IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 7 July 2022, accepted 15 August 2022, date of publication 8 September 2022, date of current version 12 October 2022.
Digital Object Identifier 10.1109/ACCESS.2022.3205311

RESEARCH ARTICLE

A Comparative Study on the Perceived Attractiveness of Oriental and South Asian Faces

MUHAMMAD F. MUGHAL[1], XIAOXUAN LIU[1], MING RONNIER LUO[1], AND MICHAEL POINTER[2]
[1]State Key Laboratory of Modern Optical Instrumentation, Zhejiang University, Hangzhou 310027, China
[2]Leeds Institute of Textiles and Colour, University of Leeds, LS2 9JT Leeds, U.K.

Corresponding author: Ming Ronnier Luo (m.r.luo@zju.edu.cn)

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Zhejiang University Human Research Ethics Committee.

ABSTRACT The computation of perceived attractiveness from facial images has long been a research topic. Many models have been developed to predict the attractiveness of the face from the individual models that have been used to describe the geometry of the face (symmetry, golden ratio and neoclassical canons, according to artists from the Middle Ages, and a combination of the three). An experiment was conducted based on Oriental and South Asian ethnic groups, represented by Chinese and Pakistani facial images. Visual assessments of perceived attractiveness were carried out using a 6-point categorical scale and the results were used to derive a new set of facial feature ratios that maximized the perceived attractiveness of the two ethnic groups. The results were also used to develop a new polynomial model of attractiveness, and to test four existing models. The new model performed the best for Oriental faces. The new model was also best for South Asian faces together with the combined model. Ethnic group differences did not have a significant impact on the perceived attractiveness of the two groups. A set of new facial ratios for the two ethnic groups was determined to maximise attractiveness.

INDEX TERMS Attractiveness, ethnic group difference, golden ratio, model, neoclassical canons, symmetry.

I. INTRODUCTION

In perceptual science, attractiveness has always been the most important impression to be investigated among all the visual impressions [1], [2], [3], including sociable, friendly, mature, cooperative. The other impressions were found to have a strong connection with attractiveness [4].

The authors also conducted two psychophysical experiments by varying eight individual facial features [5] (eye vertical position, eye horizontal position, eye size, nose length, nose width, lips thickness, lips width and lips position). The first experiment was to define the visual impression variables. The experiment was conducted using Chinese and Pakistani female facial images from the Leeds Liverpool Skin Colour (LLSC) dataset. The individual facial features of each facial image were rendered using up to four magnitudes, e.g., very small, small, large, very large mouth sizes. In experiment 1, observers rated each image in terms of a yes/no response to each of 16 visual impression scales: (sociable/unsociable, cooperative/uncooperative, easy-going/fussy, relaxed/tense, careful/careless, imaginative/ unimaginative, attractive/unattractive, lively/dull, active/ passive, mature/immature, feminine/masculine, healthy/ unhealthy, likeable/dislikeable, elderly/young, intelligent/ stupid and natural/unnatural). Using factor analysis, three factors (attractive/unattractive, feminine/masculine and mature/immature) were found to adequately represent the sixteen visual impressions. In a second experiment [5], further analysis used

The associate editor coordinating the review of this manuscript and approving it for publication was Charith Abhayaratne.

attractiveness, femininity and maturity on a six-point categorical judgment scale. The images were rendered for the same eight facial features as that of the first experiment. Models were developed for each visual impression based on individual facial features. The results showed that both the Chinese and Pakistani faces were significantly impacted by the four facial features. However, these facial features were different for both ethnic groups. For Chinese faces, the four features were eye vertical position, eye horizontal position, eye size and lips position. For Pakistani faces, the four parameters were eye vertical position, nose length, lips thickness and lips position.

Schmid *et al.* [3], reported that facial feature geometry had a significant role in the overall perception of the face. Many models have been developed based on the geometry of facial features to predict the perceived attractiveness from facial images and the three main models are symmetry [6], the golden ratio [7] and neoclassical canons [8]. The former is based on symmetry theory; the more symmetrical the facial features are around the vertical axis at the centre of the face, the more attractive the face [3], [6]. The golden ratio theory of attractiveness states that the closer the facial feature ratios are to the golden ratio ($\approx$1.618), the more attractive the face will be. Neoclassical canons were developed by artists in the sixteenth century [8] and many of the neoclassical canons are listed by Schmid *et al.* [3], for example, face width equals four times nose width, eye interocular distance equals nose width, etc.

