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Impact of Surgical Rejuvenation on Visual Processing and Character Attribution of Periorbital Aging

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Abstract

BACKGROUND:

The perceptual response to aging changes in the periorbital region, and the impact that surgical rejuvenation might have on that response, has not been previously elucidated. We examined the reflexive visual response to periorbital aging both before and after browlift and upper blepharoplasty surgery. In addition, we investigated how observers' character attributions of the images were affected by the rejuvenative intervention.

METHOD:

Pre- and post-operative photographs were obtained of patients with brow ptosis and dermatochalasis who underwent browlift and blepharoplasty. Forty observers examined each image while an infrared eye-tracking camera continuously recorded their eye movements. The observers rated the images with respect to character attributes (attractiveness, trustworthiness, sociability, healthiness, and capability, on a 1-7 scale).

RESULT:

Fourteen patients who underwent browlift and blepharoplasty were identified and studied. The surgical intervention was found to:

(i) increase observers' attention to the eye/brow region, while decreasing relative attention to the forehead and lower eyelid areas.

(ii) increase the two-dimensional surface area of the forehead and eye/brow zones in a manner directly associated with the measured changes in visual attention.

(iii) significantly increase the ratings for all five positively valanced character attributes compared to pre op controls.

CONCLUSION:

We provide an important combination of explicit and implicit data, illustrating how surgical rejuvenation unveils the periorbital region to the observer. Moreover, this change in pattern of inspection is associated with an improvement in the perception of character.

INTRODUCTION

The aesthetic significance of the periorbital region of the human face has been appreciated since ancient times[1-3]. So much of human emotion is communicated through the appearance and movement of the eyes and brows. The widespread popularity of techniques such as glabellar chemodenervation, browlift, and blepharoplasty speaks directly to the importance that patients place on this region of the face[4]. However, as with all forms of aesthetic facial rejuvenation or enhancement, there is no objective nor universally accepted method to measure the change achieved by surgical rejuvenation of the periorbital area. In the plastic surgery literature, most of what is considered as an aesthetically pleasing outcome is based on the instinctive analysis of plastic surgeons, rather than on patient assessment, public opinion, or some objective means of evaluation.

Despite the long-appreciated link between facial appearance and personality attribution[5-7], little has been written about the effect that surgical rejuvenation has on others' perception of personality. Observers unconsciously infer meaningful information from faces; in fact, within 100 ms of facial exposure, observers make subconscious assessments of age, gender, ethnicity, attitude/emotion, well-being, trustworthiness, and social status.[8] In the current study, we explored these instantaneous, reflexive responses to the aging human face both before and after browlift and blepharoplasty procedures using eye-tracking technology. We also assessed how those instinctive responses related to observers' considered, subjective character attribution for the given faces. The purpose of our study was to reveal the visual focus of impression formation of faces with periorbital aging changes, and to evaluate the impact of those changes and surgical correction on the appraisal of personality. This report offers a unique pairing of implicit and explicit perceptual information that may benefit surgeons and their patients in assessing the value of browlift and blepharoplasty.

METHODS

Study Design and Population

Two distinct groups of participants were included in this study: "*stimulus group*" and "*observer group*".

Stimulus group: Images were obtained of patients presenting to our institution for a browlift procedure with or without a blepharoplasty for varying degrees of brow ptosis and dermatochalasis. Signed informed consent was obtained for all images, as per protocol approved by the Mayo Clinic Institutional Review Board. Twenty-eight images of patients were studied. Patient photographs were taken before and after (>3 months) the surgical correction. Only a browlift with or without a blepharoplasty was performed; no ancillary procedures were undertaken at the time of the experimental intervention nor during the follow-up period. The 28 images were then mixed with 52 additional facial images of other individuals displaying a variety of different facial findings (Parry Romberg (11), facial palsy (40), facial feminization (1), and generalized facial aging changes (40)) into two slideshows of 40 images for presentation. The additional 52 images that revealed alternative types of facial deformity were mixed with our experimental images of periorbital aging in order to prevent eye-tracking observers from becoming trained during the experimental trial to the presentation of a consistent, anatomic zone of abnormality. That type of habituation might counter the instinctive responses required during a meaningful eye-tracking study. Thus, the additional 52 images were not a focus on the current study but were used, rather, as a decoy. The two slideshows were constructed in such a manner as to present a balance of diagnosis, gender, and age range.

