes applied for emotion were consistent when coloring nonfaces. In Experiment 3, participants completed a task similar to that used in Experiment 1, but colored either a face or an abstract shape to match the emotion terms. Across these experiments, we tested our primary hypotheses that participants would increase redness and yellowness for approach-oriented emotions (i.e., anger, happiness, surprise), and decrease redness and yellowness for avoidance-oriented emotions (i.e., disgust, sadness, fear), relative to neutral.

For each experiment, all data exclusions, manipulations, and variables analyzed are reported, and data collection was completed prior to any analysis. All participants were unique; each individual only participated in one experiment. All analyses included only participants with color-normal vision, assessed by self-report at the end of each experiment; participants that reported a color vision deficiency were excluded from analyses *a priori*. Data and example materials for each experiment are available online at: osf.io/9ds8h.

Experiment 1

For this experiment, participants were asked to manipulate the color of faces along the two color axes, CIELAB a* (red-green) and b* (yellow-blue), for each of six emotion terms (afraid, angry, disgusted, happy, sad, surprised) and a neutral category. We chose these terms because they resemble exemplars of classic emotion categories (Ekman, Friesen, & Ellsworth, 1982), and reflect how people commonly understand and communicate conceptions of emotion (Shaver, Schwartz, Kirson, & O'Connor, 1987).

In this experiment (and Experiment 2), sample size was determined a priori via power analysis (targeting .80 power to detect a $d = .50$ effect at $p < .05$), and then slightly exceeding the target value.

Method

Stimuli. Experimental stimuli were generated the same way as in Stephen, Law Smith, Stirrat, and Perrett (2009). Caucasian participants from a university in southeastern Scotland were photographed with neutral faces in a setting with standard illuminant controls. Photographs were color corrected using in-frame color standards. Eight (4 female) target faces were used as stimuli.

Color was manipulated and evaluated in CIELAB color space. CIELAB consists of three orthogonal dimensions of color; Lightness (L), a red-green opponent axis (a*), and a yellow-blue opponent axis (b*). The CIELAB color space is modeled on the human visual system and is considered to be perceptually uniform, meaning a change in one unit is approximately equivalent for each dimension (Fairchild, 2013).

Matlab was used to produce color masks that were applied to the skin areas of the faces. Each face was manipulated on CIELAB a* and b* color axes in combination, by ±32 units in 12 steps for each axis. For instance, manipulating a* alone produced a series of 13 frames, such that the first frame had skin redness reduced by 32 units of a*, increasing incrementally so that frame 7 was the baseline image, and the final frame had face redness increased by 32 units of a*. The b* color axis was manipulated in the same way, along with every combined permutation of the two axes, resulting in a total of 169 frames per face. This allowed each face to vary on both color axes simultaneously. For all transforms, lightness, hair, eyes, clothing, and background remained constant.

Procedure. 40 (31 female, M_{age} = 20.21) undergraduate students from a northeastern U.S. university participated in exchange for course credit. All stimuli were presented on a CRT monitor (color calibrated using an i1 Pro Spectrophotometer). A computer program presented the facial stimuli one image at a time. Participants were able to alter the skin color along CIELAB a* and b* axes simultaneously by moving the mouse horizontally and vertically across the image. Mouse movement at an angle to the Cartesian axes produced a mixture of CIELAB a* and b* color change. The initial color transform that was presented was randomized, and the direction of color change was randomized (i.e., moving the mouse in any direction either increased or decreased a* and b* values differently between trials). Participants were instructed to "make the face as [afraid / angry / disgusted / happy / neutral / sad / surprised] as possible". Emotion terms were not defined for participants. Participants performed this task for each of the 8 faces, once for each emotion condition, for a total of 56 trials. The emotion conditions were grouped in blocks, so that participants completed each set of emotion trials in a single block. Block order was randomized, and face order within blocks was randomized.

Results and discussion

Due to the nested structure of the data (color changes across emotions were nested within targets, and targets were nested within participants), we chose to analyze the data using multi-level modeling (HLM: Bryk & Raudenbush, 1992). We built a three-level model with color changes across emotions modeled at level 1, targets modeled at level 2, and participants modeled at level 3. Intraclass correlations were computed to determine whether there was sufficient variance at each level to continue. Results indicated that most of the variance in color changes (98% a*; 97% b*) could be attributed to level 1 (i.e, differences across emotions). Essentially 0% of the variance was at level 2, meaning the color changes that participants made did not vary across different targets ($p > .50$). The remaining variance in color changes between participants at level 3 was significant for a* and b* ($p < .001$).

Due to the lack of variance at level 2, we reduced our final model to two levels with targets now modeled at level 1. Target sex (dummy coded; 1 = male, 0 = female) and emotions (dummy coded; neutral was the reference group) were included as level 1 predictor variables. Participant sex (dummy coded; 1 = male, 0 = female) was included as a level 2 predictor[2]. Sex variables at each level were mean-centered and emotions were uncentered.

