Facial Surgery

How We Look At Mature Faces—An Eye-Tracking Investigation Into the Perception of Age

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Abstract

Background: It is still unclear which facial region contributes most to the perception of an aged face when evaluated by eye-tracking analyses.

Objectives: The authors sought to apply eye-tracking technology to identify whether mature faces require longer fixation durations than young faces and which facial region contributes most to the perception of a mature face.

Methods: Eye-tracking analyses were conducted in 74 volunteers (37 males, 37 females; $43 \leq 40$ years, $31 > 40$ years) evaluating their gaze pattern and the fixation durations for the entire face and 9 facial subregions. Frontal facial images of 16 younger (<40 years) and older (>40 years) gender-matched individuals were presented in a standardized setting.

Results: Independent of age or gender of the observer, a younger stimulus image was viewed shorter than an older stimulus image with 0.82 (0.63) seconds vs 1.06 (0.73) seconds with $P < 0.001$. There was no statistically significant difference in their duration of a stable eye fixation when observers inspected a male vs a female stimulus image [0.94 (0.70) seconds vs 0.94 (0.68) seconds; $P = 0.657$] independent of the observer's age or gender. The facial image that captured the most attention of the observer (rank 9) was the perioral region with 1.61 (0.73) seconds for younger observers and 1.57 (0.73) seconds for older observers.

Conclusions: It was revealed that the perioral region attracts the most attention of observers and contributes most to an aged facial appearance. Practitioners should be mindful of the importance of the perioral region when designing an aesthetic treatment plan.

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In 2000, Langlois et al published their meta-analysis on the theories behind beauty and revealed that people are generally aligned in their opinion about attractiveness independent of gender, age, and cultural background.[1,2] In 2004, Ramsey et al revealed that 6-month-old infants gazed longer at faces judged by adults as attractive and spent less time looking at faces that were judged as not attractive, thus providing support for a genetically imprinted recognition algorithm when observing beauty.[2,3] At the same time, a plethora of neuroscientific studies were conducted that tried to increase our understanding of how and where in the brain beauty is perceived based on the assumption that, despite the adage, "beauty is in the eye of the beholder," a general underlying concept might be present.[4-13]

Trying to understand and provide proof for such a concept, recent studies applied eye-tracking technology, which captures eye movements, gaze patterns, and fixation durations; all are indirect information about people's unconscious and conscious attention and preferences.[14] Based on their eye-tracking results, researchers postulated their theory of the internal representation of beauty.[15-19] This theory assumes that in every individual an internal blueprint or internal representation of beauty is present that determines what is perceived by the individual as beautiful or not. Following that theory, inspected objects or people that were perceived as beautiful matched with their internal standard of beauty. Conversely, inspected objects or people that did not match with their internal blueprint were perceived as not beautiful. Mismatching, however, forces the observer to align the visual input to their internal blueprint, and the extent of the mismatch needs additional cognitive processing time and additional visual information to be aligned and understood. The time needed for capturing additional visual information, that is, measurement of fixation duration, can be measured with eye-tracking analyses.[20-23]

Mature faces were previously shown to be perceived as less attractive, less likeable, less distinctive, and less energetic when rated by both younger and older evaluators.[24] These results can be explained by the presence of altered facial features in mature faces, which can be associated with certain character traits.[25] However, it is still unclear which facial feature contributes most to an aged facial appearance and which facial feature should be addressed first based on its visual perception during aesthetic treatments.

Therefore, the objective of this study was to apply eye-tracking technology to (1) identify whether mature faces require longer fixation durations than younger faces, and (2) which facial region contributes most to the perception of a mature face. The analysis will provide a deeper understanding of the perception of facial aging and will allow for a further exploration of the internal representation of beauty theory.

METHODS

Investigated Study Sample (Observers)

The volunteers investigated were recruited through the outpatient clinic of the Department of Hand, Plastic and Aesthetic Surgery, University Hospital Munich, Germany, without specific inclusion or exclusion criteria. All volunteers had no medical background or exposure to delivering aesthetic medical care.

Prior to inclusion into the study, volunteers were informed and provided signed consent about the procedure performed (eye tracking) and about the data collected (demographic information, eye-tracking results). The study was reviewed and approved by the IRB of Ludwig Maximilian's University, Munich, Germany (IRB protocol number: 20-1018) and was conducted between July 2021 and March 2022.