The models based on the above theories have been better predictors of perceived attractiveness than those of the earlier models. Schmid *et al.* [3], also proposed another model that combined the above three main models. There are, however, some contradictory results to these theories. Swaddle *et al.* [9] found asymmetric faces to be more attractive. Pallet *et al.* [2] found a new set of facial ratios to maximise the attractiveness of the face based on revised golden ratios. Torsello *et al.* [10], found that neoclassical canons were not found in the faces of female models who were considered to be 'beautiful'. The present authors have proposed a model that measured the facial feature ratios with respect to full-face dimensions and the results showed that the model was a better predictor of perceived attractiveness than earlier models [5]. However, this model was only tested on the individual facial features, and not tested by considering cross features.

Some studies have investigated the impact of ethnic group differences on perceived attractiveness and showed considerable agreement in the judgment of perceived attractiveness [11], [12], [13], [14] However, there were discrepancies between the results for Asian and Western observers [15], [16], [17], [18]. Also, Swaddle *et al.* [9] found asymmetric faces to be more attractive and there was an ethnic group difference. The present authors studied the Oriental and South Asian ethnic groups and the results showed some discrepancies between the two groups.

With the above in mind three goals were set for the present study.

1. to develop a model by measuring the ratios based on multiple facial features with respect to length, width or area, from two databases, with images captured under a standardized capturing condition and those from the internet,
2. to reveal the difference in attractiveness between the two ethnic groups studied, and
3. to find the ratio of the facial features to enhance the perceived attractiveness between the Oriental and South Asian ethnic groups.

II. MATERIAL AND METHOD

A. OBSERVERS

In total, 36 observers were recruited for the experiment. Out of the 36, 19 observers were Chinese (10 Male + 9 Female) and 17 Pakistani (10 Male + 7 Female). All the participants were students at Zhejiang University, but were of either native Chinese or Pakistani nationality. The latter were postgraduate students in China to study for a period about 2-5 years until they had completed their degrees. Hence, the participants should represent their native ethnic groups well. The age of the Chinese observers was between 23 and 27 years, with a standard deviation of 3.12 years. The age of the Pakistani observers ranged from 24 to 31 years, with a standard deviation of 2.36 years. They represented Oriental and South Asian ethnic groups respectively, the two world's largest population ethnic groups. The Oriental and South Asian ethnic groups will be used in the subsequent discussions.

B. STIMULI

78 Oriental female facial images were used as stimuli for the experiment (34 from the LLSC dataset and 44 from the internet) and 40 Pakistani (7 from LLSC and 33 from the internet). The Chinese and Pakistani images were collected from the internet websites, including google.com, pixabay.com, pinterest.com dreamstime.com shutterstock.com etc.. The images were selected to represent Oriental and South Asia ethnic groups considering a wide range of facial characters, to possess a pleasant experience, to exclude celebrities.

C. PROCEDURE

The experiment was conducted using an Eizo GM-243W LCD display located in a dark room. The display had a screen diagonal of 24.1 inches and a native resolution of 1920×1200 pixels. The peak white of the monitor was set to the chromaticity of CIE illuminant D65 and a luminance of 100 cd/m2. The luminance uniformity showed approximately 8% deviation from the centre of the screen to the corners.

An image processing procedure was used to process each image. Firstly, each pixel of the LLSC facial image was transformed from camera RGB signals to CIE XYZ tristimulus values via a 3×11 polynomial camera characterization model [19]. The RGB values of the Internet images were computed to CIE XYZ tristimulus values using sRGB space [20] and CIE illuminant D65 [21]. Secondly, to transform the XYZ values to monitor RGB values, a GOG monitor characterisation model was used [22]. The performance of the monitor model was evaluated using the 24 colours in the Macbeth ColorChecker Chart and the average colour difference was approximately one CIEDE2000 unit [23]. The experiment was designed in two parts to include images from the LLSC and internet datasets, respectively.

The experiment was conducted using a 6-point categorical judgment method using a scale from -3 to $+3$ with no zero in the middle, as shown in Figure 1. As an example, Figure 1 also shows the face of the first author. However, during the experiment, the Oriental and South Asian female facial images were used from the LLSC and Internet datasets.

