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The Perception of Facial Beauty: The Contribution of Image Statistics and Perceived Symmetry

Pi-Chun Huang[1] and Chien-Chung Chen[2]
Department of Psychology, National Cheng Kung University[1]
Department of Psychology, National Taiwan University[2]

The judgement of facial beauty was influenced by many factors. In current study, we investigated how the image statistics (including slope of amplitude spectrum and symmetry index) and perceived symmetry influenced facial attractiveness. 228 faces were normalized to the same rms contrast and modified to produce its symmetrical face and asymmetrical face by morphing technique. The task of the observers was to rate each face for its attractiveness, perceived symmetry, valence and arousal in the emotion dimension. In Experiment 1, we used symmetrical and asymmetrical faces as stimuli. Our results showed that the symmetrical face has higher values of symmetry index and slope, and was rated as more attractive, symmetrical and with higher positive emotion. Furthermore, the facial attractiveness could be predicted by symmetry index, slope, perceived symmetric and emotional valence by linear regression. In Experiment 2, we used original faces and asked other participants to do the same task. The results were similar to Experiment 1. The attractiveness rating for randomly chosen faces could be also predicted by the rest of the faces by using the same parameter weights in linear regression. We also adapted path analysis to investigate how the physical properties (symmetry index and slope) influences participants’ attractiveness rating via perceived symmetry and emotion judgement. Our results suggested the beauty of the faces was contributed by the image statistics, perceived symmetry and valence of the emotion.

Keywords: *facial attractiveness, image statistics, symmetry perception.*

Extended Abstract

Facial attractiveness plays an important role in social interactions. It is usually associated with inferences about positive personality characteristics and affects the nature of social interactions (Griffin & Langlois 2006; Hamermesh, 2011; Judge, Hurst, & Simon, 2009; Langlois, Kalakanis, Rubenstein, Larson, Hallam & Smoot, 2000). Standards for beauty among observers are relatively consistent across cultures and age groups, from infancy to adulthood (Cunningham, Roberts, Barbee, Druen, & Wu, 1995; Langlois, Roggman, & Rieser-Danner, 1990; Rhodes, 2006).

Several factors affect the perception of facial beauty. Menzel et al. (2015) divided these factors into two categories: the first related to the image properties of a face the second related to the morphological properties of the face (Menzel, Hayn-Leichsenring, Langner, Wiese, & Redies, 2015). The former emphasizes how image statistics such as spatial frequency, contrast, skin color and texture influence judgments of facial attractiveness (Fink, Grammer, & Matts, 2005; Jones, Little, Burt, & Perrett, 2004; Russell, 2009), and the latter emphasizes how morphological properties such as symmetry, averageness and sexual dimorphism modulate judgement of facial attractiveness (Rhodes, 2005; Thornhill & Gangestad, 1999).

In terms of low-level image properties, the relationship between amplitude spectrum distribution and aesthetic judgment has been frequently studied.

People have been shown to favor images, including natural scenes, portraits, other art works, and various types of photograph, with an amplitude spectrum slope of 1 (Redies, Hasenstein, & Denzler, 2007; Graham & Field, 2007; Braun, Amirshahi, Denzler, & Redies, 2013; Graham & Redies, 2010; Koch, Denzler, & Redies, 2010). However, studies have shown that people do not favor images of real faces with an amplitude spectrum slope equal to 1 (Keil, 2008; Menzel et al., 2015). These findings indicate that perceptions of facial attractiveness are affected by the specific properties of facial images, as distinct from other types of images. The relationship between the amplitude spectrum distribution and facial attractiveness remains unclear.

Another statistical property of images is the symmetry index. Huang (2019) trained artificial intelligence (AI) to judge facial beauty and found that when the symmetry index was used as a decision criterion to evaluate beauty, AI performed similarly to humans.