Redness. The intercept for redness was the average a* value across all participants and targets for the neutral category. No effect of target sex was observed. Main effects emerged for each of the six emotion categories (see Table 1; reported values are the unstandardized *B* coefficients). Specifically, participants increased redness for anger, happiness, and surprise, but decreased redness for fear, disgust, and sadness. Redness changes for anger and fear differed across participant sex ($B = -8.77$, $p = .010$; $B = -8.57$, $p = .012$, respectively). Men increased redness for anger ($B = 23.20$, $p < .001$) and decreased redness for fear ($B = -15.87$, $p < .001$); the same pattern emerged for women, but to a lesser extent (anger: $B = 14.42$, $p < .001$; fear: $B = -7.30$, $p < .001$).

Yellowness. The intercept for yellowness was the average b* value across all participants and targets for the neutral category. No effect of target sex was observed. Main effects emerged for three of the emotion categories (see Table 1). Specifically, participants increased yellowness for happiness and decreased yellowness for fear and sadness. Additionally, a participant sex by anger interaction was observed ($B = 10.67$, $p = .006$), such that men increased yellowness for anger ($B = 11.33$, $p = .002$), but women did not ($B = .67$, $p = .62$). See Figure 1 for a plot comparing color changes across emotion categories.

Table 1. Changes in a* and b* values, relative to the neutral category, across different emotion categories in Experiments 1 and 2.

	Δa*	**redness**	**Δb***	**yellowness**
Emotion	**Experiment 1**	**Experiment 2a**	**Experiment 1**	**Experiment 2b**
Intercept	24.06	20.85	23.53	19.80
Afraid	-8.37***	-3.63	-13.72***	-13.40***
Angry	15.22***	17.39***	2.00	11.06***
Disgusted	-11.81***	-11.82***	-1.36	-9.70**
Happy	7.10***	4.19*	6.83***	13.00***
Sad	-12.91***	-8.37***	-15.26***	-13.79***
Surprised	6.60***	7.43***	-1.06	3.11

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

The results of Experiment 1 indicated that participants manipulated facial coloration differently across discrete emotion categories. This was, numerically, more pronounced along the redness dimension, where approach-oriented emotions (i.e., anger, happiness, surprise) were associated with increased redness, and avoidance-oriented emotions (i.e., sadness, fear, disgust) were associated with decreased redness. This is consistent with how vascular responses are presumed to impact actual skin coloration when these emotions are experienced (Changizi & Shimojo, 2011). Participants' color changes along the yellowness dimension only differed from neutral for happiness, fear, and sadness, with participants increasing yellowness for happiness and decreasing yellowness for fear and sadness. This is also consistent with how facial coloration is presumed to be affected by hemoglobin oxygenation and concentration. However, participants did not adjust the yellowness axis for anger, disgust, and surprise, relative to the neutral category. In Experiment 2 (a and b), we conducted a more focused investigation of these emotion-color associations by having participants manipulate facial coloration for each dimension while constraining the values of the other.

