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Asymmetry in Facial Expressions as a Function of Social Skills

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SUMMARY This study investigated the relationship between social skills and facial asymmetry in facial expressions. Three-dimensional facial landmark data of facial expressions (neutral, happy, and angry) were obtained from Japanese participants (n = 62). Following a facial expression task, each participant completed KiSS-18 (Kikuchi's Scale of Social Skills; Kikuchi, 2007). Using a generalized Procrustes analysis, faces and their mirror-reversed versions were represented as points on a hyperplane. The asymmetry of each individual face was defined as Euclidian distance between the face and its mirror reversed face on this plane. Subtraction of the asymmetry level of a neutral face of each individual from the asymmetry level of a target emotion face was defined as the index of "expression asymmetry" given by a particular emotion. Correlation coefficients of KiSS-18 scores and expression asymmetry scores were computed for both happy and angry expressions. Significant negative correlations between KiSS-18 scores and expression asymmetries were found for both expressions. Results indicate that the symmetry in facial expressions increases with higher level of social skills.

key words: *facial expression, facial asymmetry, social skills, landmark-based 3D shape analysis*

1. Introduction

Facial expressions provide various signals for social interactions. Human faces and facial expressions are somewhat symmetrical as documented in numerous studies on facial bilateral symmetry, namely the symmetry reflected by the degree to which one half of a face is similar to the other half. At the same time, these studies also reveal facial asymmetries especially when creating emotional expressions [1]. In this study, we focused on facial expression asymmetry.

Facial asymmetry derives from two sources: structural asymmetry and movement asymmetry [2]. Structural asymmetry reflects physical differences in the laterality of facial structure, whereas movement asymmetry derives from lateralized facial muscle movement during facial expressions. Thus, asymmetries in facial expression are attributed not only to asymmetrical facial structure but also to asymmetrical facial movement.

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The primary source of facial movement asymmetry is brain lateralization in emotion processing. Several studies have shown that emotions are expressed more intensely in the left hemiface [3], [4]. The dominance of the left hemiface in facial expressions has been interpreted as supporting the hypothesis of brain lateralization of emotional processing [5], [6], i.e., right hemispheric dominance for emotion, because most facial muscles, particularly those in the lower part of the face, are innervated by the contralateral hemisphere [7]. More recent studies have asserted that both hemispheres process emotion, but each hemisphere is specialized for particular types of emotion [8] such as positive-negative emotion [9], [10], or approach-withdrawal [11].

Although laterality characterizes most facial expressions, human face perception is primarily influenced by the facial information contained in only one hemiface, the right hemiface [12]–[15]. When asked to judge the facial expression of a briefly presented chimeric face image, perceivers tend to base their decision more frequently on the expression associated with the right side of the face, i.e., the left hemiface from a viewer's perspective. In this respect, lateralization in facial expressions can lead to failure in conveying the face's real emotions to an observer.

The role of asymmetry of facial expressions in social interactions remains unclear. However, it is possible that asymmetries in facial expression are important factors in social interactions. For instance, facial asymmetry has been proposed as a signal of developmental stability that can indicate mate quality [16]–[18]. And, generally, the less asymmetric a face is, the more attractive it appears [16], [19]. This asymmetry is believed to reflect past developmental stresses and to be related to the likely quality of the individual as a potential mating partner [20]. If preference for facial symmetry extends to the preference for facial expression, creating symmetrical facial expression can be an adaptive behavior in social interactions. Practically speaking, it is difficult to examine the roles of symmetric facial expressions during actual social interactions. Therefore, we chose to investigate the extent to which social skills relate to facial asymmetry in emotional expressions. Social skills are generally defined as the set of skills that enable a person to interact and communicate with others in verbal and nonverbal forms of communication. For example, they entail the ability to effectively apologize or to cope with another's anger and so on. If higher social skills are related to more symmetrical facial expressions, then an individual's acquisition of social skills may entail learning to display symmetrical facial expressions as an effective means of communicating one's emotions in social settings.

As we mentioned, the degree of facial asymmetry in creating emotional expressions depends not only on the level of structural asymmetry but also on movement asymmetry. In order to investigate the effect of social skill level on symmetry in facial expressions, the effect of structural asymmetry on facial expression asymmetry should be excluded. In this study, we defined "expression asymmetry" of each individual face as the difference between the asymmetry level of the neutral face and the asymmetry level of a target emotional face.

