Effects of Lip and Eye Color on the Emotion Categorization of Facial Expressions

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The design and analysis plans were not registered.

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The authors have declared that no competing interests existed at the time of publication.

Ethics Approval Statement

The study was approved by the Institutional Review Board of Center for Experimental Research in Social Sciences (CERSS) (Study R3-18).

Abstract: This study examined whether people's ability to recognize facial expressions is affected by manipulating the color of their lips or eyes. Participants comprised 100 Chinese adolescents (mean age = 13.79 years, SD = 1.06). The stimuli consisted of happy, neutral, and sad facial expressions, which were manipulated to have different lip or eye colors. Participants

reacted to the images by indicating their perceived emotion. Performance speed and accuracy were assessed during the experiment. Results indicated that for happy and neutral expressions, the use of color significantly reduced reaction times, while the accuracy remained unchanged. Conversely, for sad expressions, reaction time was not affected by color, but all color categories exhibited reduced accuracy.

Keywords: color manipulation, facial expression, perceived emotion, performance accuracy, reaction time

Introduction

For successful social engagement, it is essential to recognize emotional states from facial expressions. It is commonly assumed that people's emotional states can be readily inferred from their facial movements, typically called emotional or facial expressions. [1] However, multiple factors influence this ability, including the effects of background colors[2] and complexions.[3,4] Facial color is suggestive of emotional states; people identify the correct emotion category and valence from these facial colors, even in the absence of any facial muscle movement.[5] Thorstenson et al.[6] found that facial coloration can influence perceived emotion within the emotion pairs of anger-disgust, surprise-fear, and tearful sadness-happiness. Furthermore, according to Ikeda et al.,[7] facial radiance influences facial attractiveness and affective impressions of women's faces. Takahashi and Kawabata[8] tested the influence of color on perceived emotions and found distinct color-emotion associations that varied across

different emotions. These studies support the view that associations between facial color and emotion perception exist.

Moreover, research on human color perception has established an interaction between color and emotion.[9] Specific colors have been identified as having the ability to be linked with certain emotions, which is consistent across individuals.[8,10] Although color itself has no intrinsic emotional value, each color has both positive and negative symbolic significance.[11] Considering emotions expressed by facial expressions and those induced by colors, Fruhholz et al.[12] claimed that although facial expressions might be processed automatically in a context-independent situation, the processing of facial expressions might be affected by additional and task-independent stimulus features.

In addition to facial complexion color, no research has assessed the influence of partial facial color (i.e., color of features such as eyes and lips) on the perception of emotion in facial expression recognition. This is surprising, given that lips and eyes are prominent facial features that attract attention, are essential for nonverbal communication, and are important factors for emotional expression. Indeed, different parts of the face express emotions differently.[13] The eye and mouth regions serve as primary sources of facial information regarding an individual's emotional state.[14] While reading facial emotions, people frequently concentrate on these regions.[15] Thus, changes in lip and eye color may alter the attention-grabbing visual signals, which may affect how emotions are perceived. In addition, people today are used to changing the color of their facial features through the use of cosmetics. The pursuit of beauty has a long history. For example, about 5,000 years ago, ancient Sumerian people crushed gemstones and

used them to decorate their faces, mainly on the lips and around the eyes. In ancient Egypt, both men and women used brown, orange, and fuchsia lipstick. With the development of science and aesthetic tastes, people use colorful contact lenses to change their eye color. These attempts may make the color of their lips or eyes contrast with surrounding facial features, making them more visible and easier to recognize; this can be considered an enhanced visibility that could potentially enable the correct detection and identification of emotional expressions. Moreover, people are born with different lip and eye colors, depending on their ethnicity or individual differences. Research suggests that facial features that deviated from the norm,[16] as well as color contrasts, might affect how emotions are interpreted.[17] We, therefore, presumed that lip or eye colors could draw attention to and possibly affect how emotions are perceived. Furthermore, different emotions or emotional expressions may be linked to certain colors on the lip and eye regions; for instance, dark circles under the eyes might be associated with anxiety or depression,[18] whereas increased contrast between the features and facial skin may enhance femininity and attractiveness.[19,20] Additionally, adjusting lip color may create a contrast and therefore affect people's perception of skin color,[21] whereas facial color may vary depending on the emotional state; additionally, emotions are often described in relation to facial color.[22] Thus, it is possible that lip color effects emotion recognition. To test these speculative explanations, empirical research is required to prove a strong and direct connection between lip and eye color and the perception of emotions.