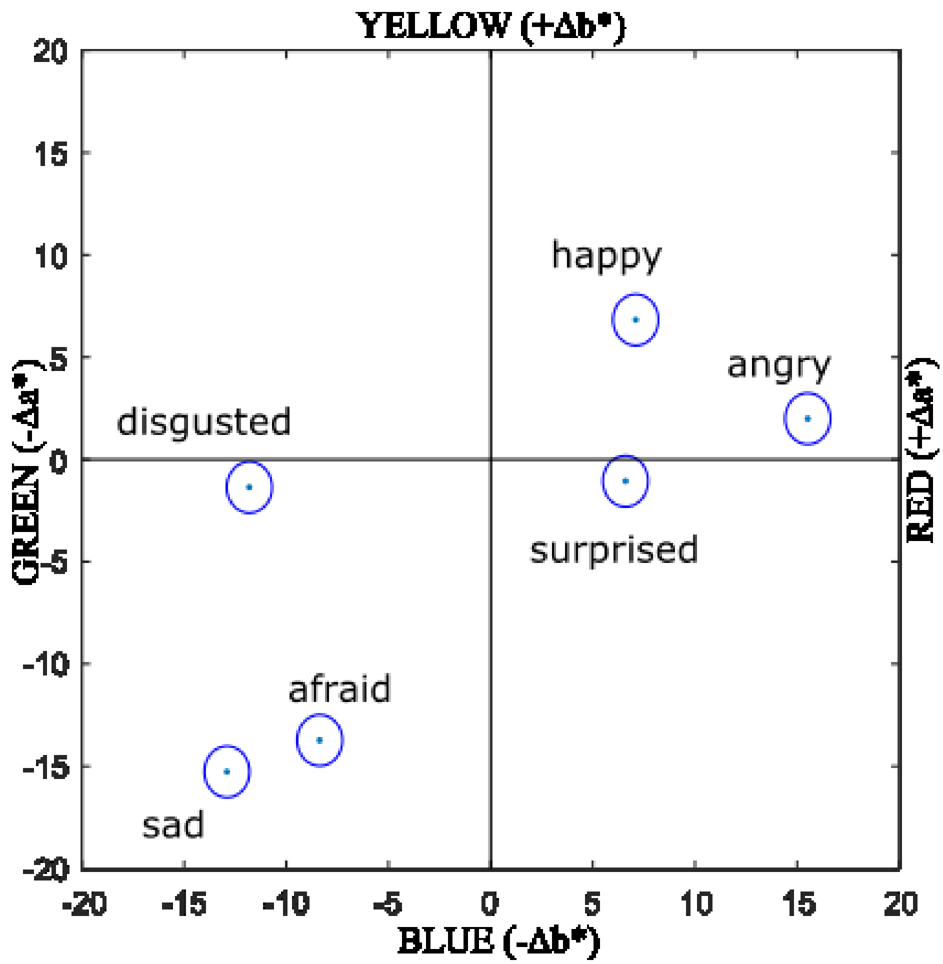

Figure 1. Mean and standard error ellipses for color changes, relative to the neutral category, applied in Experiment 1. Participants simultaneously changed a* (red-green) and b* (yellow-blue) dimensions for the six emotion terms.

Experiment 2a

Experiment 1 showed that participants had distinct color associations for each of the six emotion terms. Thus far, participants applied changes along the two color axes simultaneously. However, if these emotion-color associations are grounded in a physiologically-related perceptual expectation, then we would expect the patterns to be consistent when assessed along each of the color axes independently. Therefore, in Experiments 2a and 2b, we sought to assess emotion-color associations along each of the axes separately. In Experiment 2a, participants were able to manipulate the color of faces along a* (red-green) only, for each of the six emotion terms and a neutral category. In Experiment 2b, participants performed the same task, manipulating the color of faces along b* (yellow-blue) only.

Method

Stimuli. The same eight (4 female) target faces from Experiment 1 were used as stimuli. Color masks were generated and applied in a similar way as in Experiment 1, except that each face was manipulated on the a* axis only.

Procedure. 40 (23 female, M_{age} = 19.65) undergraduate students from a northeastern U.S. university participated in exchange for course credit. Participants viewed the stimuli using the same program, computer, and monitor as in Experiment 1. Participants were able to alter the skin color along the CIELAB a* axis only, by moving the mouse horizontally across the image. Participants were instructed to “make the face as [afraid / angry / disgusted / happy / neutral / sad / surprised] as possible”. Emotion terms were not defined for participants.

Results and discussion

We built a three-level model with color changes across emotions modeled at level 1, targets modeled at level 2, and participants modeled at level 3. As in the previous experiment, there was insufficient variance at level 2 ($p > .50$), so we reduced our model to two levels, which were identical to those in Experiment 1.

Redness. The intercept for redness was the average a* value across all participants and targets for the neutral category. No effect of target sex was observed. Main effects emerged for each emotion category except fear (see Table 1). Specifically, participants increased redness for anger, happiness, and surprise, but decreased redness for sadness and disgust. The decrease observed for fear was not significant, although it was in the same direction as in Experiment 1. There was also an interaction between participant sex and disgust ($B = -12.11$, $p = .022$). Men decreased redness ($B = -18.78$, $p < .001$); women numerically decreased redness, though this was not significantly different from zero ($B = -6.67$, $p = .11$). See Figure 2 for a graph comparing redness changes across emotion categories.

These results were largely consistent with those observed in the previous experiment. Facial redness was increased for approach-oriented emotions, and it was decreased for avoidance-oriented emotions (except fear) when holding facial yellowness constant.