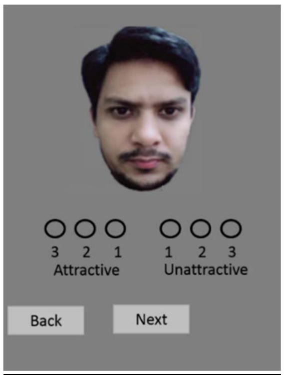
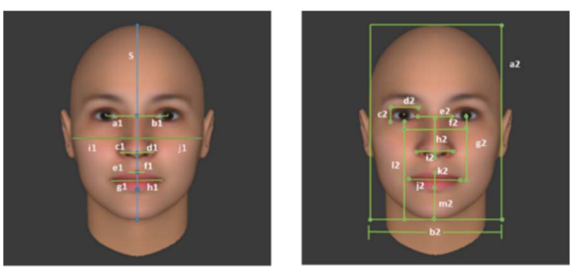


FIGURE 1. Example of the interface of the experiment. Note. This is an example interface – in the actual experiment the Oriental and South Asian female faces were used. This image is used here to avoid any copyright issues.

D. METHOD TO MEASURE THE FACES

After the experiment was finished and the experimental data obtained, the four previous models: symmetry, golden ratio, neoclassical canon and their combination were implemented. Then a new model was constructed by measuring the individual facial features with respect to the dimensions of the face.



(a) (b)

FIGURE 2. Method to measure the face (a) symmetry (b) all the other methods. Note. A computerized figure is used to demonstrate the different measurement methods including Symmetry, golden ratio, neoclassical canons and new method.

Figure 2(a) shows the symmetry measures of the eyes, nose and lips in a facial image. A vertical axis "S". the axis of symmetry, was obtained by joining points from the top to the bottom of the face. The distances dL and dR represent the distances of the various features to the left and right of the axis of symmetry. The symmetry is calculated by (1).

$$Symmetry\ measure = \frac{|d_L - d_R|}{(d_L + d_R)} \tag{1}$$

According to this definition, the symmetry of the eye, nose, lips and full face are defined by ((|a1-b1|)/ (a1+b1), ((|c1-d1|)/ (c1+d1)), ((|g1-h1|)/ (g1+h1)), and ((|i1-j1|)/ (i1+j1)), respectively (see Figure 2(a).

The golden ratio was measured by calculating the difference between the ratio of the facial feature and 1.618 (the so-called golden number). The ratios of the facial features included the mouth width to the inter-ocular distance (j2/e2), the mid-eye distance to the interocular distance (f2/e2), the mid-eye distance to the nose width (f2/i2), the mouth width to the nose width (j2/ i2), the interocular distance to the thickness of the lips (e2/k2), and the nose width to the thickness of the lips (i2/k2) (Figure 2b). Neoclassical canons include the face width equal to four-times the nose width ($b2 = 4\times\ i2$); the lips width equal to 1.5 times the nose width ($j2 = 1.5\times\ i2$); the interocular distance equal to the nose width ($e2 = i2$) (Figure 2). The above rules calculate ratios of symmetry, golden ratio, and neoclassical canons from facial images [3].

Table 1 lists the definition of each facial feature according to the new model. The third column "Facial Ratio Measurement" shows that for each facial ratio the denominator was the face length, width, or area. These ratios were used to implement the new model to predict the attractiveness of the face.

TABLE 1. Method of measurement according to the new model.

No.	Facial Feature	Facial Ratio measurements	Definition (Figure2b)
1	eye vertical position	eye-chin distance to face length	e2 /a2
2	eye horizontal position	interocular distance to face width	f2 /b2
3	eye size	eye area to face area	(c2× d2) /(a2 × b2)
4	nose length	nose length to face length	h2 /a2
5	nose width	nose width to face width	i2 /a2
6	lips thickness	lips thickness to face length	k2 /a2
7	lips width	Lips width to face width	j2 /a2
8	lips position	Lips chin distance to face length	m2 /b2

Note. The new method to measure the facial features required that every facial feature should be measured with respect to the length, width or area of the face. Table I and Figure 2 explain this method.

III. RESULTS AND DISCUSSION

The intra-observer and inter-observer variability of the observers were investigated using the correlation coefficient

TABLE 2. Intra-observer and inter-observer variability in terms of STRESS and correlation coefficient (R).