Displayed Study Sample (Stimulus)

The investigated volunteers were exposed to a visual stimulus for a total duration of 10 seconds. The visual stimulus consisted of standardized frontal images of 16 individuals: 8 males and 8 females. Each gender group consisted of 4 individuals younger than 40 years of age and 4 individuals older than 40 years of age. The presentation of the visual stimulus was randomized prior to image exposure (randomization was performed online via: www.random.org [Dublin, Ireland]), and the randomized images were then imported into the eye-tracking device. The eye-tracking device displayed all images in the same (but randomized) sequence, and all observers inspected the images in the same sequence. Image presentation was separated by a 2-second resting period displaying a black screen. The images utilized for the visual stimulus were stock images of males and females younger and older than 40 years of age (www.shutterstock.com, New York, NY, USA).

Data Analysis

Eye Movement Analysis

The data were analyzed according to a previously published protocol.[16,19] In brief, a Tobii Pro Nano binocular eye-tracking device (Tobii Pro AB, Stockholm, Sweden) operating at 60 Hz was positioned at the inferior aspect of a 15-inch laptop monitor. The monitor displayed stimulus images as described above, and the eye-tracking device captured the eye movements of the observers when inspecting the stimulus images. The parameter of interest for this investigation was the duration of fixation (measured in seconds). This parameter represents the time a stable eye fixation within the 10-second interval of visual stimulus exposure focused on the same facial region. This variable can be understood as the ability of the displayed stimulus to capture an observer's attention, with longer viewing times more strongly capturing an observer's attention.

The following facial regions were separately investigated during the eye-tracking analyses:

- forehead
- temple (bilateral)
- periorbital region (bilateral)
- nose
- medial midface (bilateral)
- lateral midface (bilateral)
- perioral region
- chin
- jawline (bilateral)

Statistical Analysis

Preliminary analyses revealed that the eye-tracking data were not normally distributed, as assessed by Kolmogorov–Smirnov test ($P < 0.05$). Therefore, nonparametric tests were applied. All calculations were performed employing SPSS Statistics 23 (IBM, Armonk, NY, USA), and results were considered statistically significant at a probability level of ≤0.05 to guide conclusions. To account for multiple testing when investigating differences between the 9 facial regions, Bonferroni adjustment was performed; this resulted in a new significance level of 0.05/9 = 0.006. For better readability, however, data are presented as mean value and the respective ±1 standard deviation, but statistical testing was conducted with nonparametric testing.

RESULTS

Demographic Data

The investigated study sample (individuals exposed to the visual stimulus and subject of the eye-tracking analyses) consisted of 74 volunteers (37 males, 37 females) with a mean age of 44.54 (19.9) years (range = 24-84 years). Of those, 43 were 40 years or younger, whereas 31 were older than 40 years of age.

General Observations

Independent of age or gender of the observer, a younger stimulus image was viewed significantly shorter than an older stimulus image [0.82 (0.63) seconds vs 1.06 (0.73) seconds; $P < 0.001$] (Supplemental Figure). There was no statistically significant difference in the duration of stable eye fixation when observers inspected a male vs female stimulus image [0.94 (0.70) seconds vs 0.94 (0.68) seconds; $P = 0.657$] independent of the observers age or gender. No association was identified when correlating the age of the observers with the fixation duration ($r_p = -0.037$, $R^2 = 0.001$).

Full-Face Analyses (Independent of Facial Regions)

When displaying a younger stimulus image (<40 years of age) to both younger (≤40 years of age) and older (>40 years of age) observers, no statistically significant difference was detected in the duration of stable eye fixation [0.83 (0.63) seconds vs 0.81 (0.62) seconds; $P = 0.337$, respectively]. Similarly, when displaying an older stimulus image (>40 years of age) to both younger and older observers, again no statistically significant difference was observed in the duration of stable eye fixation [1.07 (0.74) seconds vs 1.03 (0.72) seconds; $P = 0.129$, respectively]. No difference between genders was detected in their response to the younger/older stimulus image (all $P >$ 0.05).