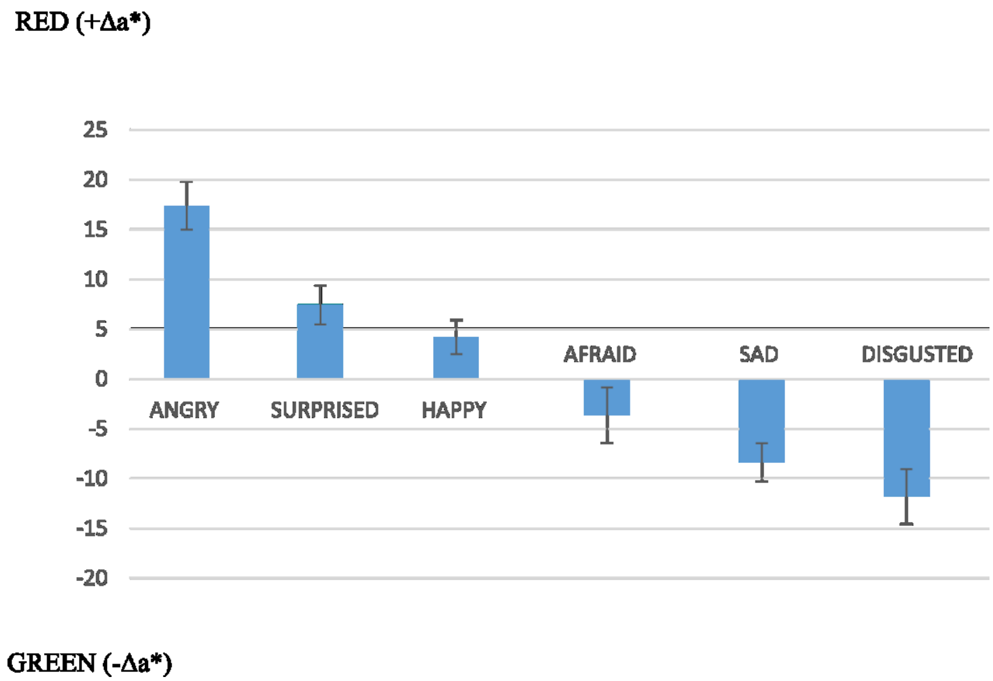

Figure 2. Mean and standard error bars for color changes, relative to the neutral category, applied in Experiment 2a. Participants changed a* (red-green) for the six emotion terms.

Experiment 2b

Method

Stimuli. The same eight (4 female) target faces from Experiment 2a were used as stimuli. Color masks were generated and applied in the same way as in Experiment 2a, except that each face was manipulated on the b* axis only.

Procedure. 40 (27 female, M_{age} = 19.7) undergraduate students from a northeastern U.S. university participated in exchange for course credit. Participants viewed the stimuli using the same program, computer, and monitor as in the previous experiments. Participants were able to alter the skin color along the CIELAB b* axis only, by moving the mouse horizontally across the image. Participants were instructed to "make the face as [afraid / angry / disgusted / happy / neutral / sad / surprised] as possible". Emotion terms were not defined for participants.

Results and discussion

We built a three-level model with color changes across emotions modeled at level 1, targets modeled at level 2, and participants modeled at level 3. As in the previous experiments, there was insufficient variance at level 2 ($p > .50$), so we reduced our model to two levels, which were identical to those in the prior experiments.

Yellowness. The intercept for yellowness was the average b* value across all participants and targets for the neutral category. No effect of target sex or participant sex was observed. Main effects emerged for each emotion except surprise (see Table 1). Participants increased yellowness for anger and happiness, and decreased yellowness for fear, disgust, and sadness. See Figure 3 for a graph comparing yellowness changes across emotion categories.

The results of Experiment 2b revealed that participants increased facial yellowness for approach-oriented emotions (except surprise), and decreased facial yellowness for avoidance-oriented emotions. It is interesting to note that yellowness values for anger and disgust were significantly different from the neutral category in the present experiment, but were not significantly different from the neutral category in Experiment 1. This may indicate that facial redness is a stronger indicator of these two emotions, such that when participants can manipulate both color dimensions simultaneously for these emotions, they focus mainly on the redness dimension. However, when constrained to only manipulating the yellowness dimension, they are more sensitive to yellowness (redness being eliminated from consideration), and they increase it for anger and decrease it for disgust. Participants did not manipulate the yellowness axis for surprise, relative to neutral, in either experiment. This may indicate that only facial redness, but not facial yellowness, conveys social information regarding surprise.

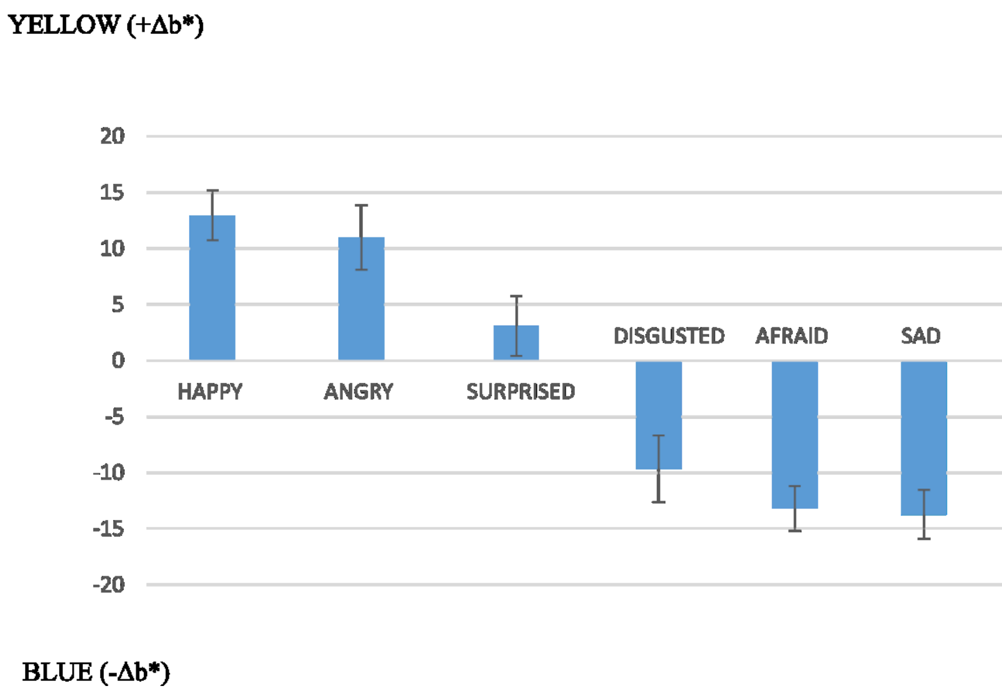

Figure 3. Mean and standard error bars for color changes, relative to the neutral category, applied in Experiment 2b. Participants changed b* (yellow-blue) for the six emotion terms.