Based on previous studies, this study examines whether highlighting partial facial features (specifically eyes and lips), instead of the whole face, with different colors is likely to influence

the perception of emotion in facial expression recognition. Specifically, we aimed to consider changes in accuracy and reaction time (RT) as indices to test whether the performance was higher for certain colors. Our experimental design utilized RT as a measure to assess the impact of color manipulation on facial emotion recognition and to identify potential differences between colors. Additionally, we examined the accuracy to test the effect of local color use (lips and eyes) on participants' ability to correctly judge facial emotions. By comparing accuracy across different colors, we aimed to identify which emotions were more susceptible to color manipulation.

Thorstenson et al.[3] emphasized the utility of skin color as a social-communicative tool. Similarly, we hypothesized that color perception enhances the assessment of expressed emotions when the perceived color aligns with features representative of a specific emotion. Furthermore, we hypothesized that women are more influenced than men by the emotional effect of color, as women are more susceptible to the color-emotion associations.[23] Nevertheless, women appear to be better at facial emotion recognition[24]; they have more accurate facial emotion recognition compared to men and are faster in correctly recognizing facial emotions.[25,26] Therefore, we assumed that this female advantage might be counterbalanced to a certain degree by their sensitivity to color. According to Olderbak et al.[27], emotion perception abilities peak between the ages of 15 and 30 for both males and females. This female advantage was largest for persons under the age of 15. We therefore recruited younger secondary school students as participants. Through this study, we aimed to determine whether emotional expressiveness could be subjectively controlled through color.

Methods

Participants

The participants comprised 100 students (52% female; 100% Chinese) from a junior high school in Central China. Their mean age was 13.79 years (standard deviation = 1.06; range: 9–16 years). All participants self-reported that they had normal or corrected-to-normal acuity and color vision. Participation was voluntary and they did not receive any financial compensation. Informed consent was obtained from their parents, and the study was approved by the local committee board and the Institutional Review Board of the Center for Experimental Research in Social Sciences (CERSS) (Study R3-18).

Materials

Ekman et al.[28] identified six categories of emotions conveyed through facial expressions: happiness, surprise, fear, sadness, anger, and disgust. In the current study, we selected happiness and sadness from the six expressions, and neutral facial expressions. Our stimuli pictures were adapted from the ATR Facial Expression Image Database DB99,[29] which includes images of front face data, face angle change data, and gaze change data, as portrayed by 10 men and women in their late 20s and early 30s. For the current study, we selected nine original frontal and 15° face angle-changed pictures of three Asian people who portrayed happy, sad, and neutral facial expressions.

Three sets of stimuli were used in the experiments. Stimulus Set A comprised the nine

initially selected images. Stimulus Set B consisted of 36 color-processed photographs derived from Set A, with changes made to the lip color of the original figures from light pink (untreated) to orange, red, purple, and blue. Stimulus Set C consisted of 27 color-processed photographs, also derived from Set A, with changes made to the eye color of the original figures from brown (untreated) to blue, red, and green. Figures 1 and 2 depict the photographs with different color manipulations. Tables 1 and 2 present the mean CIELAB a*b* value for lip and eye colors. The specific color values of a*b* are shown in Figure 3. Image editing was conducted in Adobe Photoshop, and CIE xy values were measured using the Chroma Meter/Luminance Meter CS-150 on the monitor. These values were then converted to CIELAB values.

The random order and display settings of the stimulus presentation were controlled by a software created using PsychoPy (version 3.1.2),[30] which also recorded participant responses and response times. The participants were instructed to judge the emotions depicted on each facial image. After providing instructions to the participants, a sample task was performed. Before beginning the experiment, participants were presented with 10 pictures of faces to allow them to become comfortable with the laboratory environment and computer operation. When a photo was presented, participants were required to click as quickly as possible on the emotion label (happy, neutral, or sad in Chinese) that best described what they thought the individual was feeling. Once they made a decision, the picture was changed to the next one, and the same process was repeated until every picture (a total of 72 trials) was judged. The experiment lasted approximately five minutes for each participant.

Results

Statistical analysis

Data analysis was performed by SPSS (IBM, Armonk, USA) and JASP Version 0.16.2 using accuracy and RT as dependent variables. As for RT, trials with incorrect answers and those with right answers but a reaction time that deviated by more than two standard deviations from the individual mean, were removed.

Lip color task

A 2 (gender: female, man) × 3 (emotion: neutral, happy, and sad) × 5 (lip colors: untreated, orange, red, purple, and blue) three-factor mixed-model ANOVA was conducted for accuracy of lip color task, with gender as a between-participant factor and color and emotion as within-participant factors. Significant effects of emotion, $F(2, 196)=15.082$, $p<.001$, $\eta p2=.133$; lip color, $F(4, 392)=3.50$, $p=.008$, $\eta p2=.03$; and emotion×lip color, $F(8, 784)=6.200$, $p<.001$, $\eta p2=.059$, were observed, whereas there was no significant effect of gender ($F(1, 798)=1.189$, $p<.278$, $\eta p2=.012$) and interaction effects between gender and any other factors. The simple main effect of lip color was significant when the facial stimuli expressed sadness ($p <.001$). Post hoc comparisons with Bonferroni correction revealed that lip colors (blue, orange, purple, and red) significantly reduced accuracy for sad faces (all ps <.001), see Figure 4. P-values and confidence intervals were corrected using the Bonferroni method.