In terms of the morphological properties of the face, perceived symmetry is positively correlated with attractiveness judgments (Grammer & Thornhill, 1994; Jones, Little, Penton-Voak, Tiddeman, Burt, & Perrett, 2001; Mealey, Bridgestock, & Townsend, 1999; Rhodes, 2006; Scheib, Gangestad, & Thornhill, 1999). Studies have reported a preference for symmetry in both real faces and computer-generated faces (Little et al., 2001; Perrett et al., 1999; Rhodes, 2006; Rhodes, Proffitt, Grady, & Sumich, 1998). This preference appears to be consistent across cultures (Rhodes, Yoshikawa, Clark, Lee, McKay, & Akamatsu, 2001) and species (Waitt & Little, 2006).

However, some researchers have argued against the role of symmetry in facial attractiveness, noting that the degree of perceived symmetry may be confounded with face length, cheekbone shape and facial expression (Otta, Abrosio, & Hoshino, 1996; Reis et al., 1990). For example, compared with a positive facial expression, a negative facial expression, which is inherently less symmetrical, is judged as less attractive (Borod, 1993; Skinner & Mullen, 1991). Other studies have also found that perfect symmetry is less attractive than imperfect symmetry (Kowner, 1996; Langlois et al., 1994; Swaddle & Cuthill, 1995). Thus, the role of symmetry, including the symmetry index and perceived symmetry, may not be as distinct as previously expected.

In summary, judgments of facial beauty are influenced by many factors. In this study, we investigated how image statistics (including the amplitude spectrum slope and symmetry index) and perceived symmetry influenced facial attractiveness. We also explored the relationships between the symmetry index, perceived symmetry and facial attractiveness to clarify the confounding factors in the dimension of symmetry. Thus, we conducted two experiments. In experiment 1, we used symmetrical and asymmetrical faces produced by the same models as stimuli. The observers were required to rate each face in terms of its attractiveness, perceived symmetry, emotional valence and emotional arousal. We calculated the differences in judgment scores for each model to investigate the relationship between the changes in image statistics and the rating tasks. In experiment 2, we used original faces and asked the observers to perform the same tasks as in experiment 1. Next, we investigated the correlations between all of the factors. We also conducted path analysis to investigate how the interaction between the factors contributed to the assessment of facial attractiveness.

Experiment 1

Methods

Participants

The participants comprised 14 males (M = 20.14, SD = 2.28) and 14 females (M = 21.71, SD = 2.49) with normal or corrected-to-normal vision. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the National Cheng Kung University Research Ethics Committee for Human Behavioral Sciences and the Department of Psychology, National Cheng Kung University.

Stimuli

We selected 228 faces, comprising 38 Asian male faces, 84 Caucasian male faces, 52 Asian female faces and 54 Caucasian female faces. Pairs of symmetrical