	Intra-observer Variability				Inter-observer Variability			
	Cn/ Cn	Cn/ Pak	Pak/ Cn	Pak/ Pak	Cn/ Cn	Cn/ Pak	Pak/ Cn	Pak/ Pak
STR ESS	20	22	25	21	32	34	33	32
R	0.8 3	0.82	0.64	0.70	0.7 2	0.66	0.61	0.66

Note. Intra-observer and inter-observer variability across ethnic groups in terms of STRESS and R. Cn/Cn, Cn/Pak, Pak/Cn and Pak/Pak represent Oriental observers/Oriental faces, Oriental faces/South Asian observers, South Asian faces/Oriental observers and South Asian faces/South Asian observers, respectively.

and standard residual sums of squares (STRESS) [24]. STRESS values can have a range from 0 to 100, implying total and zero agreement, respectively. Mathematically, STRESS is defined by (2).

$$STRESS = \left(\frac{\sum_{i=1}^{n} (A_i - FB_i)^2}{\sum_{i=1}^{n} F^2 B_i^2} \right)^{1/2} \times 100 \tag{2}$$

where A_i and B_i are the two measurements to be compared, and F is given by

$$F = \sum_{i=1}^{n} A_i^2 / \sum_{i=1}^{n} A_i B_i$$

where n is the number of sample pairs and F is a scaling factor to adjust the A and B datasets onto the same scale.

Table 2 lists the intra-observer and inter-observer variability of the average observer both in terms of the STRESS and correlation coefficient R. The results also show that the inter-observer variability was always larger than the intra-observer variability. Thus, the observers were more consistent rating the same image twice (intra-observer variability) than their difference from a mean observer (inter-observer variability).

Note that the inter-observer variability can be considered as a baseline to evaluate the performance of each model. If the model performance is less than the inter-observer variability in terms of the STRESS value, then the performance of the model can be acceptable [24].

IV. IMPLEMENTING THE MODELS

The methods used to measure the symmetry, golden ratio, neoclassical canons. and the further model proposed by Schmid *et al.* [3], which uses a combination of symmetry, golden ratio and neoclassical canons were implemented. Mughal *et al.* [5], has also shown that Oriental attractiveness depends upon four different facial features: eye vertical position, eye horizontal position, eye size and lips position. For South Asian faces, however, the corresponding four features are eye vertical position, nose length, lips thickness and lips position.

TABLE 3. Comparison among the existing and new models in terms of correlation coefficients and STRESS values.

Models	Oriental	South Asian
Symmetry	*0.37/33*	*0.31/32*
Golden Ratio	*0.51/31*	*0.39/31*
Neoclassical Canons	*0.40/33*	*0.38/31*
Combination	*0.60/28*	***0.56/28***
New Model	***0.69/26***	***0.58/28***

Note. The numbers follow the format coefficient/STRESS. Bold values show the best model(s).

As noted earlier, for Oriental faces,, the four features used by Oriental and South Asian observers are eye vertical position, eye horizontal position, eye size and lips position. For South Asian faces, the four parameters are eye vertical position, nose length, lips thickness and lips position.

The following are the main requirements of the analysis:

- Optimization algorithm
- Polynomial model equation
- Metric to minimize the difference between visual data and output of the model

All five models were implemented using MATLAB software. The method used to obtain the coefficients was Quantum Particle Swarm Optimization (QPSO) which recursively optimizes the result of a mathematical equation. The hyper-parameter STRESS value was used to find the minimum difference between the output of the equation and the appropriate experimental data. The lower value of STRESS implies the better agreement between the model and the experimental data. That is why QPSO was used to recursively minimize the STRESS value and to find out the optimal coefficients. The linear polynomial model equation used for the optimization is given by (3).

$$T = a_1F_1 + a_2F_2 + a_3F_3 + a_4F_4 + C \tag{3}$$

where a_1 to a_4 are the coefficients to be optimized and F_1 to F_4 are the facial features, and C is a constant. For symmetry F_1 to F_4 are the symmetry of the eye, nose, lips and full face.

For the symmetry, golden ratio and the new model there were four terms F_1 to F_4 in (3). For neoclassical canons, there were three facial ratios so the term a_4 F_4 was omitted from (3). The reason to use three neolcassical canons was the inclusion of three facial features in the original model [8]. The others like ears, neck were not part of facial image. The combination of the existing models contained 12 terms, 4 each for symmetry and the golden ratio, 3 terms for neoclassical canons and a constant C. Hence five models were implemented.

