Chiang Mai Dental Journal

Review Article

The Important Facial Components for Facial Approximation: A Review of the Literature

Sumon Thitiorul[1,2], Pagorn Navic[3], Srijit Das[4], Pasuk Mahakkanukrauh[3,5]

[1]PhD's Degree Program in Forensic Osteology, Faculty of Medicine, Chiang Mai University, Thailand.
[2]Department of Preclinical Sciences (Anatomy), Faculty of Medicine, Thammasat University, Thailand.
[3]Department of Anatomy, Faculty of Medicine, Chiang Mai University, Thailand.
[4]Department of Human and Clinical Anatomy, College of Medicine and Health Sciences, Sultan Qaboos University, Sultanate of Oman.
[5]Excellence in Osteology Research and Training Center (ORTC), Chiang Mai University, Thailand.

Received: April 11, 2021 • Revised: May 12, 2021 • Accepted: May 27, 2021

*Corresponding Author: **Pasuk Mahakkanukrauh** Professor, Research Cluster in Osteology Research and Training Center (ORTC), Chiang Mai University, Chiang Mai 50200, Thailand. (E-mail: **pasuk034@gmail.com**)*

Abstract

One main tool that humans use to communicate with each other is the face. It is also used to verify personal identity. During social interaction, people learn the way to use their eye contact. The ways they use their eyes vary in each culture. The processes of facial encoding and recognition develop during they gaze their eyes on the colloquist's face. The whole face, outer face, inner face, eyes, nose, and mouth were used in these processes. This article informs the facial components that impacts for facial recognition, and thereafter are the components that are required to pay attention to facial approximation. Current studies on facial recognition using the whole face and separated facial components as well as accuracy tests on some approximated faces contributed using computer 3-D were reviewed. The data suggested that the facial components that used in recognition process develops from using the whole face, outer face, inner face, mouth, eyes, and nose, respectively. During communication, people fixed their eyes on the inner face more that the outer face, especially the nose. The facial component that still have error more than 5 mm in current 3-D facial approximations are the nose, eyes, chin, mouth corner and zygoma. However, some studies suggested that only 2-3 mm change in size of the nose, eye, and lips could impact the facial perception. Therefore, these components would require new prediction models to improve the accuracy of the facial approximation.

Keywords: facial approximation, facial component, facial recognition, face, forensic medicine

Critical facial components

Face is the structure that humans use in communication and to verify personal identity. Several studies have been conducted to reveal the facial components that humans use to signify the face. Many studies[(1-10)], based on eye-tracking examination, suggested that the way people use their eye gazing at colloquist's face vary in different cultures. In other words, people learn the way to use their eye contact with others during social interaction in their culture. It is known that most whites Caucasians prefer eye-to-eye contact while talking with each other to express trust and sincerity, whereas most east Asians avoid sustained eye-to-eye contact as it can be considered impolite. This hypothesis was proved by eye-tracking studies when participants were asked to remember and recognize faces.[(1,2)] White western participants predominantly fixated their eyes on the eye region, and partially the mouth, whereas east Asian participants consistently fixated on the nose region, irrespective of the race of the target face. Kelly *et al.*[(3)] studied on children (7–12 years old) from western and eastern cultures also reported similar eye movement strategies as adults from their relevant culture. They conclude that these cultural influences begin as early as in childhood. Different eye strategies between black and white participants when they looked at black and white faces were reported in Hills and Pake's study.(7) Black participants preferably fixated their eyes on the mouth and cheeks, whereas white participants preferably fixated on the eyes and hair of the target faces, irrespective of the observed face race. The first three fixation points used in black participants were the dorsum of the nose, ala, and medial canthus, whereas those in white participants were the bridge of the nose (between the eyes region), the right and left pupils.

Although previous studies reported differences in eye strategies on different race-face, Tan *et al.*(6) reported dissimilar results in Malaysian Chinese participants. Malaysian Chinese people are in a multicultural environment. They are mostly influenced by western culture and less familiar with African people. When participants from Malaysian Chinese were asked to learn and recognize east Asian, white and African faces, they use the same visual strategies regardless of the observed face-race. The eyes and nose were frequently fixated more than the mouth. This is the mixed pattern of eastern and western visual strategies. The recognition accuracies for east Asian and white western faces were more than that for African faces. Using the eyes and nose strategies in Malaysian Chinese participants showed the learning experience of these participants to use the effective components for the faces of east Asian and white that they are familiar with. Low recognition accuracy for African faces could be due to the lower face area (mouth and cheeks), which is the effective area for the African faces, was not used in these participants.