As for RT, generalized linear mixed models (GLMM) were performed, with gender, emotion, and color as fixed effects and subjects as the random effect; interaction terms among

the fixed factors were tested. We found significant main effects of lip color (χ^2 (4) = 32.453, p<.001) and emotion (χ^2(2) = 27.745, p<.001) on RT. We also observed a significant emotion × lip color interaction (χ^2(8)=14.045, p<.001). However, there was no significant main effect of gender or interaction effect between gender and any other factors (ps >.1).

As for the main effect of lip color (Figure 5), color-manipulated figures were recognized faster than untreated ones (ps <.001).

Regarding the main effect of emotion (Figure 6), results of pairwise comparisons showed that neutral expressions were recognized faster than happy (t=3.852, p<.001) and sad ones (t=7.445, p<.001). Moreover, the RT of happy expressions was shorter than that of sad ones (t=3.704, p<.001).

Regarding the interaction effect between emotion and lip color (Figure 7), according to results of pairwise contrasts, a shorter RT for lip-color-adjusted figures was detected in the neutral and happy groups (ps <.001) compared with that for untreated figures. In the happy group, significant differences between purple and orange (t=3.029, p=.015) were detected. There were also significant differences observed between orange and blue (t=3.855, p=.001), orange and red (t= 3.855, p=.001), purple and blue (t=3.348, p=.003), and purple and red (t=3.331, p=.003) in the neutral group; no significant differences were observed between colors or between the color groups and control group for sad faces. Gender did not show a significant effect (χ^2(2) = .714, p=.398), and there were no significant interactions with any other factors. The reported p values were all Bonferroni-adjusted.

Eye color tasks

Similarly, a 2 (gender: male, female) × 3 (emotion: neutral, happy, sad) × 4 (color: brown, blue, red, green) three-factor mixed-model ANOVA was conducted for accuracy; the results are shown in Figure 8. There were significant effects of emotion ($F(2, 196)=15.976$, $p<.001$, $\eta p2=.140$), eye color ($F(3, 294)=3.673$, $p=.013$, $\eta p2=.036$), and emotion*eye-color ($F(6, 588)=6.757$, $p<.001$, $\eta p2=.065$). No significant effect of gender ($F(1,98)=0.414$, $p=0.521$, $\eta p2=.004$), or interaction effect between gender and any other factors was detected. Similar to the results of the lip color task, the simple main effect of eye color was significant when the emotion was sad ($p <.001$) but not when it was happy ($p= 0.819$) or neutral ($p=0.517$). The Bonferroni post hoc test revealed a higher accuracy for the untreated sad face pictures compared with all the color-adjusted ones (ps <.001).

As for RT, GLMM were performed, with emotion and color as fixed effects and subjects as the random effect. As a result, we found significant main effects of eye color on RT ($\chi^2(3) = 41.381$, $p<.001$), emotion ($\chi^2(2) = 8.912$, $p<.001$) on RT, and significant interaction effects between emotion and eye color ($\chi^2(6)=10.150$, $p<.001$). There was no significant main effect of gender or interaction effect between gender and any other factors (ps >.1).

Concerning the main effect of emotion (Figure 9), pairwise comparisons revealed that neutral expressions were recognized faster than happy ($t=2.578$, $p=.02$) and sad ones ($t=4.17$, $p<.001$). There was no significant difference in the RT of sad and happy expressions ($t=1.661$, $p=.097$).

As for the main effect of eye color (Figure 10), eye-color-manipulated figures (blue, green

and red) were recognized faster than untreated ones (ps <.001).

Concerning the interaction effect between emotion and eye color (Figure 11), pairwise contrasts revealed that a shorter RT for eye-color-adjusted figures was detected in the neutral and happy groups (ps <.001) compared with that for untreated figures. No significant difference was observed between color groups.

DISCUSSION

In the present study, we focused on low-level features to detect color effects. Previous research focused on dynamic or static approaches according to the Facial Action Coding System (FACS), which describes each basic facial expression with small facial movements called "action units" (AUs).[31] By contrast, we conducted this experiment based on the hypothesis that perception of emotional valence in facial expressions was not only affected by the facial movements themselves (supported by the results of comparing two different facial features) but also by other variables, such as color or the combination of color and facial features. The AUs are considered in the following explanation.