Experiment 3

In Experiment 3, we aimed to replicate the results of Experiment 1 with a larger sample. Additionally, we sought to address whether the same results would emerge when participants colored faces versus abstract shapes with regard to emotion terms. We did not conduct a formal power analysis for this experiment (given the lack of basis on which to make an estimate for the between-subjects factor), but instead simply targeted a minimum of 100 participants per each of the two between-subjects conditions.

Method

Stimuli. For the faces condition, the eight (4 female) target faces from Experiments 1 and 2 were used as stimuli. Color masks for variations along a*, b*, and the combination of the two were produced and applied in the same way as in Experiments 1 and 2. For the shapes condition, we generated eight shape templates: a rectangle and an oval, each rotated at 0, 45, 90, and 135 degrees. The color of each template was manipulated along a*, b*, and the combination of the two, resulting in an equal number of steps and magnitude of change as in the faces condition. We chose to manipulate the shape color in the same way as the face color in order to keep the conditions consistent. This provided an advantage in that the conditions would be equated as much as possible. However, it also provided a disadvantage in that it constricted the range of colors that participants could alter. In other words, the range of possible colors for faces and shapes were equal, but were limited to the range of change that could be applied to faces in the previous experiments.

Procedure. 210 (133 female, M_{age} = 19.85) undergraduate students without a color vision deficiency from a northeastern U.S. university participated in exchange for course credit. Participants viewed the stimuli using the same program, computer, and monitor as in Experiments 1 and 2. Participants were randomly assigned to one of two between-subjects conditions, either changing the color of the faces or the abstract shapes. In the faces condition, participants were asked to "change the face's appearance to make the face as [afraid / angry / disgusted / happy / neutral / sad / surprised] as possible". In the shapes condition, participants were asked to "change the shape's appearance to the color you associate with [afraid / angry / disgusted / happy / neutral / sad / surprised]". Emotion terms were not defined for participants.

Participants performed this task for each of the 8 faces (or shapes), once for each emotion condition and a neutral condition, for a total of 56 trials. The emotion conditions were grouped in blocks, so that participants viewed each of the 8 faces (or shapes) in a single emotion block, before moving on to the next emotion block with each of the 8 faces (or shapes). Block order was randomized, and face (or shape) order within blocks was randomized.

Results and discussion

We built a three-level model with color changes across emotions modeled at level 1, targets modeled at level 2, and individual participants modeled at level 3. As in the previous experiments, we collapsed across levels 1 and 2 due to insufficient variance at the second level ($p > .50$). Emotions were included as level 1 predictor variables (dummy coded; neutral was the reference group). Condition (dummy coded; 1 = shapes, 0 = faces) and participant sex (dummy coded; 1 = male, 0 = female) were included as level 2 predictors. 24 participants (faces = 10, shapes = 14) were excluded from the level 2 model, because they did not provide sex data. Sex variables were mean-centered; emotion categories and experimental condition were uncentered. Given that target sex only applied to participants in the faces condition (with target shapes varying in the shapes condition), we omitted this variable from the omnibus model, but included it in subsequent models described below.

Redness. A main effect of condition emerged, such that the intercept for redness (i.e., the average a* values across all participants and targets for the neutral category) was greater for faces than for shapes ($p < .001$). Main effects also emerged for each of the six emotion categories (all *p*s < .001). However, each of the six main effects was qualified by an interaction with condition (all *p*s < .001; see Table 2; reported values are the unstandardized *B* coefficients).

Thus, we report results separately for faces and shapes below. Target sex/shape was included in these models as a mean-centered level 1 predictor. No effects were observed for target sex or participant sex.

Table 2. Changes in a* and b* values, relative to the neutral category, across different emotion categories for faces vs. shapes in Experiment 3.

	Δa*		**Δ b***	
Emotion	**Faces**	**Shapes**	**Faces**	**Shapes**
Intercept	21.21	8.18	24.23	13.88
Afraid	-6.40***	4.18*	-10.88***	-.32
Angry	17.27***	27.38***	2.90*	15.03***
Disgusted	-15.92***	-6.82***	3.01**	13.66***
Happy	5.84***	25.39***	7.31***	3.74*
Sad	-11.60***	-5.84***	-16.04***	-11.40***
Surprised	7.75***	26.27***	-1.57	11.32***

Note: *$p < .05$, **p < .01, ***$p < .001$.

Faces. Participants ($N = 104$) increased redness for anger, happiness, and surprise. Participants decreased redness for disgust, sadness, and fear.

Shapes. Participants ($N = 106$) increased redness for anger, happiness, surprise, and fear. Redness was decreased for disgust and sadness.