Another interesting study mimics the visual mechanism of learning and recognizing faces in real life was conducted by Tan *et al.*(9) They examined recognition sensitivity and eye movement strategies of Malaysian Chinese participants on dynamic faces of African, east Asian, and white actors; in which the actors were managed to introduced themselves while were taking muted video records of them. The race and age of the actors have no impact on the participants' recognition abilities. Different eye movement strategies were used during learning phase and recognition phase. During the learning phase, they fixated on the mouth and nose more than the eyes. In the recognition phase, they fixated mainly on the nose, followed by the mouth then the eyes. The authors assumed that the advantage in using the nose as the fixation object is that that the whole face can be processed at a time since the nose is located at the center of the face. But recognition assessment using dynamic facial information has confounding factors in that participants may use some habits or facial movements of the target faces to assist their recognition ability instead of using only facial components. However, this study gives useful information about eye strategies in the learning phase and recognition phase on dynamic faces.

Another eye-tracking study(10) was employed on 6-12 years old UK children. Eye strategy using in self-, familiar- and unfamiliar faces were compared. The results indicated that in self- and familiar faces, the fixation counts for the nose were more than that for the mouth and eyes. But in unfamiliar faces, the fixation counts for the eyes were more than that for the nose and mouth. Again, the participants frequently fixated on the internal components (nose, eyes and mouth) more than the external components (the forehead and hair region, chin, cheek and ears region). The fixation times for the eyes were more than that for the nose and mouth, respectively. Different eye strategies were also reported when own- and other-race faces were used to test 6- to 10- month old white infants.(4) The infants used similar strategies when looked at dynamic displayed of their own-and other-race faces, but they spent more time at the eyes and less time at the mouth of own-race faces.

Although the above-mentioned studies reported that participants used the same eye movement strategies when they look at the target faces, irrespective of the face race; Fu *et al.*(5) reported differently. They stated that Chinese participants; who have no direct contact with white foreigners, predominantly fixated on the nose and mouth of their own-race faces more than the eyes and mouth. But they use different visual strategies when looking at other race faces by spending more time on the eyes more than the nose and mouth. The time they spent on the mouth of the other- and own-race faces were not different. Moreover, even the participants became more familiar with the target faces of both races; these visual strategies were not changed. This study gave some interesting details on the fixation points. They reported that the eye region that

Chinese participants used to observe in white faces was predominantly at the pupil, whereas that in Chinese faces was the region right below the eyes; this information supported the influence of culture that Asian people avoid sustained eye-to-eye contact during social interactions. Moreover, the details of specific regions of the nose and mouth being focused on their participants were reported. In white faces, those regions were the nasal tip, the columella, the philtrum and the center of the lips, whereas those in Asian faces were the regions just below the nasal bridge, the columella, the philtrum and the center of the lips. A study on other-race face effects on eye strategies in Chinese children (4-7 years old) and Chinese adults, who have no direct contact with foreigners (whites) has been conducted by Hu *et al.*[8] They reported the same results as Fu *et al.*[5] except that differences when looking at the other-race faces were more pronounced in adult participants. From these studies, though there is diversity in eye-fixation strategies, their results informed that humans, from childhood to adulthood, use internal components of the face (eye, nose, mouth) to achieve facial recognition. However, different eye-fixation strategies were reported when isolated facial components were used instead of a whole face. Liu *et al.*[11] test the recognition ability of the whole face and isolated facial components in 8-9 years old children, 13-14 years old children and 18-26 years old adults of Han Chinese. Participants were trained with whole faces and received a recognition test for the whole face, outer face (facial outline and hair), inner face (eye, nose, and mouth), and isolated facial components (eyes or nose or mouth). Children were able to recognize only the whole faces, outer faces and inner faces, whereas adults were able to recognize all components above chance, except for the nose. In the second experiment of their study, participants were trained with isolated facial components (eye, nose, or mouth). All participants could recognize the eyes and mouths above chance. The eyes were recognized with higher score than the mouth in children. But the mouths were recognized with higher score than the eyes in adults. The nose was the component that could separately recognized with the lowest score even in trained adults, that the younger children could not recognize it above chance. This study represented the developmental process in facial recognition, which were started using the whole face, outer face, inner face, mouth, eyes, and nose, respectively.