Observer group: Eighty observers were recruited from the general lay population in a city center. Observers agreed to have their eyes tracked while observing one of two sets of images that were randomly displayed on a computer screen. Therefore, each image in the slideshow was viewed by 40 observers. Visual acuity testing was also performed, and 20/40 vision or better was required in each eye for inclusion in the study (lens correction permitted). Observers also completed a demographic survey. After completion of the slideshow, the observers were asked to rate the same images one by one on a slideshow, on a Likert scale of 1 to 7, for the following character attributes: attractiveness, trustworthiness, sociability, health, and capability. In order to provide the observers with scale anchors, sample images of males and females representing '7' (highest character attribute, i.e., most attractive) and '1' (lowest character attribute, i.e., least attractive) based on the authors' judgment, were presented at the beginning of their survey. There was no time limit applied to the character attribution task which was generally completed within 3 minutes for the 40 images.

Eye-tracking Protocol

Each study image was presented to the observers on a 17" flat screen computer monitor for 6 seconds. It required approximately 7 minutes for the subjects to complete the entire 40 image slideshow, including 3 second intervals of a blank, black screen displayed in between the images. No specific instructions were given to the observers; they were simply asked to freely view the images. Quick Screen Capture software (version 3.0, Etrusoft, Kaysville, UT) was used to present PowerPoint (Microsoft, Redmond, WA) slideshows containing the image stimuli displayed in random order from one subject to another. An EyeTech TM4 desktop mounted, high resolution eye-tracking system was utilized (EyeTech Digital Systems, Mesa, AZ) which captures infrared light reflected off the cornea with a binocular data tracking rate of 30 Hz, and an accuracy of 0.5 degrees' visual angle. The low profile TM4 console was placed unobtrusively at the base of the computer monitor. Each participant's head was held stationary in an optometric chinrest 60 cm from the monitor. At that distance, and with the eye-tracking system reporting an accuracy of +/- 0.5-degree visual angle, the maximum eye-tracking error is calculated to be +/- 5 mm. Even the smallest region of interest on the faces in the study, when projected onto the 17-inch monitor, measured at least 1.4 cm in each dimension, with an area of at least 2 cm^2.

The eye-tracking procedure started with a calibration/validation sequence in which participants were asked to follow a dot presented randomly at nine different locations on the screen. The system was calibrated on a per subject basis at the beginning of each experiment.

Twenty aesthetic regions of interest ("lookzones") were hand-drawn post-hoc onto each image using pre-determined anatomic landmarks chosen in advance of the study (Figure 1). Ten matching zones were identified on each side of the face, classified as: forehead (1,2); eye and brow(3,9); glabellar (5,6); lower lid (4,10); lateral nasal sidewall (7,8); mid-cheek (11,12); nasal tip, nares, and columella (13,14); upper lip (15,16); lower lip, chin, mandible (17,18); and ear (19,20). EyeTech's Quick Link API software was used to compute real time data from the eye-tracking system which captured the X, Y position of the eye during each 33-millisecond interval. Fixation count and duration, relative to each facial aesthetic lookzone, was computed. A fixation was defined as a gaze duration of >100ms. All information was imported from Excel (Microsoft, Redmond, WA) files and analyzed in relation to the particular details of the stimulus and observer groups.

Data Analysis

All data analysis and statistical testing was performed using open source R programming language (www.r-project.org) and standard procedures, and is replicable with alternative commercial software packages. The lookzone surface areas were calculated with ImageJ, an open source image processing program (https://imagej.net; Bethesda, MD). Visualization of the data was facilitated with Excel and Tableau version 8.3.3 (Tableau Software, Seattle, WA). Mean fixation duration was computed across all 20 lookzones. The effect of the surgical intervention on character attribution, as well as percent visual fixation and surface area by lookzone, were all analyzed using the Wilcoxon sign rank test (following Shapiro Wilk testing demonstrating non-normal distribution of data). The association of lookzone surface area to corresponding visual fixation was evaluated using Spearman's rank correlation test. Significance was set at the $p < 0.05$ level.

RESULTS

Participant and procedural details:

Twenty-eight images of 14 patients were included in this study (8 female, 6 male, ages 47-92 years, mean age: 65.14 years, SD: 10.32 years). The procedure was performed bilaterally in 13 patients, and addressed only the left side in one individual. All 14 patients underwent browlift procedures (10 endoscopic, 4 open mid-brow or pre-trichial). Thirteen patients underwent additional blepharoplasty (11 upper, 2 combined upper and lower). Age range of the observers was 13 to 72 years old (mean = 41.76 years, SD: 9.93 years). There were 46 females, 30 males, and 4 did not specify gender.