A. COMPARISON BETWEEN MODELS

Table 3 lists the performance of all five models to predict attractiveness, both in terms of correlation coefficients and STRESS values.

The new model outperformed all the previously existing models for Oriental faces. However, for South Asian faces, the new model and the combination model gave nearly equal performance. For Oriental faces, all the models, except the symmetry and neoclassical canons models, had a STRESS value less than the inter-observer variability. Thus these can be considered reliable models to determine the attractiveness of the face (Inter-observer variability STRESS = 32 for both Oriental and South Asian faces).

Although for South Asian faces, the combination and new model performed nearly equally, the new model performed better for Oriental faces. Furthermore, the combination models required more terms and hence had a more complicated structure than the new models. For Oriental faces and the symmetry model, the golden ratio and the neoclassical canons performed equally well, and the golden ratio performed the best. The new model to predict the attractiveness of Oriental faces is given in (4):

$$newAtt_{Cn-T1} = 0.9602ES + 0.0511EVP - 0.0119EHP - 0.1631LP - 0.0132 \quad (4)$$

where ES, EVP, EH and LP refer to eye size, eye vertical position, eye height and lips position, respectively.

The new model to predict the attractiveness of South Asian faces is given in (5):

$$newAtt_{Pak-T1} = -0.5460EVP + 0.3331NL + 0.5390LT + 0.8975LP + 0.1181 \quad (5)$$

where NL and LT refer to nose length and lips thickness, respectively. Figure 3 shows the performance of all the models in terms of scatter plots between model predictions and visual data. Separate scatter plots are shown for Oriental and South Asian faces. The STRESS and R values of each model are included in each plot. This figure shows that the new model performed better than the four previous models. The model in (3) is linear. A non-linear model was also implemented with additional terms which included the possible combinations. For example, the additional terms in (3) were $a_5F_1\,F_2, a_6F_1\,F_3, \ldots, a_{15}F_1\,F_2\,F_3\,F_4$. The results of linear and non-linear models were compared. An ANOVA test revealed that linear and non-linear models were not significantly different. This indicated that linear models were adequate to describe both the attractiveness of both Oriental and South Asian faces.

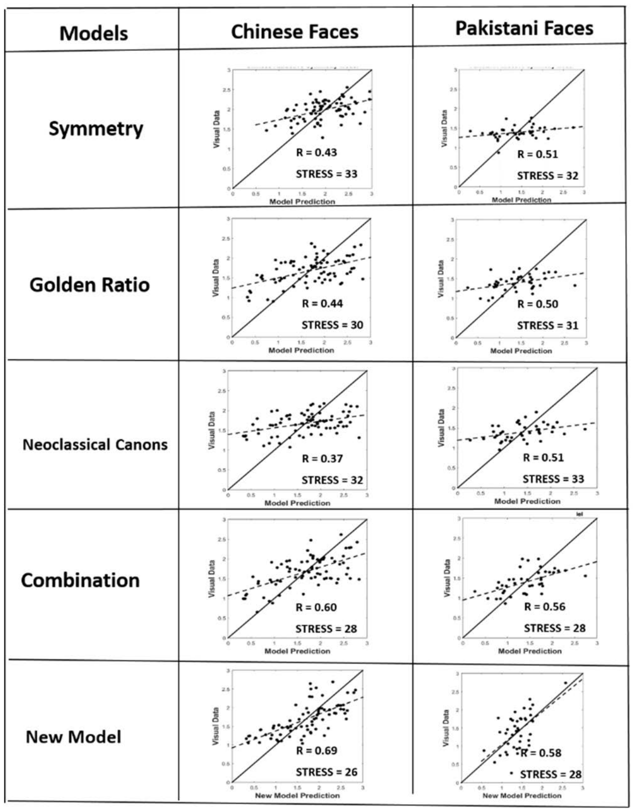


FIGURE 3. The scatter plots between the the predictions of the models and the visual data. Note. The scatter plot shows the performance of model of symmetry, golden ratio, neoclassical canons and their combination and new method. The STRESS and R values are also included.

TABLE 4. Optimal ratios to maximise the attractiveness of Oriental and South Asian faces.