Younger observers (≤40 years of age) displayed a statistically significant reduction in overall duration of stable eye fixation when inspecting a younger [0.83 (0.63) seconds] vs an older [1.07 (0.74) seconds] stimulus image ($P < 0.001$). Similarly, observers of older age (>40 years of age) had a statistically significant shorter duration of their average stable eye fixation when inspecting a younger [0.81 (0.62) seconds vs an old 1.03 (0.72) seconds] stimulus image ($P < 0.001$). No difference between genders was detected in their response to the younger/older stimulus image ($P > 0.05$).

Facial-Region Analyses

Independent of whether a younger or older stimulus image was presented, both younger and older observers had their shortest duration of a stable eye fixation (rank 1-3) for the forehead, the lateral midface, and the jawline; this represents the facial outline in a frontal image (Table 1). There was no statistically significant difference between younger and older observers ($P > 0.006$; Bonferroni adjusted). The facial regions inspected longest (rank 7-9) were independent of the age of the stimulus image or of the observer: periorbital, nasal, and perioral, respectively, representing the central facial regions. No statistically significant difference between younger and older observers was detected ($P > 0.006$).

When a young observer was presented with a younger/older stimulus image, the ranks for the duration of stable eye fixation were similar for both groups (Table 2). The facial regions that attracted the viewers' attention for the longest period of time were the periorbital [1.50 (0.32) seconds (rank 8)] and [perioral 1.61 (0.73) seconds (rank 9)] regions. Both facial regions displayed a statistically significant difference in the duration of a stable eye fixation between a younger vs older stimulus ($P < 0.001$) when viewed by a young observer. A similar pattern was observed for older observers: the periorbital [1.41 (0.31) seconds (rank 8)] and

Table 1. Time in Seconds (±1× Standard Deviation) for the Duration of a Stable Eye Fixation During the 10-Second Stimulus Image Exposure

Facial feature	Younger stimulus				Older stimulus			
	Younger observer	Older observer	*P*	Rank younger/ older observer	Younger observer	Older observer	*P*	Rank younger/ older observer
Forehead	0.42 ± 0.33	0.47 ± 0.32	0.173	3/3	0.46 ± 0.48	0.50 ± 0.56	0.959	1/1
Temple	0.75 ± 0.63	0.77 ± 0.69	0.770	5/5	0.94 ± 0.80	1.06 ± 0.94	0.323	5/5
Periorbital	1.35 ± 0.34	1.32 ± 0.29	0.182	8/8	1.50 ± 0.32	1.41 ± 0.31	0.054	8/8
Nose	1.31 ± 0.18	1.33 ± 0.18	0.813	7/9	1.38 ± 0.21	1.36 ± 0.23	0.730	7/7
Medial midface	0.85 ± 0.54	0.94 ± 0.63	0.065	6/6	1.16 ± 0.70	1.16 ± 0.68	0.789	6/6
Lateral midface	0.41 ± 0.49	0.39 ± 0.37	0.968	2/2	0.86 ± 0.96	0.62 ± 0.49	0.124	4/3
Perioral	1.37 ± 0.79	1.15 ± 0.70	0.002*	9/7	1.61 ± 0.73	1.57 ± 0.73	0.630	9/9
Chin	0.59 ± 0.36	0.49 ± 0.34	<0.001*	4/4	0.72 ± 0.31	0.65 ± 0.33	0.029	2/4
Jawline	0.22 ± 0.13	0.25 ± 0.15	0.398	1/1	0.77 ± 0.60	0.61 ± 0.39	0.348	3/2

The longer the duration, the greater is the ability of the visual stimulus to capture the observer's attention. Here, the same younger/older stimulus image was presented to different younger/older observers. The difference in their observation times is represented by the *P* value; results are considered statistically significant if $P \leq 0.006$ following Bonferroni correction for multiple testing. The times of the younger/older observers were ranked according to their observational duration ranging from 1 to 9, shortest to longest. *Indicate statistical significance at the Bonferroni adjusted *P* values.