In measuring facial asymmetry, the majority of studies have focused upon facial landmarks using a few critical landmarks (e.g., eye pupils) as anchoring points to align the faces for determining a midline (e.g., [16]). Thus, pupils were aligned horizontally in order to create the horizontal axis, then facial asymmetry was calculated either by summing the distances from all facial landmarks to the midline, which is orthogonal to the horizontal axis [21]–[23], or by summing the differences in horizontal locations between all midpoints of all paired feature points [16], [24]. One problem with this procedure is that aligning anchoring points results in increasing the variance of facial elements located at a distance from these anchoring points. Thus, the farther a facial element is from anchoring points, the stronger its impact will be on some measures of symmetry. Another problem with these conventional procedures is that planar differences between hemifaces describe only asymmetries in horizontal axis. However, locations of facial landmarks vary not only along horizontal but also in the vertical and depth axes. Thus such techniques cannot appropriately evaluate 3D facial asymmetry.

The present study aims at solving these difficulties by using a generalized Procrustes method [25]–[27]. This methodology does not necessitate specific anchoring points for standardization of faces. Through a generalized Procrustes analysis, landmark coordinates of faces and their mirror reversed versions are each represented as multidimensional normally distributed values that can be statistically analyzed.

We defined asymmetry of each individual face as the Euclidean distance between the face and its mirror reversed face. The measure of facial asymmetry is based on our previous study [28] in which photographed facial shapes were examined using two dimensional coordinates. The present study extended this measure to assessment of three-dimensional facial shapes.

2. Method

2.1 Facial Expression Task

Japanese undergraduate and graduate students (n = 62: 20 men and 42 women; age: 19 to 26 years, mean age = 21.3, SD = 1.37) provided three-dimensional facial shape data of neutral, happy, and angry expressions. Three-dimensional (3D) shapes and textures of facial expressions of each face were captured using a 3D picture measurement device (TRiDY-S: JFE Techno-Research Corp.) based on pattern-projection method. It took approximately two seconds for each facial scanning.

First, the participants were instructed to show and maintain a neutral facial expression. Then, they were asked to recall experiences in which they had felt the target emotions (happy or angry). Each facial expression trial began with a 30 second baseline period in which the participant was not instructed which emotional experience the participant would be asked to recall. Subsequently, participants recalled the experiences following a cue of "Recall <target emotion word> experience," and the facial expression was captured several seconds after the cue. If the scanning failed because the expression changed drastically during the two second scanning, the scanning was retried. After each 3D image was taken, the participants were instructed to describe the experience.

2.2 Assessment of Participants' Social Skill

After the facial expression task, each participant completed KiSS-18 (Kikuchi's Scale of Social Skills [29]), an 18-item self-report measurement of social skills in which higher scores indicate higher level of social skills. The possible range of the scale is 18 to 90. The mean score is reported as 56.40 (n = 83, SD = 9.64) for male undergraduates and as 58.35 (n = 121, SD = 9.02) for female undergraduates. This scale is based on six categories of social skills proposed by Goldstein [30]; basic skills, advanced skills, emotional management skills, stress management skills, offence management skills and planning skills. Basic skills include 'talking with others', 'maintaining a conversation' and 'introducing oneself'. Advanced skills include 'asking for help', 'giving instructions', 'obeying instructions', 'apologizing' and 'persuading'. Emotional management skills include 'managing fear', 'emotional expression' and 'managing others' anger'. Stress management skills include 'managing criticism' and 'managing a contradiction in message'. Offence management skills include 'helping others', 'conflict resolution' and 'managing trouble'. Planning skills include 'staying on target' and 'taking initiative'. The scale has demonstrated high reliability and validity in previous studies [29].

2.3 Facial Shape Measurement

Thirty-six facial landmarks were selected on the basis of our previous study [31] (Fig. 1, Table 1). All 3D coordinates of the landmarks were visually measured using a computer program (Rapid Form 2004: INUS Technology) by referring to each of the 3D shape data and texture.

2.4 Facial Shape Standardization

Each facial representation differed in location, size, and ori-

Fig. 1 Landmark locations. Photographs were formed by warping average facial texture.

Table 1 Set of 36 facial landmarks.

No.	Location
1	hairline
2	forehead
3	forehead
4	outer corner of eyebrow
5	upper point of maximum width of eyebrow
6	lower point of maximum width of eyebrow
7	innner corner of eyebrow
8	innner corner of eyebrow
9	upper point of maximum width of eyebrow
10	lower point of maximum width of eyebrow
11	outer corner of eyebrow
12	root of nose
13	side of root of nose
14	side of root of nose
15	lateral angle of eye
16	center of upper eyelid
17	center of lower eyelid
18	medial angle of eye
19	medial angle of eye
20	center of upper eyelid
21	center of lower eyelid
22	lateral angle of eye
23	zygomatic
24	zygomatic
25	apex of nose
26	ala of nose
27	ala of nose
28	subnasal point
29	angle of mouth
30	upper lip (philtrum edge)
31	central upper lip
32	upper lip (philtrum edge)
33	angle of mouth
34	stomion
35	bottom of lower lip
36	chin

entation. To standardize these stimuli, we performed a Generalized Procrustes Analysis (GPA) on the facial landmarks of all faces irrespective of the gender of the face. A GPA is an analytical method used for multivariate statistical analysis of landmark locations expressed in Cartesian coordinates. This method preserves information about the relative spatial relationships of landmarks throughout the standardization, and that has recently been applied to psychological research on human faces [28], [32].