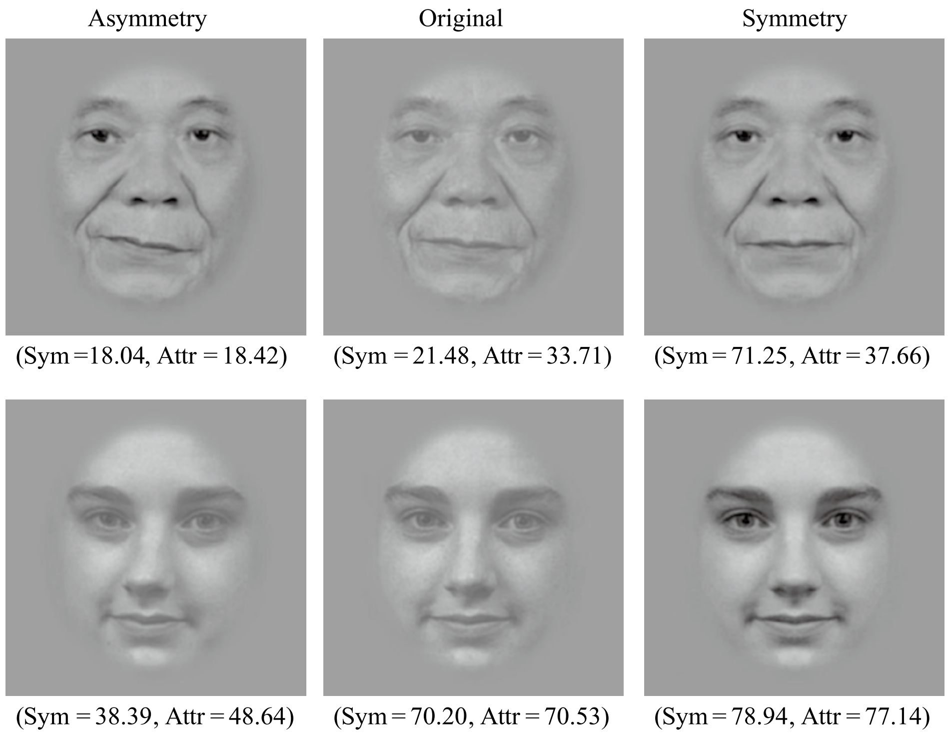

Figure 1. **Demonstration of the face stimulus. The values in the bracket was the averaged symmetry score (Sym) and attractiveness score (Attr).**

and asymmetrical faces were created using Fantamorph (version 5.47, FantaMorph 5, Abrosoft Co.). The symmetrical faces were produced by averaging the normal and mirror images of each face. The asymmetrical faces were produced by moving the corresponding points 25% from the original face in the opposite direction to the mirror faces. We then masked the faces (including the original faces) with an oval window to remove their contours and adjusted them to give an equal root mean square contrast. Examples from the stimulus set are shown in Figure 1.

Procedure

The faces were presented in a random order. Each face was presented once and then disappeared until the observer had answered all of the questions. For each face, the participants were required to complete four tasks, namely an aesthetic judgement task (ranging from 0 to 100), a symmetrical judgment task (ranging from 0 to 100), an emotional valence task (ranging from -100 to 100) and an emotional arousal task (ranging from 0 to 100), by moving the cursor of the mouse to the appropriate scale.

Results

The symmetry index was defined as the mean of the Pearson correlation coefficients of all pairs of vertical pixel vectors at an equal distance from the midline (Huang, 2019). A paired t-test revealed that the symmetry index was significantly larger for symmetrical than asymmetrical faces (99.81% ± 0.01% vs. 99.46% ± 0.02%, $t(227) = 20.82$, $p < .001$). We also estimated the amplitude spectrum slope, and a paired t-test showed that the slope for symmetrical faces was significantly larger than that for asymmetrical faces (1.05 ± 0.01 vs. 1.04 ± 0.01, $t(227) = 6.02$, $p < .001$). This indicated that our manipulation of the faces was valid.

The difference in rating scores for each pair of symmetrical and asymmetrical faces was calculated and used for further analysis. Reliability analysis was performed separately for the four tasks. Cronbach's alpha was 0.97 for the attractiveness task, 0.99 for the symmetry task, 0.77 for the valence task and 0.71 for the arousal task. All of the tasks showed good reliability.

A one-sample t-test was carried out to measure the differences in the mean attractiveness, symmetry, valence and arousal ratings. The results showed that the symmetrical faces were perceived to be more attractive than the asymmetrical faces (50.62 ± 1.37 > 41.51 ± 1.14, $t(27) = 7.10$, $p < 0.01$). The participants rated the symmetrical faces more symmetrical (70.74 ± 1.36) than the asymmetrical faces (40.23 ± 1.94, $t(27) = 15.39$, $p < 0.01$). The symmetrical faces had a higher emotional valence (8.54 ± 1.76 > 5.28 ± 1.65, $t(27) = 4.74$, $p < 0.01$) and the symmetrical faces elicited lower emotional arousal (31.28 ± 2.82 > 34.60 ± 3.03, $t(27) = -5.68$, $p < 0.01$). Therefore, in different tasks, the participants viewed the symmetrical and asymmetrical faces differently.

We calculated the Pearson correlation coefficients (based on differences between pairs of faces) between image statistics and tasks and found a significant Pearson correlation between beauty judgement and perceived symmetry ($r(226) = .43$, $p < .01$), valence ($r(226) = .26$, $p < .01$) and the symmetry index ($r(226) = .15$, $p < .05$). Perceived symmetry was significantly correlated with valence ($r(226) = .20$, $p < .01$) and the symmetry index ($r(226) = .28$, $p < .01$). We also found that the slope was not corrected with any of the rating tasks. Linear regression analysis showed that changes in perceived facial attractiveness could be estimated by perceived symmetry ($\beta = .39$, $p < .01$) and emotional valence ($\beta = .19$, $p = .003$).