Table 2. Time in Seconds (±1× Standard Deviation) for the Duration of a Stable Eye Fixation During the 10-Second Stimulus Image Exposure

Facial feature	Younger observer				Older observer			
	Younger stimulus	Older stimulus	*P*	Rank younger/ older stimulus	Younger stimulus	Older stimulus	*P*	Rank younger/ older stimulus
Forehead	0.42 ± 0.33	0.46 ± 0.48	0.889	3/1	0.47 ± 0.32	0.50 ± 0.56	0.163	3/1
Temple	0.75 ± 0.63	0.94 ± 0.80	0.005*	5/5	0.77 ± 0.69	1.06 ± 0.94	0.002*	5/5
Periorbital	1.35 ± 0.34	1.50 ± 0.32	<0.001*	8/8	1.32 ± 0.29	1.41 ± 0.31	0.007	8/8
Nose	1.31 ± 0.18	1.38 ± 0.21	0.024	7/7	1.33 ± 0.18	1.36 ± 0.23	0.175	9/7
Medial midface	0.85 ± 0.54	1.16 ± 0.70	<0.001*	6/6	0.94 ± 0.63	1.16 ± 0.68	<0.001*	6/6
Lateral midface	0.41 ± 0.49	0.86 ± 0.96	<0.001*	2/4	0.39 ± 0.37	0.62 ± 0.49	<0.001*	2/3
Perioral	1.37 ± 0.79	1.61 ± 0.73	<0.001*	9/9	1.15 ± 0.70	1.57 ± 0.73	<0.001*	7/9
Chin	0.59 ± 0.36	0.72 ± 0.31	<0.001*	4/2	0.49 ± 0.34	0.65 ± 0.33	<0.001*	4/4
Jawline	0.22 ± 0.13	0.77 ± 0.60	<0.001*	1/3	0.25 ± 0.15	0.61 ± 0.39	<0.001*	1/2

The longer the duration, the greater is the ability of the visual stimulus to capture the observer's attention. Here, the same younger/older observer looked at a different younger/older stimulus image, respectively. The difference in the observation times is represented by the *P* value; results are considered statistically significant if $P \leq 0.006$ following Bonferroni correction for multiple testing. The times for viewing the younger/older stimulus image per each younger/older observer were ranked according to their observational duration ranging from 1 to 9, shortest to longest. *Indicate statistical significance at the Bonferroni adjusted *P* values.

[perioral 1.57 (0.73) seconds (rank 9)] regions were inspected longest and displayed a statistically significant difference between a younger vs older stimulus image when viewed by an older observer (< 0.001) (Table 2; Figures 1, 2).

DISCUSSION

This eye-tracking study sought to elucidate the differences between younger and more mature faces relative to the fixation duration and the gaze pattern of both young and old

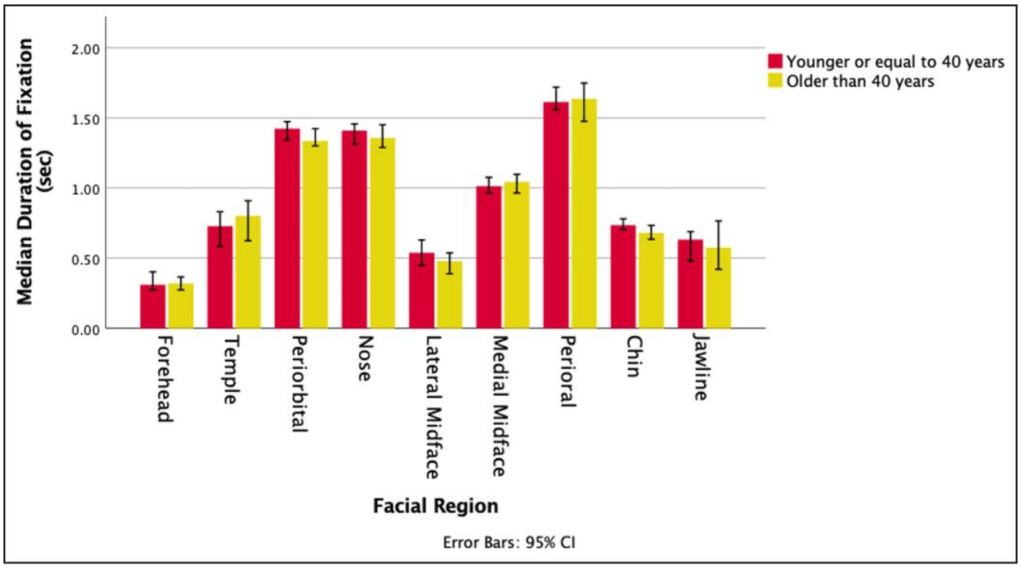

Figure 1. Time of total fixation for each investigated facial region between subjects younger or equal to 40 years and subjects older than 40 years. Bars represent median value and whiskers represent 95% CI.