To sum up, the easiest way to recognize people face is to use the whole face. The next facial components are the outer face, inner face, mouth, eyes and nose.[11] In contrast, the fixation points that people use while looking at a face were at the inner face, rather than the outer face.[1-10] Participants from different races/cultures use different facial components while learning and recognizing faces. The components that are frequently being fixated are the nasal bridge, pronasale (nasal tip), nasal drop and subnasale (columella), ala, mid-philtrum, labial superius, stomion, labial inferius, medial canthus, pupil, and the region right below the eye.

Accuracy test in three dimensional (3-D) facial approximation

According to Wilkinson[12], facial approximation is the scientific art of building a face onto a skull. This method is used to assisted in forensic cases when matching between the post-mortem and ante-mortem data from common identification methods such as fingerprint, teeth and DNA is not available, especially in decomposition body. The approximated face is made in order to elicit someone familiar with the face to suggest a possible identity for the deceased.

Advancement in current technology offer applications of facial approximation in 3-D computerized technique. Thereafter, direct comparisons between the approximated and the relevant actual faces can be applied using a superimposition technique, which is called as morphometric comparison or geometric surface comparison. The results were the amount of differences between the two faces and also the regions of the approximated face that were more or less prominent than the actual face.

Lee *et al.*[13] applied an accuracy test on three approximations from three Korean subjects. They used soft tissue thickness data from Korean residents who lived in Russia and prediction guidelines for facial components based on white or black subjects. They reported that the percentage of the facial surface that had differences within ±2.5 mm was 54% to 77%. The areas of the largest error (more or less than 4 mm) were different in each subject. In subject one; those areas were small parts of the lateral foreheads, a small part of the nose and the majority of both cheeks. In subject two; those were small parts of lateral forehead, both endocanthi, a small part of both cheeks. In subject three; those were some part of temple, both endocanthi and some part of upper eyelid.

These authors repeat their study three years later.[14] Three facial approximations from newly three Korean subjects were tested. They used the same prediction guidelines for facial components, but this time new soft tissue thickness data based on contemporary Korean subjects who lived in Korea was used and the researchers have more experience on facial approximation. They reported the improvement in the percentage of the facial surface that had differences within ±2.5 mm (80% to 88%). The areas of the largest error (more or less than 4 mm) were different from the previous study. In subject one; those areas were the nasal tip, the mouth corner, both lateral foreheads and a small part of the cheek. In subject two; those were the nasal tip, the lower cheek and small parts of lateral forehead. In subject three; those were the nasal tip, the mouth corner and some part of temple. It should be noted that the nasal tip was overestimated in all three subjects in the latter study. Moreover, the distance between the eyes in both studies was too close in all subjects.

Short *et al.*[15] applied an accuracy test on ten approximations from white subjects who had skeletal discrepancies (skeletal class II and III). They reported that the percentage of the facial surface that had differences within ±2.5 mm was 56% to 90%. The areas of the largest error (more or less than 5 mm) were around the nose, especially the nasal tip, cheek and zygoma region. The nose and mouth were consistently larger in the approximations than the actual faces.

Another comparison test was performed by Miranda *et al.*[16] using four white subjects. The percentage of the facial surface that had differences within ±2.5 mm was 56% to 90%. The areas of the largest error (more or less than 5 mm) were some parts of the nose and chin region. The cheek and the eyes were underestimated, whereas the chin and zygoma were overestimated in all cases.

In conclusion, the areas of the face that usually have error more than 4 mm in facial approximation are the nose, eyes, chin, mouth corner and zygoma. To avoid discrepancies in the gravitational effect on the face, only the studies that used soft tissue thickness data from subjects in the same position as the tested subjects were reviewed. However, the number of subjects in each study was small (three to ten subjects). Therefore, their results may not strongly represent the accuracy of the 3-D facial approximation.

Amount of difference that have practical impact

It is important to know how much of the differences between an approximated and actual faces have an impact on facial recognition. Until now, this magnitude of error remains unknown. Usually, researchers in facial approximation[13-18] recorded magnitude of errors using the percentage of facial area that has less than 2.5mm and more than 5 mm error or using 5% and 10% error from the actual face in their studies. Lewandowski[19] established a perception test on an averaged female face; the face that was created from thirty Polish female faces in a software and was used as a reference face. The size, height and width of the eyes, nose and mouth of this face were modified by reduction or enlargement every 2% until the modification extended to 20%. The observers' tasks were to judge the similarity and dissimilarity between the modification and the reference faces. The results indicated that changes in size and height of the nose mostly affect the perception of the similarity between the modified and original faces. The observers could tell the differences in the reduction modifications quicker than the enlargement modification. Tables 1 and 2 show the percentage of modification that the observers judged the dissimilarity between the two faces. This study reported no details on the size of the facial components. Therefore, to demonstrate more clearly, the size of facial components ('Mean size' in Tables 1 and 2) assessed in Polish females from Farkas *et al.*[20] were used to estimate the average size of the modification ('Difference' in Tables 1 and 2) that would affect the similarity of the face. The measurement in Italian females from Sforsa *et al.*[21] was used where the facial component was not available in study from Farkas *et al.*[20]