As mentioned above, color significantly increases the judgment errors of sad expressions. Although color did not change the accuracy for neutral and happy expressions, it impacted the accuracy for sad expressions; both lip and eye color analyses showed a significant reduction in accuracy owing to color manipulation. There are several possible explanations for this finding. First, according to FACS, sadness can be decoded into "inner brow raised + brow lowered + lip corner depressed," which means that sadness is detected in the eyes and mouth.[32] Assuming that the recognition of sadness was only decided by facial movements, our color manipulation

should have drawn participants' attention to their eyes and mouth, thus helping them judge more accurately and quickly. However, our results showed the opposite; color manipulation reduced the accuracy of sad faces, whereas the RT remained unchanged. In a cross-sectional study exploring emotional face recognition when wearing colored masks, researchers found that wearing masks, especially pink and red ones, led to faces expressing sadness being perceived as less sad or more positive, compared to wearing no masks.[33] This finding was partially consistent with our lip color task accuracy results. However, the researchers speculated that sad expressions might be better processed by focusing on the upper part of the face. By contrast, our eye color task also revealed changes in accuracy, suggesting the involvement of both lip and eye color in emotion processing.

This leads us to the second possible explanation. It is known that human faces often flush during experiences of anger or pleasure, as reflected in the phrase "flushed with anger".[34] Similarly, in everyday life, we may observe pale lips or a loss of facial color when experiencing sadness or grief. Research suggests that decreased hemoglobin levels contribute to the perception of sadness,[35] indicating a link between facial pallor and sadness, which is consistent with physiological changes in skin color.[36] Notably, human faces can appear colorless during low emotional states. A sad face appears pale[22] and lip color affects the facial skin's perceived lightness[21]; thus, our lip color manipulation is likely to confuse observers into thinking that the individual "seems healthier" due to better blood circulation, misdirecting observers to choose an unexpected answer. Furthermore, our findings indicated that accuracies in the eye color group were consistent with those in the lip color group, suggesting that eye color may also

influence the skin tone contrast similar to lip color.

Our RT findings are consistent with a study examining the impact of background colors (specifically yellow and blue) on facial expression judgments. The previous study demonstrated that the RT for perceiving happiness was reduced in the presence of background colors, particularly yellow, while the judgment of sadness remained unaffected.[37] In another study investigating facial color (reddish, bluish, natural) and emotion perception, color manipulation led to reduced RTs for perceiving happy, neutral, and sad expressions.[22] Based on these findings, it is likely that the effects of partial color manipulation on the RT of happiness and sadness may align with the effects of background color changes, rather than facial colors. This finding suggests that the observed effects may be influenced by the contrast created between facial color and background or partial (lip or eye) facial color. However, further investigation is needed to validate this hypothesis.

We also examined gender differences. The current study did not provide evidence for a female advantage in facial expression recognition compared to males, in contrast to prior research claiming that females outperformed males in facial emotion recognition[8] and that adolescent girls showed faster and more sensitive perception of facial emotions than did boys.[39] Our control and experimental groups both showed this absence of gender disparity. There are two possible reasons for the differences between our findings and prior research. First, it could be due to the small effect size of sex differences, as indicated by the effect size (d-value) reported in previous studies.[26,38] Second, it could be attributed to cultural differences, because the subjects in past studies were not from an Asian cultural background. Therefore, we cannot

test our hypothesis regarding the potential counterbalancing effect of women's sensitivity to emotion-color connections on the "female advantage."

In our study, the selection of colors was based on a comprehensive consideration of various factors. According to Liao et al.[11], different cosmetic products elicit varying affective and significance-based responses, supported by Manav's[40] statement that a color applied to different objects, environments, or contexts will produce varying emotional or affective responses, and that different colors stimulate comparable affective responses. Furthermore, many previous studies have revealed the relationship between color and emotion. According to Hanada[41], the primary association of color and emotions is mediated by perceived temperature; hence, colors associated with a high temperature in the environment are likely to be associated with happiness, whereas those associated with a low (cool) temperature are linked with sadness. For instance, Wexner[42] associated red with "exciting" and "stimulating," and blue with "secure/comfortable" and "tender/soothing"; in relation to color effects on facial emotions, Takahashi and Kawabata[8] found that the accuracy of sad expressions was the highest when these faces were presented in blue as "sadness" was associated with blue. Therefore, we chose red, blue, and purple (reddish blue) as lip colors to detect the presence of these emotion-color links. Furthermore, yellow and orange have been linked to happiness and cheeriness in prior studies[43]; we opted for an orange lip color instead of yellow to examine the effects, as yellow lips might appear incongruent. In conclusion, our study examined the emotion-color association using warm and cool lip colors. As shown in Figure 7, results indicated that color manipulation in general reduced RT, with shorter RTs observed for orange compared to purple