observers. The results revealed that, independent of who viewed the presented stimulus image (younger or older observers), older faces were inspected significantly longer than younger faces (1.06 (0.73) seconds vs 0.82 (0.63) seconds; $P < 0.001$). An explanation for this difference could be the previously postulated theory about the internal representation of beauty: objects or people perceived as less beautiful do not match the internal blueprint of beauty and, therefore, require additional information for cognitive processing. This additional cognitive processing time is reflected in a longer duration of stable fixations, which allows the observer to collect more visual information. This additional visual input allows for the alignment of the mismatch between internal blueprint and inspected object (here: a mature face). Interestingly, this finding is in line with previous investigations that have identified that older individuals are rated as less beautiful, and less beautiful can be translated into eye-tracking language as longer fixation

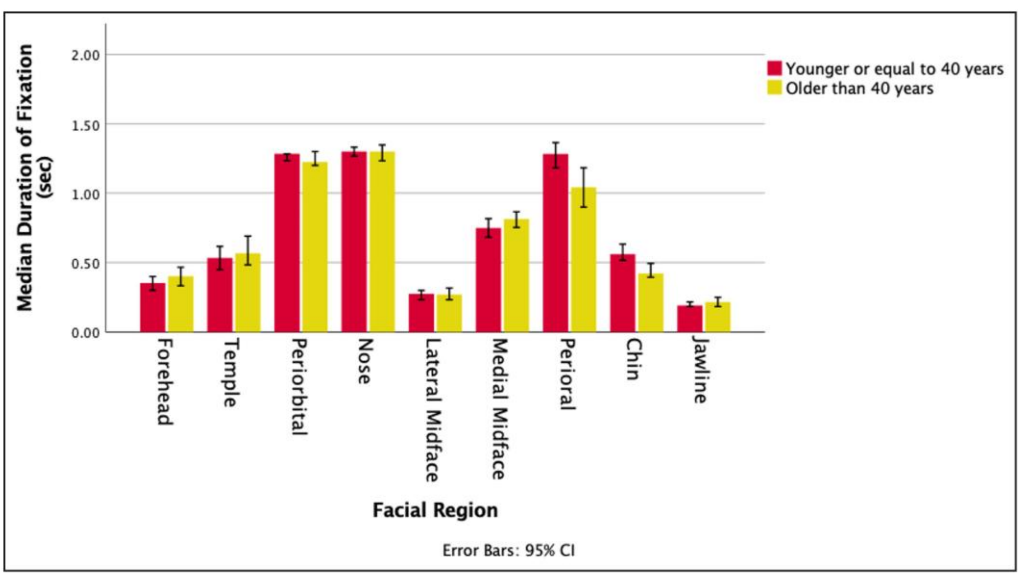

Figure 2. Bar graph depicting the time of total fixation for the respective areas of interest when subjects younger than or equal to 40 years and subjects older than 40 years looked at an elderly stimulus. Bars represent median value and whiskers represent 95% CI.

durations.[24] The fact that longer fixation durations were observed in both younger and older observers might point to an age-independent mechanism despite that younger and older stimulus images were presented.

Support for an age- and gender-independent mechanism to perceive beauty was additionally provided in this study when the same visual stimulus (younger or older facial images) was presented to either younger or older observers. No statistically significant differences were observed between the fixation duration in either of the observer groups (younger vs older observers) when viewing either the younger [0.83 (0.63) seconds vs 0.81 (0.62) seconds and $P = 0.337$] or older [1.07 (0.74) seconds vs 1.03 (0.72) seconds] facial images (Figure 1). These results indicate that the same visual stimulus has a similar effect on the observer independent of their age or gender. In other words, individuals will react similarly to viewed objects or persons because there seems to be a general underlying mechanism by which humans determine what is beautiful and what is not. This is in line with previous studies that have elaborated that people are generally aligned on their opinion about beauty independent of gender, age, and cultural background.[1,2]

When facial subregion analyses were conducted—by presentation of a frontal stock image—the outline of the face was scanned at the beginning of facial recognition; this is reflected in the fixation durations, which were shortest for the forehead, lateral midface, and jawline (ranks 1-3; Table 1). On the contrary, and in alignment with previous eye-tracking analyses, the longest fixation durations were recorded for the periorbital, nasal, and perioral facial regions (rank 7-9; Table 1), representing the central face.[22] The observed ranks of 1 to 3 for the facial outline and 7 to 9 for the central facial oval were independent of the age of the observer and of the presented visual stimulus. This again suggests an age- and gender-independent mechanism is probably present when inspecting a face and information is extracted from the visual stimulus.