From Tables 1 and 2, only about 2-3 mm reduction in nasal height or approximately 3-4 mm enlargement in nasal height could affect the likeness of the reference face. For the eye, only 3 mm in eye width reduction could affect the likeness. Although the modification in lip height could reach up to 16-20% to be indicated as dissimilarity, the average lip height is only 15.2 mm. Therefore, approximately 2-3 mm change in lip height could affect the likeness of the reference face. It should be noted that this study[19] used 2-D images in the frontal view. The craniometrics from Farkas *et al.*[20] and Sforsa *et al.*[21] that applied in Tables 1 and 2 might not represent the true

Table 1: Facial component modification: perception from female observers. (Modified from Lewandowski Z. The influence of changes in size and proportion of selected facial features (eyes, nose, mouth) on assessment of similarity between female faces. *Coll Antropol* 2015; 39: 675-684.[19]).

	Aspect	Reduction	Mean Size (mm)	Difference (mm)	Enlargement	Mean Size (mm)	Difference (mm)
Nose	size	2%			4%		
Nose	height	4%	51.2	2.0	8%	51.2	4.1
Eyes	height	6%			20%		
Eyes	size	8%			12%		
Lips	size	10%			12%		
Eyes	width	10%	32.8	3.3	18%	32.8	5.9
Nose	width	14%	32.6	4.6	8%	32.6	2.6
Lips	width	14%	49.0	6.9	12%	49.0	5.9
Lips	height	16%	15.2*	2.4*	20%	15.2*	3.0*

* *mean size of the facial component from Sforsa et al.*[21]*, the others from Farkas et al.*[20]

Table 2: Facial component modification: perception from male observers. (Modified from Lewandowski Z. The influence of changes in size and proportion of selected facial features (eyes, nose, mouth) on assessment of similarity between female faces. *Coll Antropol* 2015; 39: 675-684.[19]).

	Aspect	Reduction	Mean Size (mm)	Difference (mm)	Enlargement	Mean Size (mm)	Difference (mm)
Nose	size	4%			6%		
Nose	height	6%	51.21	3.1	6%	51.2	3.1
Eyes	height	6%			12%		
Eyes	size	8%			10%		
Lips	size	8%			20%		
Eyes	width	10%	32.8	3.3	10%	32.8	3.3
Nose	width	10%	32.6	3.3	20%	32.6	6.5
Lips	width	12%	49.0	5.9	10%	49.0	4.9
Lips	height	20%	15.2*	3.0*	20%	15.2*	3.0*

* *mean size of the facial component from Sforsa et al.*[21]*, the others from Farkas et al.*[20]

value of the adjusted length of the facial components in Lewandowski study.[19]

Conclusions

Learning of faces and recognition of faces are the processes that develop from childhood to adulthood. There is diversity in eye movement strategies in different observer-races. Many studies suggested an avoiding of eye-to-eye contact in Asian participants that resulted in the tendency of using nose and mouth fixation instead of using nose and eye fixation in European participants.[1-10] The familiarity of observers to the target race-face might be one factor that influences the eye strategies because they familiar with the typical features of specific race-face. The developmental process in facial recognition was achieved from a whole face to the outer face, inner face, mouth, eyes and nose, respectively.[11] It could be that the outer face is easier to remember than the inner face (eyes, nose and mouth) which were smaller and have more details that children may not able to notice at their age. In contrast, studies based on eye-tracking technique suggested that participants fixated their eyes on the inner face more than the outer face.[1-10] We hypothesized that people learn to catch non-verbal language, for example thoughts and feelings, from these components. Therefore, they learn to shift their attentions into the inner face. Moreover, the eyes, nose and mouth have many characteristics such as shape, orientation, color, and size that would give more details of a face. It is interesting that although the nose is component that is hard to remember, it is the component that was consistently reported as the predominant eye-fixation point in Asians[1-10], and is reported as the most impact component that a small change in its height could change the similarity of the modified face to the original face.[19] As the nose is in the center of the face, it may use to calculate a position-correlation among the nose-eyes-mouth. Changing in the nosal size and shape could change their correlation. Therefore, not only the shape and size of the nose, eye and mouth were used to recognize faces, but distances between them may also play some roles in this process.