for perceiving happy faces; there was also a tendency for shorter RT with orange compared to red and blue, although this effect was not significant. However, this effect was not observed in the neutral or sad groups, which partially supports the idea that orange is associated with happiness.[8] Nevertheless, caution is advised in interpreting these findings as it appears that the overall effect may be attributed to the color manipulation itself, rather than specific colors. Additionally, the study did not provide support for an association between warm and cool colors and emotions. Regarding the eye color selections, our goal was to maintain the overall visual harmony of the characters while allowing for the examination of the effects of emotion on different colors. Considering a previous study regarding color context effects on valence categorization of facial expressions, which found that faces on green backgrounds were more likely to be perceived as positive,[2] besides blue and red eyes, we included the green eye color to expand the range of colors. Likewise, we found that the effects of eye color were similar. There was almost no statistically significant difference between color-manipulated groups, which was different from our hypotheses stating that warm colors would help the recognition of positive expressions, while cold colors would enhance that of negative ones. None of the expected effects were detected.

We focused on the eyes and lips because they have a wide variety of colors. Modern human eyes can be brown, red, amber, blue, green, or grey. Considering lips, the history of lipsticks is long. Ancient Egyptians have always been bold in their pursuit and use of color. They combined various natural dyes to create various makeup formulas.[44] In ancient Egypt, in addition to red, purple, and brown lipsticks, they even created a blue lipstick.[45] In Asia, lipsticks have been

used in China since ancient times in various formulas and fashions. It has been said that Chinese people sometimes used brown lipstick, which was named “brown plaster,” to express a feeling of “sadness”.[45] However, in our research, we did not find evidence to suggest that lip color helps enhance this feeling of “sadness.” Perhaps this is because we used a limited range of colors, and most were not sufficiently dark. One possible future direction is to compare the results of colors with different brightness or chroma to specify the relationships between one color and another.

We paid particular attention to the red eye color. Red is synonymous with luck and fortune among the Chinese. However, when associated with eyes, individuals with reddened sclera were perceived as sadder, less healthy, and less attractive than individuals with normal (white) sclera.[46] Although the previous research focused on redness of the whites of the eyes, it still supported that red associated with the eyes may convey a less healthy state. However, in our research, red eyes did not appear to have a significant effect on emotion perception when compared to other colors.

Although comparing emotion types was not our main purpose, we noticed that overall, happy expressions were associated with faster RTs than sad expressions. This finding is consistent with the view that positive facial expressions (e.g., happiness and surprise) are identified more quickly than negative facial ones.[47] We also presumed that color would affect the recognition of neutral expressions more than happy or sad expressions. That is, the emotion-color association for neutral expressions should be easier to detect. In accordance with our expectation, more significant differences between colors were found for RTs of neutral

expressions, which is consistent with the view that neutral emotional expressions seem to be more susceptible to contextual interference than prototypical expressions.[48] The results indicated that neutral expressions were more susceptible to color. Although the emotion-color link was not strong enough to cause observers to choose unexpected options, it still changed their RTs.

Our study has some limitations. First, for our facial stimuli, actors were asked to present an emotion on their face instead of expressing a natural emotion. According to Blais et al.[49], the identification of posed expressions is more systematic than that of spontaneous expressions. More specifically, during the emotion recognition process, spontaneous expressions rely on eye areas and the mouth to an equal degree, whereas posed expressions rely more on eye areas. According to these findings, color manipulation of the lips might not affect the recognition of posed expressions as much as it would with spontaneous expressions. In our experiments, using posed expressions, lip color was likely to draw participants' attention to the mouth area, making it harder for them to recognize emotions in the eye area. Second, our participants were Chinese, for whom certain colors have a cultural meaning. Moreover, people from the East and West have different cultural backgrounds, and their focus on facial expressions may differ. According to Jack et al.[50], Asian observers persistently fixate on the eye region rather than evenly observing the face. Therefore, we speculate that the addition of more color to the lips is likely to draw Asian observers' attention away from the eyes, thereby affecting the accuracy and RTs of lip color manipulation more than eye color manipulation. Future research could further investigate this

issue by conducting cross-cultural comparisons. Third, instead of the conventional approach of pressing a specific key, we had participants click on an emotion label using a mouse for collecting RT data. This decision was based on the adolescent age group of our participants and their familiarity with using a mouse interface. However, this methodological choice may introduce confounding factors, such as varying distances between the mouse position and options, which could impact the RT data. This limitation should be acknowledged when interpreting the RT results. Last, we have a very limited selection of emotion categories; future research may produce interesting results by using emotions such as “anger” and “excitement.”