For standardization of location and size, we used the centroid size technique [25]. All facial shapes were translated into the same origin (centroid) and scaled to the unit centroid size, which is the sum of the squared distances from the centroid to each landmark. After size normalization, shapes have the same centroid size. Thus, every facial shape is shown as a point on a hyper-sphere with a radius of 1.0. For alignment of orientation, rotations around the centroid of the faces were performed [26] such that the sum of the squared distances among corresponding landmarks between samples was minimized in order to align the faces. After rotation, each facial shape is still represented as a point on a hyper-sphere. The projections of the points on a tangent plane at a reference point are used for shape analysis based on linear mathematics [26].

Using the GPA, each facial shape was represented as a point on a linear tangent hyperplane, which allowed us to treat the faces as multidimensional, normally distributed values.

The "Shapes" statistical package of Dryden and Mardia [26], which runs in an R statistical analysis environment, was employed for these analyses. In addition to the coordinates of 62 facial shapes, the mirror-reversed versions of the same faces were used in the facial shape analysis.

3. Results

3.1 Social Skill Score

The mean of KiSS-18 score was 59.47 (SD = 8.65). Previous studies have reported that males and females differ in facial shape [33] and facial muscle reactivity [34]. If males and females differed in social skills, the gender differences in social skills could be a potential confounding factor in the analysis of the relationships between social skills and facial expressions. However, the KiSS-18 scores were not significantly different between males and females ($t(60) = -.57$, $p = .57$, $r = .07$).

3.2 Facial Asymmetry

Through a generalized Procrustes method, each of the facial shapes and their mirror-reversed versions were represented as points on the tangent hyperplane. We defined asymmetry of each facial shape as the Euclidean distance between the face and its mirror-reversed face on the hyperplane (Fig. 2), based on our previous study [31]. Furthermore, all original faces and their mirror-reversed faces were combined to

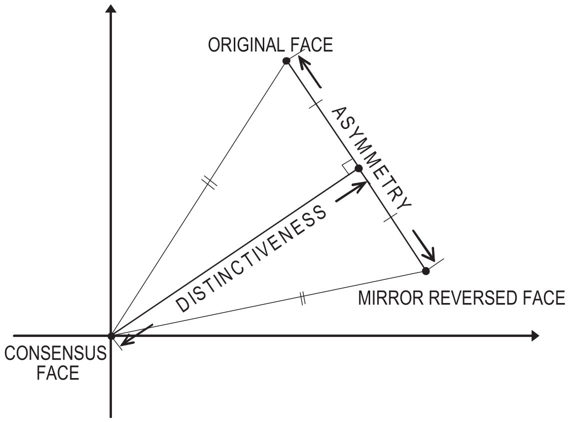

Fig. 2 Schematic illustration of asymmetry. Each facial shape and its mirror-reversed version is represented as a point on the tangent hyperplane. Only two axes are represented for ease of illustration. The "consensus face" is the origin of the space. Asymmetry is defined as the Euclidean distance from each original version to the mirror-reversed version.

(a) (b)

Fig. 3 The face shapes for (a) the most symmetric face and (b) the most asymmetric face among the samples. The photographs were made by warping average facial texture.

create a consensus face. This was the average of all facial shapes and represented the origin of the tangent hyperplane. The distance from a given original face to the origin was the same as that from its mirror image to the origin. This distance can be regarded as an index of facial distinctiveness (the converse of facial averageness). Therefore, asymmetry and distinctiveness are measured independently with this procedure; in other words, facial variations can be separated into distinctiveness and asymmetry categories.

The mean morphological asymmetry in each facial expression is shown in Fig. 4. To examine the relationship between facial expressions (neutral, happy, and angry) and facial asymmetry levels, we conducted repeated measures ANOVA with facial asymmetry levels as the dependent variable. There was no significant effect of facial expression on the facial asymmetry levels ($F(2, 122) = .34$, $p = .72$, $\eta^2 = .005$).