Yellowness. A main effect of condition emerged, such that the intercept for yellowness (i.e., the average b* values across all participants and targets for the neutral category) was greater for faces than for shapes ($p < .001$). Main effects also emerged for five of the emotion categories (surprise $p = .33$, all other *p*s < .01). However, these effects were qualified by an interaction with condition (happiness $p = .065$, sadness $p = .01$, all other *p*s < .001; see Table 2), so we report results separately for faces and shapes below. Target sex/shape was included in these models as a level 1 predictor. No effects were observed for target sex or participant sex.

Faces. Participants increased yellowness for anger, happiness, and disgust. Yellowness was decreased for sadness and fear. Yellowness for surprise was not significantly different from the neutral category (p = .27).

Shapes. Participants increased yellowness for anger, happiness, disgust, and surprise. Yellowness was decreased for sadness. Yellowness for fear was not significantly different from the neutral category (p = .86). See Figure 4 for plots comparing color changes across conditions.

The results observed for facial skin color changes along the redness axis were consistent with those from the previous experiments. Participants increased facial redness for approach-oriented emotions (anger, happiness, surprise), and decreased facial redness for avoidance-oriented emotions (disgust, fear, sadness). The results for facial skin color changes along the yellowness axis are mostly consistent with the previous experiments. Participants increased facial yellowness for anger and happiness, while facial yellowness for surprise was not different from the neutral category. In addition, participants decreased facial yellowness for sadness and fear, in accord with the results from the previous experiments. However, facial yellowness for disgust was not different from the neutral category in Experiment 3.

For each emotion category (except fear) the change in color for shapes was in the same direction as the change in color for faces. However, the magnitude of color changes differed across conditions for each of the emotion categories. For the approach-oriented emotions (anger, happiness, surprise), participants increased redness and yellowness (except yellowness for happiness) more for shapes than for faces. In contrast, for the avoidance-oriented emotions (disgust, fear, sadness), participants decreased both redness and yellowness more for faces than for shapes. This suggests that color associations for the approach-oriented emotions are more constrained when viewed in the context of the face, while color associations for the avoidance-oriented emotions are exacerbated when viewed in the context of the face. We discuss potential reasons for this patterning below.

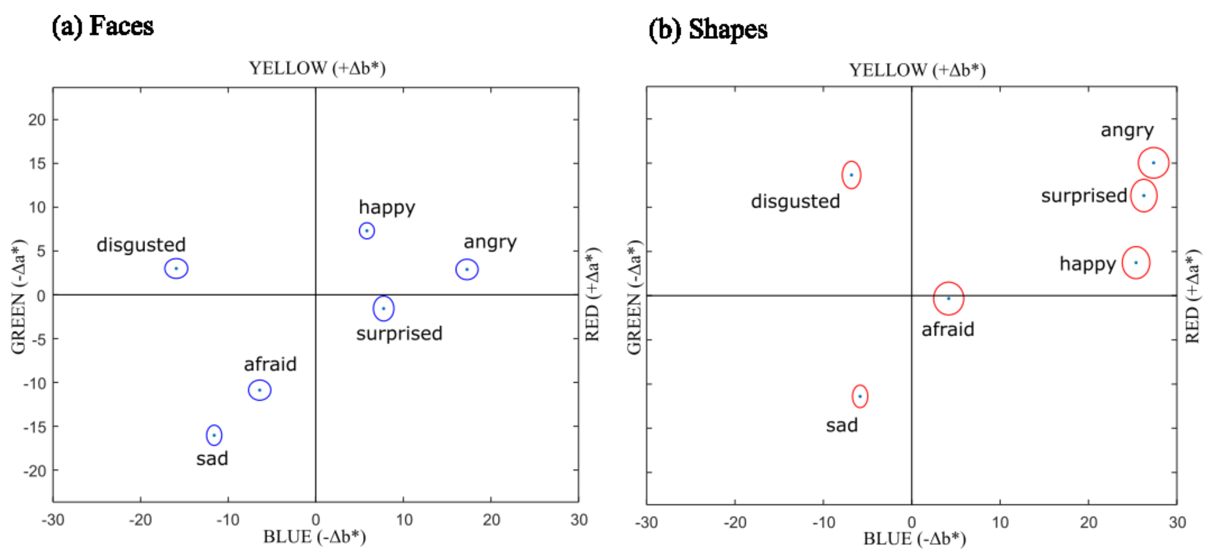

Figure 4. Mean and standard error ellipses for color changes, relative to the neutral category, applied in Experiment 3. Participants simultaneously changed a* (red-green) and b* (yellow-blue) dimensions for the six emotion terms, on either (a) faces or (b) shapes.

General Discussion

Across four experiments, participants were asked to manipulate the color of neutral faces to best match several target emotion terms. The results revealed a pattern of emotion-color associations that maps well onto physiological and psychological correlates of emotion expression. Participants consistently increased facial redness for anger, happiness, and surprise. Conversely, participants decreased facial redness for disgust, fear, and sadness. Participants increased facial yellowness for anger and happiness. Conversely, participants decreased facial yellowness for fear and sadness. Finally, participants did not consistently manipulate facial yellowness for disgust across experiments, and participants did not manipulate facial yellowness for surprise, relative to neutral, across experiments. Thus, although both redness and yellowness changes were associated with the focal emotions, the patterns were, numerically, clearest for redness. This would seem to be in accord with evidence that individuals are more sensitive to redness (relative to yellowness) changes on the face (Tan & Stephen, 2013), likely because redness on the face is a particularly strong indicator of socially-relevant information (Re et al., 2011).