When presenting an older facial image, the responses from both younger and older observers were similar (Table 2): the facial image that captured most the attention of the observer (rank 9) was the perioral region at 1.61 (0.73) seconds for younger observers and 1.57 (0.73) seconds for older observers. The long fixation durations can be understood in this context as the area of the face that required the most visual information to be processed by both younger and older observers. When presenting a younger facial image to both younger and older observers, the perioral region was ranked in the top 3 for longest fixation durations; this emphasizes again the importance of this region. This signifies that the perioral region is the facial area that attracts an observer's attention the longest and that seems to be most responsible for an aged facial appearance. It is subject to speculation whether the increased attention to the perioral region is in post-pandemic times the result of a lack of perioral exposure due to previous masking mandates.[26]

Elongation of the upper lip; thinning of the vermilion; inversion of lips; perioral radial lines; depression of the oral commissure; deep nasolabial, labiomandibular, and labiomental lines; and general perioral volume loss are signs of aging of the perioral region.[27-30] Apart from skin surface effects, these changes negatively influence the facial expression of the individual and indicate an emotional status by creating a sad or angry facial appearance.[31] This perioral area is only rivalled by the periorbital region in its expressiveness, and they both are unlike any other facial region in this regard. There is no sad temple for comparison.

Clinically, the results of this study suggest that independent of the patients' aesthetic desires, the perioral region should be included in the therapeutic plan in a direct or indirect manner. Despite previous studies that have shown that superior outcomes can be achieved by following the 3 aesthetic principles (lateral face first, upper face first, deep regions first), the results of the present study advocate that a lower, midline facial region should not be forgotten.[25] Budgetary constraints might be a reason to not include the perioral region if a patient's complaint is midfacial volume loss or the tear trough deformity. However, neuromodulator injection with the "lip flip" technique to evert the upper lip and the "toxin lift" injection technique along the jawline to elevate the upper lip and the oral commissure and improve the nasolabial folds are viable and reasonably priced possibilities to treat the perioral region.[32,33] According to the general bony shape of the face, patients should be informed about the anticipated course of perioral aging and the benefits of addressing this region early and adequately. This holds true especially for patients with upper lip elongation who might not have the desire to undergo corrective upper lip surgery. However, it must be kept in mind that inspecting people's faces serves the purpose of extracting visual information from the object (face) inspected such as age, gender, ethnicity, mood, and other static and dynamic information. Beauty is a side aspect of this information capture.

This study is not free of limitations, however. First, the stimulus image presented was a frontal stock image; there were no lateral or oblique views. A facial image series showing all 3 facial views might allow for a better or more holistic evaluation and analysis. Due to the methodology applied, however, the display of multiple facial images showing the same visual stimulus from different angles might have introduced a learner's bias or skewed the gaze pattern toward facial regions that were known to the observer from the first viewing angle. This could likely be overcome in subsequent studies. Second, eye-tracking analyses were conducted in only a Caucasian sample, and future investigations must identify and present differences or similarities in other ethnic groups. It might be important to conduct similar experiments in a mixed ethnic sample where both observers and visual stimuli represent different ethnic groups.

CONCLUSIONS

This eye-tracking investigation provided additional support for the previously postulated theory of the internal representation of beauty. Independent of the age or gender of observers, mature facial images were inspected longer than younger facial images; this implies that younger facial images were perceived as more beautiful. This perception of beauty is in line with longer fixation durations for the alignment of the mismatch between the observed visual stimulus and the internal beauty blueprint. By conducting facial regional analyses, we identified that the way study participants inspected a facial image was from the facial outline inward toward the central facial oval. Of all investigated facial regions, it was revealed that the perioral region attracts an observer's attention the longest and contributes most to an older facial appearance. Practitioners should be mindful of the importance of the perioral region when designing an aesthetic treatment plan.