Facial Feature	Oriental Faces	South Asian Faces
Eye Vertical Position	*0.54*	*0.56*
Eye horizontal Position	*0.27*	-
Eye Size	*0.021*	-
Nose Length	-	*0.26*
Lips Thickness	-	*0.16*
Lips Position	*0.13*	*0.13*

B. OPTIMAL RATIOS TO MAXIMISE THE ATTRACTIVENESS

As the new model performed better than previously existing models, a set of new facial feature ratios to maximise the attractiveness of the face were determined based on the new model. Oriental models were implemented for eye size, eye vertical position, eye horizontal position and lips position. According to the definition of facial features from Table 2, the optimal values to maximise the attractiveness of Oriental and South Asian faces are listed in Table 4. The common facial ratios were close to each other for both the Oriental and South Asian faces. These ratios were measured according to the new model measurement methods. This also implies little ethnic group difference.

C. ETHNIC GROUP DIFFERENCE

Figure 4 shows the ethnic group difference in terms of scatter plots plot between Oriental and South Asian observers for (a) Oriental faces and (b) South Asian faces. The associated R and STRESS values are included in the plots. The results show that the observers agreed more on Oriental faces (R = 0.72, STRESS = 25) than South Asian faces (R = 0.66, STRESS = 32). Comparing ethnic group differences and baseline noise (inter-observer variability), they were quite similar, indicating there was little difference between Oriental and South Asian observers. An ANOVA test revealed no significant impact of ethnic group differences on Oriental and South Asian faces.

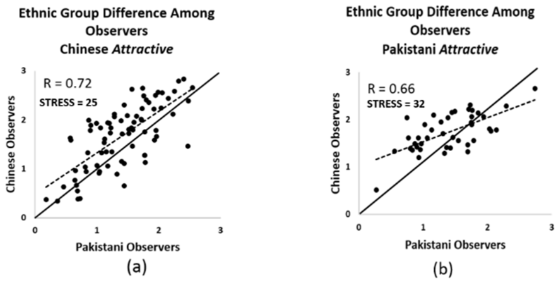


FIGURE 4. Ethnic group difference (a) Chinese (Oriental) and (b) Pakistani (South Asian) faces.

V. CONCLUSION

This study investigated the attractiveness between Oriental and South Asian groups and there were two goals. The first was to develop a model by measuring cross facial features by the ratios with respect to length, wide or area of the face. The models were successfully developed and compared with the existing models. It was found that the newly developed model outperformed the previous models.

The second goal was to compute the impact of ethnic group differences on Oriental and South Asian facial images. First, the ethnic group difference was lower for Oriental faces than for South Asian faces. The STRESS values of the ethnic group differences were not greater than the baseline noise (inter-observer variability). This result indicates that ethnic group differences had a negligible impact on the attractiveness of the face. This result agreed with the second hypothesis that the ethnic group difference had less impact on perceived attractiveness. The cross-culture study was also examined by the ratio of the facial features to achieve the perceived attractiveness of the Oriental and South Asian faces. It was found that facial features had very close optimal ratios to achieve attractiveness across ethnic groups.

In future work, observers from different ethnic groups should be recruited to perform the same experiment. Their results can then be used to test the versatility of the models developed and reveal cultural differences. In addition, the general face for that ethnic group will be generated and their faces can be directly compared. Finally, similar experiments should be performed to study the skin colour for different ethnic groups using colour-calibrated images in different countries. Thus more parameters will be taken into account by the model. Also, the study of culture differences can be extended to include more ethnic groups.

REFERENCES

[1] A. L. Jones and B. Jaeger, "Biological bases of beauty revisited: The effect of symmetry, averageness, and sexual dimorphism on female facial attractiveness," *Symmetry*, vol. 11, no. 2, pp. 279–303, Feb. 2019, doi: 10.3390/SYM11020279.

[2] P. M. Pallett, S. Link, and K. Lee, "New 'golden' ratios for facial beauty," *Vis. Res.*, vol. 50, no. 2, pp. 149–154, Jan. 2010, doi: 10.1016/j.visres.2009.11.003.

[3] K. Schmid, D. Marx, and A. Samal, "Computation of a face attractiveness index based on neoclassical canons, symmetry, and golden ratios," *Pattern Recognit.*, vol. 41, no. 8, pp. 2710–2717, Aug. 2008, doi: 10.1016/j.patcog.2007.11.022.