Anger, happiness, and surprise can be considered approach-oriented emotions (Carver & Harmon-Jones, 2009; Fredrickson, 1998; Meyer, Niepel, Rudolph, & Schützwohl, 1991), have been shown to elicit peripheral vasodilation (Collet, Vernet-Maury, Delhomme, & Dittmar, 1997; Drummond, 1994; Drummond & Quah, 2001), and were adjusted to look redder and yellower on faces (except for surprised faces, which were not significantly altered along b*). Sadness and fear can be considered avoidance-oriented emotions (Nesse, 1990, 1991), have been shown to elicit peripheral vasoconstriction in some instances (Drummond, 1997; Kreibig, Wilhelm, Roth, & Gross, 2007; although this is not always the case; Kreibig et al., 2007), and were adjusted to look less red and yellow on faces. Disgust can also be characterized as an avoidance-oriented emotion (Tybur, Lieberman, Kurzban, & DeScioli, 2013), and has been shown to elicit peripheral vasoconstriction in one type of disgust manipulation, but not another (Rohrmann & Hopp, 2008). While disgust was consistently adjusted to look less red for faces, the color changes along the b* dimension for this emotion were largely inconsistent and therefore difficult to interpret. Recent research has shown that disgust can be elicited by different types of stimuli, and that these types prompt differing patterns of physiological reactivity (Shenhav & Mendes, 2014). This might help to explain the inconsistency along the b* dimension across our experiments. It is additionally important to note that while general inferences can be made about the relation between skin blood flow and skin color, it is not currently clear how some distal measures of peripheral blood flow used in the research reviewed above are related to facial blood flow. For instance, digital PPG and skin temperature indicate change in blood flow, but are typically measured from the finger. While this could represent global changes in peripheral cardiovasculature, it is unclear whether the face, specifically, is affected.

One unexpected, but interesting pattern in our data is that several yellowness associations were numerically weaker when assessed along the two axes simultaneously (Experiments 1 and 3), but stronger when assessed alone (Experiment 2b). The two color-opponent dimensions (red-green and yellow-blue) are orthogonal (Fairchild, 2013), have been shown to involve distinct functional and neural pathways (Dacey & Packer, 2003; Krauskopf & Gegenfurtner, 1992), and can be independently influenced on skin by hemoglobin oxygenation and concentration (Changizi & Shimojo, 2006). However, color is naturally viewed as the combination of these dimensions, and the hemoglobin variables are likely correlated with respect to cardiovascular reactivity. That yellowness associations became stronger when assessed independently might reflect an existing expectation that gets "washed-out" in the presence of a more salient one (redness).

By comparing the face coloration changes to the shape coloration changes (Experiment 3), we aimed to distinguish between physiologically plausible color associations (on faces) versus more abstract color associations (on shapes). We found that the direction of color changes applied between faces and shapes was consistent, but that the magnitude of the color changes differed. Specifically, the approach-oriented emotions (anger, happiness, surprise) were adjusted more for shapes than for faces, while the avoidance-oriented emotions (fear, disgust, sadness) were adjusted more for faces than for shapes. The findings for the approach-oriented emotions suggest that participants limited the amount of redness and yellowness that they added to the faces because they sought to make the faces look plausibly angry, happy, and surprised; the shape context provided no such constraints, and therefore participants likely relied entirely on abstract associations in their color selections. The findings for the avoidance-oriented emotions suggest that participants eliminated (i.e., “drained”) color from the faces even more so than from the shapes; plausibility seems less critical to the absence of redness and yellowness than to its presence, and participants went out of their way to minimize these colors on faces (relative to shapes) to convey these avoidance-oriented emotions.

Another, not necessarily independent, factor that may have played a role in the observed interactive patterns in Experiment 3 is that the participant-generated baseline values for the neutral category across the face and shape conditions differed from each other, with the neutral faces being redder and yellower than the neutral shapes. It is likely that participants used this neutral point as an anchor for the face judgments, and adjusted from this anchor to produce the color for each emotion. This anchoring and adjustment process is not relevant for shapes; transient emotion-based color changes on the face are naturally observed as shifts from a neutral, baseline state, while there is no natural expectation for an abstract shape to change from one color to another. The relatively high anchors for faces may have reduced the amount of additional redness and yellowness needed to convey the approach-oriented emotions, and may have enhanced the amount of redness and yellowness needed to convey the avoidance-oriented emotions.