From Tables 1 and 2, only 2-3 mm change in size of the nose, eye, and lips could impact the facial perception. The facial components that have error more than 5 mm in the 3-D facial approximations[13-16] are the nose, eyes, chin, mouth corner and zygoma. Therefore, these components would require new prediction models to improve the accuracy of the facial approximation.

Acknowledgement

We would like to thank the Excellence in Osteology Research and Training Center (ORTC) with partially supported by Chiang Mai University.

References

1. Blais C, Jack RE, Scheepers C, Fiset D, Caldara R. Culture shapes how we look at faces. *PLoS One* 2008; 3: e3022.
2. Caldara R, Zhou X, Miellet S. Putting culture under the 'spotlight' reveals universal information use for face recognition. *PLoS One* 2010; 5: e9708.
3. Kelly DJ, Liu S, Rodger H, Miellet S, Ge L, Caldara R. Developing cultural differences in face processing. *Dev Sci* 2011; 14: 1176-1184.
4. Wheeler A, Anzures G, Quinn PC, Pascalis O, Omrin DS, Lee K. Caucasian infants scan own- and other-race faces differently. *PLoS One* 2011; 6: e18621.
5. Fu G, Hu CS, Wang Q, Quinn PC, Lee K. Adults scan own- and other-race faces differently. PLoS One 2012; 7: e37688.
6. Tan CBY, Stephen ID, Whitehead R, Sheppard E. You look familiar: how Malaysian Chinese recognize faces. *PLoS One* 2012; 7: e29714.
7. Hills PJ, Pake JM. Eye-tracking the own-race bias in face recognition: revealing the perceptual and socio-cognitive mechanisms. *Cognition* 2013; 129: 586-597.
8. Hu C, Wang Q, Fu G, Quinnd PC, Lee K. Both children and adults scan faces of own and other races differently. *Vision Res* 2014; 102: 1-10.
9. Tan CBY, Sheppard E, Stephen ID. Recognizing dynamic faces in Malaysian Chinese participants. *Perception* 2015; 45: 300-314.
10. Hills PJ. Children process the self face using configural and featural encoding: Evidence from eye tracking. *Cogn Dev* 2018; 48: 82-93.
11. Liu S, Anzures G, Ge L, *et al.* Development of recognition of face parts from unfamiliar faces. *Infant Child Dev* 2013; 22: 165-179.
12. Wilkinson C. Forensic Facial Reconstruction. Cambridge: Cambridge University Press; 2004.
13. Lee WJ, Wilkinson CM, Hwang HS. An accuracy assessment of forensic computerized facial reconstruction employing cone-beam computed tomography from live subjects. *J Forensic Sci* 2012; 57: 318-327.
14. Lee WJ, Wilkinson CM, Hwang HS, Lee S. Correlation between average tissue depth data and quantitative accuracy of forensic craniofacial reconstructions measured by geometric surface comparison method. *J Forensic Sci* 2015; 60: 572-580.
15. Short LJ, Khambay B, Ayoub A, Erolin C, Rynn C, Wilkinson C. Validation of a computer modelled forensic facial reconstruction technique using CT data from live subjects: a pilot study. *Forensic Sci Int* 2014; 237: 147.e141-148.
16. Miranda GE, Wilkinson C, Roughley M, Beaini TL, Melani RFH. Assessment of accuracy and recognition of three-dimensional computerized forensic craniofacial reconstruction. *PLoS One* 2018; 13: e0196770.
17. Rynn C, Wilkinson C, Peters H. Prediction of nasal morphology from the skull. *Forensic Sci Med Pathol* 2009 ;6: 20-34.
18. Mala PZ. Pronasale position: an appraisal of two recently proposed methods for predicting nasal projection in facial reconstruction. *J Forensic Sci* 2013; 58: 957-963.
19. Lewandowski Z. The influence of changes in size and proportion of selected facial features (eyes, nose, mouth) on assessment of similarity between female faces. *Coll Antropol* 2015; 39: 675-684.
20. Farkas LG, Katic MJ, Forrest CR, *et al.* International anthropometric study of facial morphology in various ethnic groups/races. *J Craniofac Surg* 2005; 16: 615-646.
21. Sforza C, Grandi G, Binelli M, Dolci C, Menezes MD, Ferrario VF. Age- and sex-related changes in three-dimensional lip morphology. *Forensic Sci Int* 2010; 200: 182. e181-187.