The facial shapes of the most symmetric and asymmetric faces among the participants are shown in Fig. 3. Illustrations were created by warping individual facial surface profile data and surface texture data (RGB values for each boxel of the surface) onto the most symmetric and asymmetric facial shapes and then averaging the grey level values in

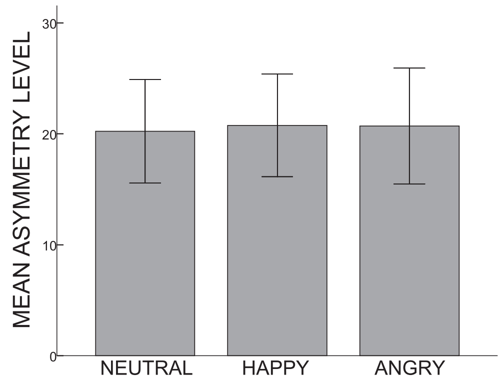

Fig. 4 Mean facial asymmetry level. Error bars represent 1 S.D.

corresponding regions of the faces. For the warping, Thin Plate Spline (TPS) technique [25] was used. This is a kind of nonlinear image deformation technique. The process of using TPS in image warping involves minimizing a bending energy function for a transformation over a set of given landmark points. The interpolated value at a point (x, y, z) is given by

$$f(x, y, z) = a_1 + a_x x + a_y y + a_z z + \sum_{i=1}^{n} w_i U(|P_i - (x, y, z)|)$$

where the kernel function $U(r) = |r|$.

3.3 Local Asymmetry

To investigate the degree of asymmetry in each local region of a face, such as eyebrows, eyes, and mouth, three facial subspaces were identified. These were constructed from the standardized landmark coordinates of eyebrows (from No.4 to No.12 of Table 1), eyes (from No.15 to No.22), and mouth (from No.29 to No.34). Local asymmetry within each such region of a face was defined as the Euclidian distance from the original version to the mirror-reversed version of each part in each subspace.

Local asymmetries were calculated for eyebrows, eyes, and mouth (Fig. 5). A repeated measures ANOVA was performed for each facial part, and a significant effect of facial expressions on the asymmetry in mouth shape was found ($F(2, 122) = 4.10$, $p = .019$, $\eta^2 = .06$). Bonferroni posttests among expressions demonstrated that the mouth shape was more asymmetrical in happy expression than in neutral face ($p = .02$). However, there was no effect of facial expressions on the asymmetries in eyebrows or eyes (eyebrows: $F(2, 122) = .28$, $p = .76$, $\eta^2 = .005$; eyes: $F(2, 122) = .16$, $p = .21$, $\eta^2 = .03$).

3.4 Relationship between Social Skills and Facial Expression Asymmetry

Because no significant correlation obtained between the KiSS-18 scores and facial asymmetry levels of neutral expression ($r = .20$, $p = .13$), structural asymmetry of faces

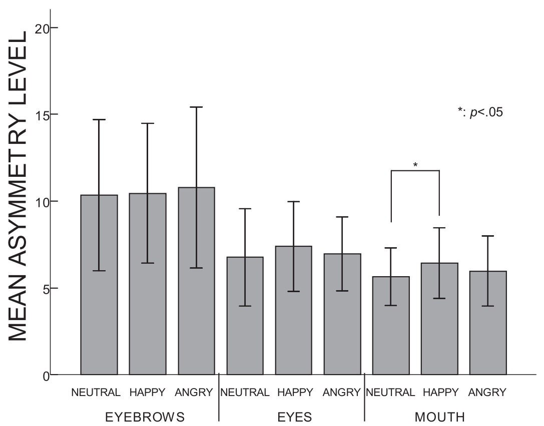

Fig. 5 Mean facial asymmetry levels of facial parts. Error bars represent 1 S.D.

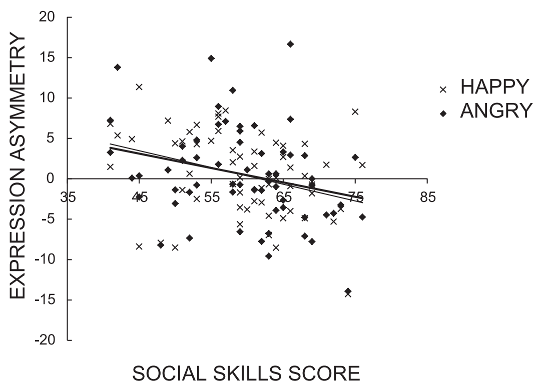

Fig. 6 Relationship between social skill score and degree of facial expression asymmetry.

may be assumed to be unrelated to social skills. Thus, the subtraction of the asymmetry level of the neutral version of an individual's face from the asymmetry level of a target emotional face was used to index of facial expression asymmetry, i.e., asymmetry that derives from facial expression. Here we refer to the value as the "expression asymmetry score." (happy: mean = .54, SD = 5.14; angry: mean = .47, SD = 5.95).