Although we are focusing primarily on the differences in the magnitude of color changes observed between the faces and shapes, it is also important to highlight that the direction of the color changes was highly similar across conditions. Participants' color changes were presumably a function of both concrete, experiential viewing of color-emotion pairings on the face over time and more abstract stereotype- or metaphor-based knowledge of color-emotion connections. These sources of influence are unquestionably intertwined (e.g., the abstract knowledge is likely, at least in part, an extension and perhaps elaboration of the concrete experiential knowledge) and likely promote the same (directional) pattern of color changes for faces and shapes. Thus, the similarity in the direction of color changes in our data was both expected and quite straightforward to explain; it is the disentangling of these sources of influence that is much more complex and in need of considerable more empirical attention.

Strengths of our design include descriptive specificity. Participants applied color changes to the faces continuously, rather than categorically. This is important for multiple reasons. First, it mimics the way that color varies in the natural environment and therefore allows for a more precise description of color. Second, it allowed us to access more implicit associations. Laypersons may not explicitly describe emotion expressions in terms of blood-flow characteristics, but our results suggest that people still appear to have some knowledge of these characteristics (likely through repeated pairings of facial color and emotion expression).

There is currently contention around how emotions are best characterized. For instance, some view emotions as basic, distinct, culturally universal, and modular states (e.g., Ekman, 1992; Izard & Ackerman, 2000; Ortony, Clore, & Collins, 1988), while others view emotions as context-dependent constructions informed by underlying dimensions (e.g., Barrett, 2006; Cacioppo, Gardner, & Berntson, 1999; Carver & Scheier, 1998). In conducting the research herein, it is not our intention to argue that emotions are basic in nature or that they are limited to the six emotion terms included in the present work (see Ortony & Turner, 1990, for a review). Instead, we took advantage of the utility of using prototypical emotion terms, because such terms reflect the cognitive representation of emotion in memory and language (which likely varies across culture), and therefore are useful for studying networks of associations related to emotion (see Shaver et al., 1987). Nor do we argue that facial coloration is a marker of discrete emotions, but rather presume that facial coloration changes correspond to more basic psychological and physiological processes such as arousal or motivational orientation, which are expressed and perceived in context-dependent situations.

In the present research, we have documented emotion-color associations that are consistent with perceptual manifestations of emotion physiology. Although emotion expression in the natural environment unfolds dynamically over time, in our experiments participants applied color to static stimuli. Future work should aim to investigate how dynamic changes of color influence social perception. Although we only measured changes in chrominance (a* and b*), blood flow also predictably affects luminance (L*) of skin (Välisuo, Kaartinen, Kuokkanen, & Alander, 2010). Future work could address whether luminance is salient in conceptions of emotion. Subsequent work is also needed to objectively assess *actual* color changes on the skin of individuals during *actual* emotion expressions unfolding over time. Such research would be useful in documenting regional differences in color expression (e.g., forehead vs. cheeks) and the temporal course of color expression. Another limitation of our research is that the facial stimuli used in our experiments were all Caucasian. Future work should investigate whether these associations are influenced by racial differences in the stimuli, the observer, or both.

The importance of the emotion-color associations studied herein may be seen in the common use of color in culture. For example, visual-expressive communications (i.e., emoticons) often display happy faces in yellow, disgusted faces in green, and angry faces in red. Further, *Oxford English Dictionary* definitions of “blue” include the terms “fear” and “depressed” (Changizi et al., 2006). Still further, abstract emotion-color associations have been shown to vary across culture (Barchard, Grob, & Roe, 2016), possibly due to diverging uses of color in figurative language. While emotion is expressed and perceived differently across cultures (Gendron, Roberson, van der Vyver, & Barrett, 2014), it is unclear if underlying physiological processes (e.g., arousal) modify skin color appearance in different ways across cultures. In sum, we think the current work highlights the importance of color in the way that people think about emotion, suggests how color-emotion associations might have developed over time, and emphasizes the utility of skin color as a social-communicative tool.

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Footnotes

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[1] In addition to the reported experiments, we also conducted a preliminary experiment. In this experiment, participants simultaneously manipulated faces along a* (red-green) and b* (yellow-blue) axes to match two target emotions: anger and fear. Participants increased facial redness and yellowness for anger, and decreased facial redness and yellowness for fear. The study details and data are available online at: osf.io/9ds8h.

[2] Level 1 model

$Y = \pi_0 + \pi_1(\text{targetsex}) + \pi_2(\text{afraid}) + \pi_3(\text{angry}) + \pi_4(\text{disgusted}) + \pi_5(\text{happy}) + \pi_6(\text{sad}) + \pi_7(\text{surprised}) + r$

Level 2 model

$\pi_0 = B_{00} + B_{01}(\text{sex}) + \mu_{10}$

$\pi_1 = B_{10} + B_{11}(\text{sex})$

$\pi_2 = B_{20} + B_{21}(\text{sex})$

$\pi_3 = B_{30} + B_{31}(\text{sex})$

$\pi_4 = B_{40} + B_{41}(\text{sex})$

$\pi_5 = B_{50} + B_{51}(\text{sex})$

$\pi_6 = B_{60} + B_{61}(\text{sex})$

$\pi_7 = B_{60} + B_{61}(\text{sex})$