Experiment 2

Methods

Participants

The participants were 13 males ($M = 20.08$, $SD = 2.36$) and 21 females ($M = 20.00$, $SD = 1.67$) with normal or corrected-to-normal vision. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and approved by the National Cheng Kung University Research Ethics Committee for Human Behavioral Sciences and the Department of Psychology, National Cheng Kung University.

Stimuli and Procedure

We used the 228 original faces described in experiment 1. The experimental procedure was the same as in experiment 1.

Results

The mean symmetry index was 99.28 ± 0.03% and the mean slope was 1.01 ± 0.01. Reliability analysis was performed separately for the four tasks. Cronbach's alpha ranged from 0.94 to 0.99. All of the tasks showed good reliability. The Pearson correlation coefficients between the image statistics and different tasks were calculated and the results are shown in Table 1.

Linear regression analysis showed that perceived facial attractiveness could be estimated by perceived

Table 1. **Correlation matrix ($N = 228$)**

	Attractiveness	Perceived symmetry	Valence	Arousal	Slope
perceived symmetry	.62**	-			
Valence	.72**	.31**	-		
Arousal	.36**	-.06	.55**	-	
Slope	.41**	.23**	.24**	.14*	
Symmetry index	-.04	.25**	-.01	-.10	.13*

* $p < .05$, ** $p < .01$

symmetry (β = .48, p < .01), emotional valence (β = .48, p = .003), slope (β = .20, p < .01) and the symmetry index (β = -.17, p < .01).

To understand the relationships between the variables, path analysis was conducted using AMOS 20. We treated the image statistics as the independent variables, perceived symmetry and perceived emotional valence as the mediators and perceived attractiveness as the dependent variable. The results and the values of the parameters are shown in Figure 2. The model suggested that perceived symmetry was modulated by the symmetry index and emotional valence. The slope also influenced emotional valence. Finally, attractiveness was modulated by the symmetry index, slope, perceived symmetry and emotional valence.

Discussion

This study investigated the relationships between the amplitude spectrum slope, the symmetry index, perceived symmetry and facial attractiveness. In experiment 1, we manipulated the degree of symmetry to investigate how symmetry influenced the image statistics, perceived symmetry and facial attractiveness. In experiment 2, we used the original faces to investigate how facial attractiveness was modulated by the image statistics and perceived symmetry. Below we discuss the relationships between the factors.

Slope and facial attractiveness

Experiment 2 showed that the amplitude spectrum slope was correlated with facial attractiveness (r = .41). The steeper the slope, the more attractive the face. However, in experiment 2, we also found that changes in the slope did not predict changes in facial attractiveness. We inferred that the amplitude spectrum slope anchors the degree of attractiveness, and that a small change in slope cannot modulate facial attractiveness.

Valence and facial attractiveness

In this study, we used faces with neutral facial expressions but asked the participants to evaluate their emotional valence and arousal. Our experimental results