Overall, our results indicated that color manipulation significantly reduced RT for perceiving happy and neutral expressions. In terms of accuracy, while the results for happy and neutral expressions remained almost unchanged, the color manipulation reduced accuracy for sad expressions.

Finally, as noted above, it is common for people to change their facial color using cosmetics. Thus, it is helpful to know that the local use of color on eyes and lips is unlikely to be confused with the color-emotion link, as facial movements appear to provide much stronger emotion information than color. Although the color of facial features, such as lips and eyes, is not likely to enhance or weaken people’s ability to recognize an emotion correctly, it does help observers judge a specific emotion more quickly. However, the color on eyes or lips is likely to make someone look happier, as color manipulation reduces judgment errors of sad expressions.

Conclusion

This study aimed to investigate whether partial color manipulation influences emotion recognition. According to the results, the effects of partial color manipulation are supported, and we speculate that there are several reasons for this. First, partial color is a contextual interference that arouses people. Second, partial color strengthens the specific facial features. Third, only a minimal difference was found between colors, indicating that any emotion-color association is unlikely to be very strong. Additionally, this study advances the understanding of color's impact on emotions by exploring the effects of localized facial color changes and provides a reference for future color research and may serve as a framework for the application of colors, similar to those examined in this study, in conveying emotions in artificial entities such as robots and avatars.

Figure Captions

Figure 1. Five standard lip color stimuli (emotion: neutral), from left to right: untreated, orange, red, purple, and blue. (Note: The photographs in this figure have been blurred for illustrative purposes only. Clear versions were used in the actual experiment.)

Figure 2. Four standard eye color stimuli (emotion: sad), from left to right: untreated, blue, red, and green. (Note: The photographs in this figure have been blurred for illustrative purposes only. Clear versions were used in the actual experiment.)

Figure 3. Mean a*b value for lip and eye color across 3 individuals. Error bars represent the standard deviation from the mean color values across 3 individuals; The arrows indicate the

general trend from untreated color photographs towards manipulated color variations.

Figure 4. Mean accuracy for the lip color task (***p < 0.001; **p < 0.01; *p < 0.05, +p < 0.1), error bars represent the standard deviation from the mean values.

Figure 5. Main effect of lip color on RT. Error bars represent the standard deviation of the mean values. *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001

Figure 6. Main effect of emotion on RT (in the lip task). Error bars represent the standard deviation of the mean values. +p < 0.1, *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001

Figure 7. The interaction between emotion and lip color on the RT. The error bars show the standard error of the mean of the RTs across participants. Asterisks indicate a significant difference as a result of multiple comparison test for a facial color main effect; *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001.

Figure 8. Mean accuracy for the eye color task. The error bars show the standard error of the mean of the accuracy across participants. Asterisks indicate a significant difference as a result of multiple comparison test for a facial color main effect; *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001.

Figure 9. Main effect of emotion on RT (in the eye task). The error bars show the standard error of the mean of the RTs. *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001.

Figure 10. Main effect of eye color on RT. The error bars show the standard error of the mean of the RTs. *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001

Figure 11. The interaction between emotion and eye color on RT. The error bars show the standard error of the mean of the RTs. *p < 0.05, **p < 0.01, ***p < 0.005, ****p < 0.001