[4] A. M. Griffin and J. H. Langlois, "Stereotype directionality and attractiveness stereotyping: Is beauty good or is ugly bad?" *Social Cogn.*, vol. 24, no. 2, pp. 187–206, Apr. 2006, doi: 10.1521/soco.2006.24.2.187.

[5] M. F. Mughal, M. R. Luo, and M. Pointer, "Modelling visual impressions for Chinese and Pakistani ethnic groups," *Pattern Recognit.*, vol. 103, pp. 107259–107271, Jul. 2020, doi: 10.1016/j.patcog.2020.107259.

[6] B. Fink, N. Neave, J. T. Manning, and K. Grammar, "Facial symmetry and judgements of attractiveness, health and personality," *Pers. Individual Differences*, vol. 41, no. 3, pp. 491–499, Aug. 2006, doi: 10.1016/j.paid.2006.01.017.

[7] G. Meisner. *The Human Face and the Golden Ratio*. Accessed: Dec. 2006. [Online]. Available: http://Goldennumber.net/face

[8] L. G. Farkas, T. A. Hreczko, J. C. Kolar, and I. R. Munro, "Vertical and horizontal proportions of the face in young adult North American Caucasians: Revision of neoclassical canons," *Plastic Reconstructive Surg.*, vol. 75, no. 3, pp. 328–338, Aug. 1985, doi: 10.1097/00006534-198503000-00005.

[9] J. P. Swaddle and I. C. Cuthill, "Asymmetry and human facial attractiveness: Symmetry may not always be beautiful," *Proc. Roy. Soc. London B, Biol. Sci.*, vol. 261, no. 1360, pp. 111–116, Jul. 1995, doi: 10.1098/rspb.1995.0124.

[10] F. Torsello, L. Mirigliani, R. D'Alessio, and R. Deli, "Do the neoclassical canons still describe the beauty of faces? An anthropometric study on 50 Caucasian models," *Prog. Orthodontics*, vol. 11, no. 1, pp. 13–19, May 2010, doi: 10.1016/j.pio.2010.04.003.

[11] M. R. Cunningham, A. R. Roberts, A. P. Barbee, P. B. Druen, and C. H. Wu, "'Their ideas of beauty are, on the whole, the same as ours': Consistency and variability in the cross-cultural perception of female physical attractiveness," *J. Pers. Social Psychol.*, vol. 68, no. 2, pp. 261–279, Feb. 1995, doi: 10.1037/0022-3514.68.2.261.

[12] P. F. Secord and W. Bevan, "Personalities in faces: III. A cross-cultural comparison of impressions of physiognomy and personality in faces," *The J. Social Psychol.*, vol. 43, no. 2, pp. 283–288, May 1956, doi: 10.1080/00224545.1956.9919224.

[13] M. Walker, F. Jiang, T. Vetter, and S. Sczesny, "Universals and cultural differences in forming personality trait judgments from faces," *Social Psychol. Pers. Sci.*, vol. 2, no. 6, pp. 609–617, Nov. 2011, doi: 10.1177/1948550611402519.

[14] L. A. Zebrowitz, R. Wang, P. M. Bronstad, D. Eisenberg, E. Undurraga, V. Reyes-García, and R. Godoy, "First impressions from faces among U.S. and culturally isolated Tsimane' people in the Bolivian rainforest," *J. Cross-Cultural Psychol.*, vol. 43, no. 1, pp. 119–134, Jan. 2012, doi: 10.1177/0022022111411386.

[15] R. E. Jack, C. Blais, C. Scheepers, P. G. Schyns, and R. Caldara, "Cultural confusions show that facial expressions are not universal," *Current Biol.*, vol. 19, no. 18, pp. 1543–1548, Sep. 2009, doi: 10.1016/j.cub.2009.07.051.

[16] R. E. Jack, O. G. B. Garrod, H. Yu, R. Caldara, and P. G. Schyns, "Facial expressions of emotion are not culturally universal," *Proc. Nat. Acad. Sci. USA*, vol. 109, no. 19, pp. 7241–7244, May 2012, doi: 10.1073/pnas.1200155109.

[17] H. A. Elfenbein and N. Ambady, "On the universality and cultural specificity of emotion recognition: A meta-analysis," *Psychol. Bull.*, vol. 128, no. 2, pp. 203–235, Mar. 2002, doi: 10.1037/0033-2909.128.2.203.