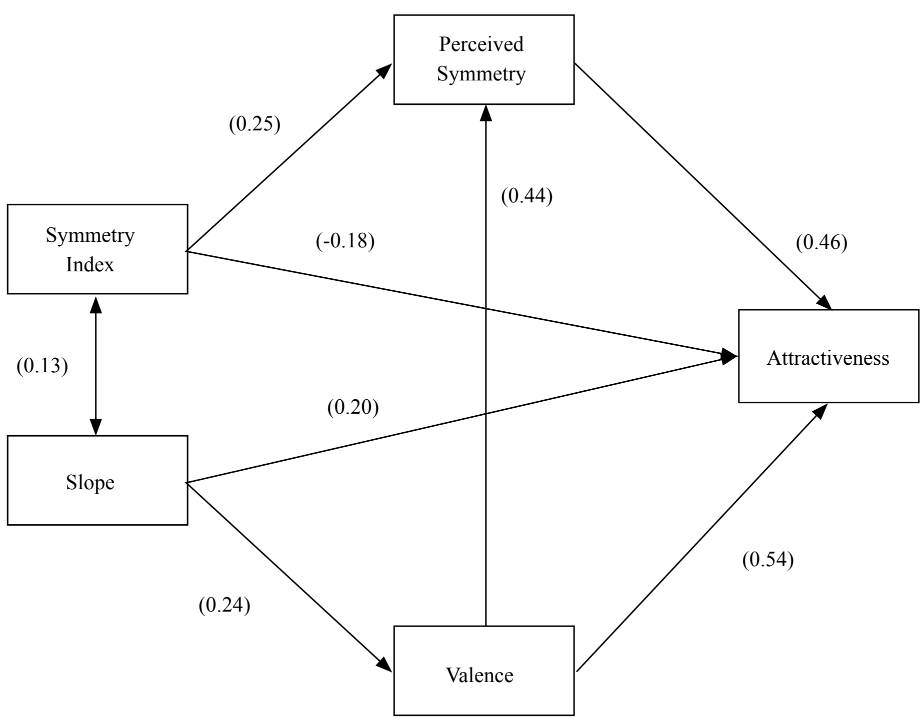

***Figure 2*. Results of the path analysis. The standardized regression parameters are shown in brackets.**

showed that our manipulation of symmetry changed the participants' evaluation of emotional valence and attractiveness. The results suggested that attractiveness and emotional valence may be processed by a similar mechanism. Oosterhof and Todorov (2008) argued that facial evaluation is based on two orthogonal dimensions: valence evaluation and trustworthiness evaluation. They used faces with neutral facial expressions and found that the participants tended to evaluate the faces with positive valence as having happy expressions. This tendency for overgeneralization may also explain the strong correlation between facial attractiveness and emotional valence, with both in the dimension of valence evaluation. Functional magnetic resonance imaging studies have also demonstrated overlaps between brain areas that process facial attractiveness and facial expression (Chatterjee, Thomas, Smith, & Aguirre, 2009; Fusar-Poli et al., 2009; Ishai, 2007; O'Doherty et al., 2003; Vuilleumier & Pourtois, 2007; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007). Therefore, the strong correlation between facial attractiveness and facial valence may have arisen because the two tasks are processed by the same brain areas.

Symmetry index, perceived symmetry and facial attractiveness

Our experimental results showed that changes in the symmetry index were correlated with changes in perceived symmetry (experiment 1) and the value of the symmetry index was correlated with perceived symmetry (experiment 2), suggesting that people may use point-by-point matching between the left and right parts of the face. The relatively low correlation coefficient (.25-.28) might be explained by the finding that perceived symmetry was processed using low spatial frequency information (Barlow & Reeves, 1979; Jenkins, 1982) instead of high spatial frequency information (point-by-point matching) when our symmetry index was calculated.

In experiment 2, the symmetry index was not correlated with facial attractiveness. This was not consistent with Huang's (2019) finding. The inconsistency was due to the choice of face stimuli. Huang (2019) used faces with hair, and hair styles and face contours were found to influence facial attractiveness. In addition, these faces broadened the range of the symmetry index. In our study, we eliminated the hair and contour information, narrowing the range of the symmetry index. Even with a narrow change of symmetry, our experimental results showed that changes in the symmetry index correlated with changes in facial attractiveness (Experiment 1), suggesting that the symmetry index can be used to predict facial attractiveness.

In the path analysis, the weight of the path from the symmetry index to facial attractiveness was negative, suggesting that if all factors are considered, a higher symmetry index indicates less attractiveness. This finding seems to contradict the results of the correlation analysis, but suggests that perceived symmetry is more important in determining facial attractiveness or that the relationship between facial attractiveness and the symmetry index is nonlinear.

Conclusion

The results of this study indicate that facial attractiveness can be predicted by image statistics (the symmetry index and slope) and perceived symmetry. We found that symmetrical faces had higher values for the symmetry index and slope, and were rated as more attractive, symmetrical and emotionally positive. We also conducted a path analysis to investigate how physical properties (symmetry index and slope) influenced the participants' attractiveness rating via perceived symmetry and emotion judgment. Our results suggested that the image statistics, perceived symmetry and emotional valence contributed to the perceived beauty of the faces. The results of the path analysis also provided a framework for studying facial attractiveness. Future research could further investigate the causal relationships between these factors.