References

1. Barrett LF, Adolphs R, Marsella S, Martinez AM, Pollak SD. Emotional expressions reconsidered: Challenges to inferring emotion from human facial movements. *Psychol Sci Public Interest*. 2019;20(1):1-68. doi: 10.1177/1529100619832930
2. Sivananthan T, de Lissa P, Curby KM. Colour context effects on speeded valence categorization of facial expressions. *Vis Cogn*. 2021;29(6):348-365. doi: 10.1080/13506285.2021.1915901
3. Thorstenson CA, Elliot AJ, Pazda AD, Perrett DI, Xiao D. Emotion-color associations in the context of the face. *Emotion.* 2018;18(7):1032-1042. Doi: 10.1037/emo0000358
4. Thorstenson CA, Pazda AD, Young SG, Elliot AJ. Face color facilitates the disambiguation of confusing emotion expressions: Toward a social functional account of face color in emotion communication. *Emotion*. 2019;19(5):799-807. doi: 10.1037/emo0000485
5. Benitez-Quiroz CF, Srinivasan R, Martinez AM. Facial color is an efficient mechanism to visually transmit emotion. *Proc Natl Acad Sci*. 2018;115(14):3581-3586. doi: 10.1073/pnas.1716084115
6. Thorstenson CA, McPhetres J, Pazda AD, Young S. The role of facial coloration in emotion disambiguation. *Emotion*. 2021. doi: 10.1037/emo0000900
7. Ikeda H, Saheki Y, Sakano Y, Wada A, Ando H, Tagai K. Facial radiance influences facial attractiveness and affective impressions of faces. *Int J Cosmet Sci*. 2021;43(2):144-157. doi: 10.1111/ics.12673
8. Takahashi F, Kawabata Y. The association between colors and emotions for emotional words and facial expressions. *Color Res Appl.* 2018;43(2):247-257. doi: 10.1002/col.22186
9. Mikellides B. 4 - Colour psychology: The emotional effects of colour perception. In: Best J, ed. *Colour Design*. Oxford: Woodhead Publishing; 2012. 105-128 pp. doi: 10.1533/9780857095534.1.105
10. Sutton TM, Altarriba J. Color associations to emotion and emotion-laden words: A collection of norms for stimulus construction and selection. *Behav Res Methods*. 2016;48(2):686-728. doi: 10.3758/s13428-015-0598-8
11. Liao CC, Lee WY, Lai YH, Wang LY. The relationship between container colors and the beauty benefits of skin care products. *Color Res Appl*. 2018;43(2):279-290. doi: 10.1002/col.22191
12. Frühholz S, Trautmann-Lengsfeld SA, Herrmann M. Contextual interference processing during fast categorisations of facial expressions. *Cogn Emot*. 2011;25(6):1045-1073. doi: 10.1080/02699931.2010.516905
13. Boucher JD, Ekman P. Facial Areas and Emotional Information. *J Commun*. 1975;25(2):21-29. doi: 10.1111/j.1460-2466.1975.tb00577.x
14. Kilpeläinen M, Salmela V. Perceived emotional expressions of composite faces. *PLoS One*. 2020;15(3):e0230039. doi: 10.1371/journal.pone.0230039
15. Eisenbarth H, Alpers GW. Happy mouth and sad eyes: Scanning emotional facial

expressions. *Emotion.* 2011;11(4:860-865. doi: 10.1037/a0022758
16. Oosterhof NN, Todorov A. The functional basis of face evaluation. *Proc Natl Acad Sci USA.* 2008;105(32):11087-11092. doi: 10.1073/pnas.0805664105
17. Zebrowitz LA, Kikuchi M, Fellous JM. Facial resemblance to emotions: Group differences, impression effects, and race stereotypes. *J Pers Soc Psychol.* 2010;98(2):175-189. doi: 10.1037/a0017990
18. Ahn I, Lee S, Jin HJ. Do dark circles under the eyes predict health status? *Int J Clin Exp Med.* 2019;12(5):5536-5544.
19. Russell R. Sex, beauty, and the relative luminance of facial features. *Perception.* 2003;32(9):1093–1107. doi: 10.1068/p5101
20. Stephen ID, Lawsmith MJ, Stirrat MR, Perrett DI. Facial skin coloration affects perceived health of human faces. *Int J Primatol.* 2009;30(6):845-857. doi: 10.1007/s10764-009-9380-z
21. Kobayashi Y, Matsushita S, Morikawa K. Effects of lip color on perceived lightness of human facial skin. *I-Percept.* 2017;8(4):2041669517717500. Doi: 10.1177/2041669517717500
22. Nakajima K, Minami T, Nakauchi S. Interaction between facial expression and color. *Sci Rep.* 2017;7:41019. Doi: 10.1038/srep41019
23. Hemphill M. A note on adults' color-emotion associations. *J Genet Psychol.* 1996;157(3):275-280. Doi: 10.1080/00221325.1996.9914865
24. Donges, US, Kersting A, Suslow T. Women's greater ability to perceive happy facial emotion automatically: Gender differences in affective priming. *PloS One.* 2012;7(7):e41745. Doi: 10.1371/journal.pone.0041745
25. Harshman RA, Hampson E, Berenbaum SA. Individual differences in cognitive abilities and brain organization, Part I: Sex and handedness differences in ability. *Can J Psychol.* 1983;37(1):144-192. Doi: 10.1037/h0080690
26. Wingenbach TSH, Ashwin C, Brosnan M. Sex differences in facial emotion recognition across varying expression intensity levels from videos. *PloS One.* 2018;13(1):e0190634. doi: 10.1371/journal.pone.0190634
27. Olderbak S, Wilhelm O, Hildebrandt A, Quoidbach J. Sex differences in facial emotion perception ability across the lifespan', *Cogn Emot.* 2019;33(3):579-588. Doi: 10.1080/02699931.2018.1454403
28. Ekman, P. Universal and Cultural Differences in Facial Expression of Emotions. In: *J. Cole (Ed.), Nebraska Symposium on Motivation.* Lincoln: University of Nebraska Press; 1972. 207-283 pp.
29. ATR-Promotions. n.d. ATR Facial Expression Database. http://www.atr-p.com/products/face-db.html. Accessed August 24, 2022.
30. Peirce J, Gray JR, Simpson S, et al. PsychoPy2: Experiments in behavior made easy. *Behav Res Methods.* 2019;51(1):195-203. doi: 10.3758/s13428-018-01193-y
31. Morales-Vargas E, Reyes-García CA, Peregrina-Barreto H. On the use of action units and fuzzy explanatory models for facial expression recognition. *PLoS One.* 2019;14:e0223563. doi: 10.1371/journal.pone.0223563
32. Cohn JF, Ambadar Z, Ekman P. Observer-based measurement of facial expression with the