[18] X. Yan, T. J. Andrews, and A. W. Young, "Cultural similarities and differences in perceiving and recognizing facial expressions of basic emotions," *J. Exp. Psychol., Hum. Perception Perform.*, vol. 42, no. 3, pp. 423–440, Mar. 2016, doi: 10.1037/xhp0000114.

[19] G. Hong, M. R. Luo, and P. A. Rhodes, "A study of digital camera colorimetric characterization based on polynomial modeling," *Color, Res. Appl.*, vol. 26, no. 1, pp. 76–84, Feb. 2001, doi: 10.1002/1520-6378(200102)26:1<76:AID-COL8>3.0.CO;2-3.

[20] *Multimedia Systems and Equipment—Colour Measurement and Management—Part 2–1: Colour Management—Default RGB Colour Space—sRGB*, IEC, Geneva, Switzerland, 1996.

[21] *Colorimetry*, 4th ed., CIE, Vienna, Austria, 2018.

[22] R. S. Berns, "Methods for characterizing CRT displays," *Displays*, vol. 16, no. 4, pp. 173–182, May 1996, doi: 10.1016/0141-9382(96)01011-6.

[23] M. R. Luo, G. Cui, and B. Rigg, "The development of the CIE 2000 colour-difference formula: CIEDE2000," *Color Res. Appl.*, vol. 26, no. 5, pp. 340–350, Oct. 2001, doi: 10.1002/col.1049.

[24] P. A. Garcia, R. Huertas, M. Melgosa, and G. Cui, "Measurement of the relationship between perceived and computed color differences," *J. Opt. Soc. Amer. A, Opt. Image Sci.*, vol. 24, no. 7, pp. 1823–1829, Jul. 2007, doi: 10.1364/JOSAA.24.001823.

MUHAMMAD F. MUGHAL is from Pakistan. He received the master's degree in signal processing from the Electronics Department, Quaid-e-Azam University, Islamabad, Pakistan. He is currently pursuing the Ph.D. degree in perceptual sciences based on imaging with the Optical Engineering Department, Zhejiang University, Hangzhou, China.

He has published more than ten journal and conference papers those include highly reputed journal like pattern recognition and conferences like CIC, AIC and CACPP. His research interests include signal processing, image processing, psychophysics, and perceptual science.

Mr. Mughal was a recipient of the Best Paper Award from CACPP Conference for calibrating 3D images in terms of spectral reflectance.

XIAOXUAN LIU received the B.S. and M.S. degrees from the University of Science and Technology Liaoning, China. Since 2019, she has been a Research Assistant with the State Key Laboratory of Modern Optical Instrumentation, Zhejiang University, China. Her research interests include the color image assessment and image quality enhancement.

MING RONNIER LUO received the Ph.D. degree in colour science from Bradford University, U.K., in 1986. He is the Chair Professor with the College of Optical Science and Engineering, Zhejiang University, China. He has published over 650 peer-reviewed articles in the fields of colour science, imaging science and illumination engineering. He is a fellow of the Society of Dyers and Colourists (SDC) and the Society of Imaging Science and Technology (SIST). He has been an Active Member of International Commission on Illumination (CIE). He was the Vice President, the Division Director of colour and vision, the Technical Chairs, members, etc. He has received numerous awards, including the Judd 2017 Award and the Newton 2020 Award for his contribution in colour science research.

MICHAEL POINTER received the Ph.D. degree from Imperial College, London. He was at the Research Division of Kodak Ltd. on fundamental issues of colour science applied to the photographic system. He was at the University of Westminster and the National Physical Laboratory he took early retirement and is currently a Visiting Professor with the University of Leeds and a Technical Advisor with the Color Engineering Laboratory at Zhejiang University, Hangzhou, China. In 2004, he received a Silver Medal from the Society of Dyers and Colourists for contributions to colour science. He is also an Honorary Member of the Colour Group of Great Britain and was awarded the 2014 Newton Medal by the Group. He has authored or coauthored over 180 scientific articles. He is a fellow of The Royal Photographic Society and an U.K. Associate Editor of the *Journal Color Research and Application*. He coauthored the 4th edition of *Measuring Colour* with Robert W. G. Hunt.