Supplemental Material

This article contains supplemental material located online at www.aestheticsurgeryjournal.com.

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REFERENCES

1. Langlois JH, Kalakanis L, Rubenstein AJ, Larson A, Hallam M, Smoot M. Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychol Bull*. 2000;126(3):390-423. doi:10.1037/0033-2909.126.3.390
2. Yarosh DB. Perception and deception: human beauty and the brain. *Behav Sci*. 2019;9(4):34. doi:10.3390/bs9040034
3. Ramsey JL, Langlois JH, Hoss RA, Rubenstein AJ, Griffin AM. Origins of a stereotype: categorization of facial attractiveness by 6-month-old infants. *Dev Sci*. 2004;7(2):201-211. doi:10.1111/j.1467-7687.2004.00339.x
4. Kirsch LP, Urgesi C, Cross ES. Shaping and reshaping the aesthetic brain: emerging perspectives on the neurobiology of embodied aesthetics. *Neurosci Biobehav Rev*. 2016;62:56-68. doi:10.1016/j.neubiorev.2015.12.005
5. Hu C-P, Huang Y, Eickhoff SB, Peng K, Sui J. Seeking the "beauty center" in the brain: a meta-analysis of fMRI studies of beautiful human faces and visual art. *Cogn Affect Behav Neurosci*. 2020;20(6):1200-1215. doi:10.1101/081539
6. Bzdok D, Langner R, Caspers S, et al. ALE meta-analysis on facial judgments of trustworthiness and attractiveness. *Brain Struct Funct*. 2011;215(3-4):209-223. doi:10.1007/s00429-010-0287-4
7. Haxby JV, Hoffman EA, Gobbini MI. Human neural systems for face recognition and social communication. *Biol Psychiatry*. 2002;51(1):59-67. doi:10.1016/s0006-3223(01)01330-0
8. Kanwisher N, Yovel G. The fusiform face area: a cortical region specialized for the perception of faces. *Philos Trans R Soc Lond B Biol Sci*. 2006;361(1476):2109-2128. doi:10.1098/rstb.2006.1934
9. Liu J, Harris A, Kanwisher N. Perception of face parts and face configurations: an FMRI study. *J Cogn Neurosci*. 2010;22(1):203-211. doi:10.1162/jocn.2009.21203
10. Kanan C, Bseiso DNF, Ray NA, Hsiao JH, Cottrell GW. Humans have idiosyncratic and task-specific scan paths for judging faces. *Vision Res*. 2015;108:67-76. doi:10.1016/j.visres.2015.01.013
11. Wiese H, Kloth N, Güllmar D, Reichenbach JR, Schweinberger SR. Perceiving age and gender in unfamiliar faces: an fMRI study on face categorization. *Brain Cogn*. 2012;78(2):163-168. doi:10.1016/j.bandc.2011.10.012
12. Iaria G, Fox CJ, Waite CT, Aharon I, Barton JJS. The contribution of the fusiform gyrus and superior temporal sulcus in processing facial attractiveness: neuropsychological and neuroimaging evidence. *Neuroscience*. 2008;155(2):409-422. doi:10.1016/j.neuroscience.2008.05.046
13. Collins JA, Olson IR. Beyond the FFA: the role of the ventral anterior temporal lobes in face processing. *Neuropsychologia*. 2014;61:65-79. doi:10.1016/j.neuropsychologia.2014.06.005
14. Asaad M, Dey JK, Al-Mouakeh A, et al. Eye-tracking technology in plastic and reconstructive surgery: a systematic review. *Aesthet Surg J*. 2020;40(9):1022-1034. doi:10.1093/asj/sjz328
15. Kassir R, Kassir S, Hofmann L, et al. Effect of surgical versus nonsurgical rhinoplasty on perception of the patient: an eye-tracking-based investigation. *Facial Plast Surg Clin North Am*. 2022;30(2):175-181. doi:10.1016/j.fsc.2022.01.004
16. Möllhoff N, Kandelhardt C, Ehrl D, et al. The impact of breast symmetry on eye movement and gaze pattern: an eye-tracking investigation. *Aesthet Surg J*. 2021;41(11):NP1512-NP1518. doi:10.1093/asj/sjab285.
17. Moellhoff N, Staiger TJ, Ehrl D, et al. Identifying the most attractive umbilical position—an eye tracking- and survey-based investigation. *J Plast Surg Hand Surg*. 2021:1-7. doi:10.1080/2000656X.2021.2017946. Online ahead of print.