Facial Action Coding System. In: *Handbook of Emotion Elicitation and Assessment*. Oxford, United Kingdom: Oxford University Press; 2007. 203-221 pp.
33. Gil S, Le Bigot L. Emotional face recognition when a colored mask is worn: A cross-sectional study. *Sci Rep*. 2023;13(1):174. doi: 10.1038/s41598-022-27049-2
34. Montoya P, Campos JJ, Schandry R. See red? Turn pale? Unveiling emotions through cardiovascular and hemodynamic changes. *Span J Psychol*. 2005;8(1):79-85. doi: 10.1017/S1138741600004984
35. Kato M, Sato H, Mizokami Y. Effect of skin colors due to hemoglobin or melanin modulation on facial expression recognition. *Vis Res*. 2022;196:108048. doi: 10.1016/j.visres.2022.108048
36. Kreibig SD, Wilhelm FH, Roth WT, Gross JJ. Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films. *Psychophysiology*. 2007;44(5):787-806. doi: 10.1111/j.1469-8986.2007.00550.x
37. Takei A, Imaizumi S. Effects of color–emotion association on facial expression judgments. *Heliyon*. 2022;8(1):e08804. doi: 10.1016/j.heliyon.2022.e08804
38. Thompson AE, Voyer D. Sex differences in the ability to recognise non-verbal displays of emotion: A meta-analysis. *Cogn Emot*. 2014;28(7):1164-1195. doi: 10.1080/02699931.2013.875889
39. Lee NC, Krabbendam L, White TP, et al. Do you see what I see? Sex differences in the discrimination of facial emotions during adolescence. *Emotion*. 2013;13(6):1030-1040. doi: 10.1037/a0033560
40. Manav B. Color-emotion associations and color preferences: A case study for residences. *Color Res Appl*. 2007;32(2):144-150. doi: 10.1002/col.20294
41. Hanada M. Correspondence analysis of color–emotion associations. *Color Res Appl*. 2018;43(2):224–237. doi: 10.1002/col.22171
42. Wexner LB. The degree to which colors (hues) are associated with mood-tones. *J Appl Psychol*. 1954;38(6):432. doi: 10.1037/H0062181
43. Liao S, Sakata K, Paramei GV. Color affects recognition of emoticon expressions. *i-Percept*. 2022;13(1):20416695221080776. doi: 10.1177/20416695221080778
44. McMullen RL, Dell'Acqua G. History of natural ingredients in cosmetics. *Cosmetics*. 2023;10(3):71. doi: 10.3390/cosmetics10030071
45. Haruyama Y. *Makeup: Cultural History of Dressing Up.* Tokyo: Heibonsha; 1988.
46. Provine RR, Cabrera MO, Brocato NW, Krosnowski KA. When the whites of the eyes are red: A uniquely human cue. *Ethology*. 2011;117(5):395-399. doi: 10.1111/j.1439-0310.2011.01888.x
47. Leppänen JM, Milders M, Bell JS, Terriere E, Hietanen JK. Depression biases the recognition of emotionally neutral faces. *Psychiatry Res*. 2004;128(2):123-133. doi: 10.1016/j.psychres.2004.05.020
48. Carrera-Levillain P, Fernandez-Dols JM. Neutral faces in context: Their emotional meaning and their function. *J Nonverbal Behav*. 1994;18(4):281-299. doi: 10.1007/BF02172290
49. Blais C, Fiset D, Roy C, Saumure Régimbald C, Gosselin F. Eye fixation patterns for

categorizing static and dynamic facial expressions. *Emotion*. 2017;17(7):1107-1119. doi: 10.1037/emo0000283
50. Jack RE, Blais C, Scheepers C, Schyns PG, Caldara R. Cultural confusions show that facial expressions are not universal. *Curr Biol*. 2009;19(18):1543-1548. doi: 10.1016/j.cub.2009.07.051

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