To assess whether higher social skills are linked to facial expression asymmetry, correlation coefficients of the KiSS-18 scores and expression asymmetry scores were computed for both happy and angry expressions. Figure 6 shows the relationship between social skills and expression asymmetries. There was a significant negative correlation between the KiSS-18 scores and expression asymmetries for both expressions (happiness: $r = -.30$, $p = .017$; angry: $r = -.30$, $p = .018$), indicating that the higher a participant scored on the social skills test, the more symmetric their facial expressions were.

The partial correlation coefficients between social skills and expression asymmetries, using gender of the participants as control variables, were also significant for both expressions (happiness: $r = -.30$, $p = .015$; angry: $r = -.30$, $p = .017$). This suggests that the relationship between facial expression asymmetry and social skills was not caused by the gender differences in social skills.

The correlation coefficient of the KiSS-18 score and expression asymmetry in each facial region was also calculated for each target emotion. For a happy expression, expression asymmetry of none of the parts was significantly correlated with social skills (eyebrows: $r = -.16$, $p = .21$; eyes: $r = -.13$, $p = .33$; mouth: $r = -.02$, $p = .89$). On the other hand, for an angry expression, expression asymmetry of mouth was found to be negatively correlated with social skills (eyebrows: $r = .03$, $p = .82$; eyes: $r = -.17$, $p = .19$; mouth: $r = -.26$, $p = .04$).

4. Discussion

In summary, forming symmetrical facial shape in expressing emotion is linked to high social skills both in happy and angry expressions. On the other hand, structural facial asymmetry, i.e., the laterality of facial structure, is not linked to social skills. This study provides evidence that symmetry in facial expression plays a role in our interactions with others. A possible explanation for the connection between social skills and facial laterality in emotional expression is that symmetrical facial expression brought about by high social skills contributes to a precise conveyance of face owner's emotions to interlocutors. If there is difference between right and left hemiface, either in kind of expressed emotion, or in the strength of facial expression, the expression can be an inconsistent signal for the receivers.

Moreover, the relationship between social skills and symmetry may be due to differences in facial shape between spontaneous and posed (voluntary) expressions. Some studies have shown that a spontaneous smile is symmetrical, but a posed smile is asymmetrical [35], [36], suggesting a possibility that symmetrical facial expression is recognized as spontaneous facial expression derived from the facial owner's emotion. In fact, Ozono et al. [37] reported that Japanese participants rated faces with greater smile symmetry as more trustworthy. Thus, the results of this study may reflect the connection between symmetrical facial expressions and skills for signaling trustworthiness. In the future, it is important to investigate the relationship between perceived personality traits of an individual and the individual's facial symmetry.

The relationship between local expression symmetry and social skills is observed particularly in lower face region. Neurologically, movements of the lower face region follow voluntary muscle control, while upper face area movements are under automatic control [35], [38]. A possible explanation for the facial region specificity of the effect of social skills is that social skills are more strongly linked to voluntary muscle control than automatic control. However, the relationship between expressional asymmetry of mouth and social skills was observed only in angry expression. The result seems not to be consistent with previous studies which have shown the connection between anger expression and upper facial parts [39]–[41]. In order to interpret this result, the effect of asymmetries in facial parts on the impressions of the face owner should be investigated in future studies.

In this study, the methodologies of geometric morphometrics were applied to the three-dimensional landmark coordinates of faces in order to assess degree of facial asymmetry quantitatively. Most previous studies on facial asymmetry have used two-dimensional photographs in which participants' facial frontal views were used. However, it is not easy to give a strict definition of "looking straight ahead" in reference to faces in photographs. Moreover we cannot rule out the possibility that the actual looking direction varies somewhat across participants even if "frontal view" has been appropriately defined. On the other hand, the procedure of this study is not based on this type of definition because three dimensional landmark coordinates were used. Furthermore, unlike conventional methods used to investigate facial asymmetry, the procedure used in this study does not necessitate anchoring landmarks for defining facial midline or midplane when evaluating facial asymmetry. This is because the degree of asymmetry of each face was defined as a disparity between the original face and the mirror-reversed version in this study. The results of the study suggest that the asymmetry quantification method of this study is an effective method for evaluating 3D facial asymmetry.

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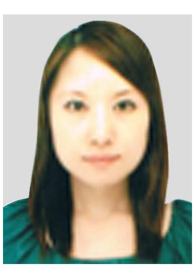

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