18. Bernardini F, Staiger T, Moellhoff N, et al. Facial recognition pattern before and after lower eyelid blepharoplasty: an eye tracking analysis. *Facial Plast Surg Clin North Am*. 2022;30(2):271-276. doi:10.1016/j.fsc.2022.01.007
19. Frank K, Moellhoff N, Swift A, et al. In search of the most attractive lip-proportions and lip-volume—an eye tracking- and survey-based investigation. *Plast Reconstr Surg*. 2022;150(2):301-308.doi:10.1097/PRS.0000000000009361
20. Cai LZ, Kwong JW, Azad AD, Kahn D, Lee GK, Nazerali RS. Where do we look? Assessing gaze patterns in cosmetic face-lift surgery with eye tracking technology. *Plast Reconstr Surg*. 2019;144(1):63-70. doi:10.1097/PRS.0000000000005700
21. Cai LZ, Paro JAM, Lee GK, Nazerali RS. Where do we look? Assessing gaze patterns in breast reconstructive surgerywith eye-tracking technology. *Plast Reconstr Surg*. 2018;141(3):331e-340e. doi:10.1097/PRS.0000000000004106
22. Dey JK, Ishii LE, Byrne PJ, Boahene KDO, Ishii M. Seeing is believing: objectively evaluating the impact of facial reanimation surgery on social perception. *Laryngoscope*. 2014;124(11):2489-2497. doi:10.1002/lary.24801
23. Morzycki A, Wong A, Hong P, Bezuhly M. Assessing attentional bias in secondary cleft lip deformities: an eye-tracking study. *Cleft Palate-Craniofacial J*. 2019;56(2):257-264. doi:10.1177/1055665618775728
24. Ebner NC. Age of face matters: age-group differences in ratings of young and old faces. *Behav Res Methods*. 2008;40(1):130-136. doi:10.3758/BRM.40.1.130
25. Freytag DL, Alfertshofer M, Frank K, et al. Understanding facial aging through facial biomechanics—a clinically applicable guide for improved outcomes. *Facial Plast Surg Clin North Am*. 2022;30(2):125-133. doi:10.1016/j.fsc.2022.01.001
26. Frank K, Schuster L, Alfertshofer M, et al. How does wearing a facecover influence the eye movement pattern in times of COVID-19? *Aesthet Surg J*. 2021;41(8):NP1118-NP1124. doi:10.1093/asj/sjab121
27. Cotofana S, Gotkin RH, Frank K, et al. The functional anatomy of the deep facial fat compartments—a detailed imaging based investigation. *Plast Reconstr Surg*. 2019;143(1):53-63. doi:10.1097/PRS.0000000000005080
28. Cotofana S, Lachman N. Anatomie der Fettkompartimente des Gesichts und ihre Bedeutungfür die ästhetische Chirurgie. *J Dtsch Dermatol Ges*. 2019;17(4):399-415. doi:10.1111/ddg.13737_g
29. Schenck TL, Koban KC, Schlattau A, et al. The functional anatomy of the superficial fat compartments of the face: a detailed imaging study. *Plast Reconstr Surg*. 2018;141(6):1351-1359. doi:10.1097/PRS.0000000000004364
30. Pooth R, Prinz V, Cajkovsky M, et al. Validated 5-point photonumeric scales for the assessment of the jowls and chin. *J Cosmet Dermatol*. 2022;21(2):600-607. doi:10.1111/jocd.14661
31. Eisenbarth H, Alpers GW. Happy mouth and sad eyes: scanning emotional facial expressions. *Emotion*. 2011;11(4):860-865. doi:10.1037/a0022758
32. Ghannam S, Bageorgou F. The lip flip for beautification and rejuvenation of the lips. *J Drugs Dermatol*. 2022;21(1):71-76. doi:10.36849/JDD.2022.6344
33. Hernandez C, Davidovic K, Avelar L, et al. Facial soft tissue repositioning with neuromodulators: lessons learned from facial biomechanics. *Aesthet Surg J*. 2022;42(10):1163-1171. doi:10.1093/asj/sjac090