Proportion of total facial visual fixation, by lookzone:

Our eye-tracking analysis demonstrated that, in general, observers preferentially fixate on the horizontal zone between the eyebrows (above) and the lower eyelid/cheek junction (below) for all faces.

Compared to pre-operative images, however, the surgical intervention was found to significantly increase observers' attention to the eye and brow region of the face from 27.7% to 30.8% of the upper quartile viewing time, (p=0.047), while decreasing attention to the forehead (8.7% to 6.7%, p=0.008]) and lower eyelid (24.4% to 20.7%, p=0.023) regions. The surgical interventions did not yield any significant difference in visual fixation in any of the other lookzones of the face. Figure 2 shows representative pre- and post-operative patient images, and the attention paid to their facial lookzones reflected by patterns of heat mapping. Pre- and post-operative visual fixation trends (% of total facial visual fixation) are demonstrated in Figure 3.

Proportion of total facial surface area, by lookzone:

Compared to pre-operative values, the median of % facial surface area, represented by the eye and brow region, increased from 10.8% to 12.8% (p=0.006), and that of the forehead decreased from 33% to 29.9% (p=0.016) (Figures 4a and 4b). The surface area of the lower eyelid zone did not change significantly with the intervention.

Correlation of % of surface area with % of visual fixation, by lookzone:

A significant correlation was found between % of total facial surface area and % of total facial visual fixation time for both the forehead (ρ=0.53, p=0.003) and eye & brow (ρ=0.41, p=0.028) lookzones (Figure 5). None of the other facial lookzones demonstrated a significant correlation between these two parameters of measurement.

Impact of surgical intervention on character attribution:

Character attribution was broadly affected by the periorbital rejuvenation procedure with four of the five positively valenced character ratings significantly increased compared to pre-operative assessment (median values): sociable 3.8 to 4.1, trustworthy 4.0 to 4.3, capable 4.3 to 4.6, and healthy 4.3 to 4.7 ($p<0.05$ for all comparisons). Attractiveness ratings also trended upwards following rejuvenative surgery, from 3.5 to 3.8 ($p=0.06$) (Figure 6).

Eye-tracking sensitivity to asymmetry:

One of the patients in our stimulus group was affected by unilateral eye and brow ptosis. This resulted in a significant relative increase in visual fixation on the ptotic left side (10.76%) versus the right side (9.63%) of that face pre-operatively, which was reversed by the surgical intervention (4.53% versus 5.10% post-operatively) (Figure 7).

DISCUSSION

Eye-tracking is a research sensor modality that offers unique insight into the visual attention paid to environmental stimuli. One key feature of the technology is that it yields information that is reflexive and largely obscure to the research observer. In contrast, while overt self-reported data discloses subjects' opinions and emotions, it can be confounded by bias or inaccurate recollection. In order to better understand the impact of surgical rejuvenation on visual processing and character attribution of periorbital aging, we endeavored to obtain both forms of information in this study.

Eye-tracking technology has been used by industry to inform the analysis of human behavior, preferences, arousal, and decision-making.[9,10] In terms of research evaluation of visual attention to the human face, most studies published to-date have focused on congenital or acquired deformity, rather than on natural aging changes[11-16]. Cai et al.[11] did use eye-tracking to assess the gaze patterns of a mixed observer group (laypeople, medical students, plastic surgery residents, non-cosmetic plastic surgeons, and cosmetic plastic surgeons) who were exposed to 15 pairs of pre- and post-rhytidectomy images. However, their protocol did not determine the effect of aging changes -- or the surgical intervention -- on visual attention. Rather, it focused primarily upon the extent of observer experience in cosmetic surgery on respective gaze distribution across the face. More recently, Frautschi et al.[17] utilized eye-tracking with 25 naïve subjects observing pre- and post-operative images of 11 facelift patients. Confounding the interpretation of their study, however, was the fact that the 11 patients also underwent a total of 28 concurrent adjunctive facial aesthetic procedures (including 2 browlifts and 4 upper blepharoplasties). While they were able to demonstrate that the combination of surgical interventions reduced visual attraction to a variety of areas of facial aging, parsing out the specific impact of the many different procedures on gaze within various anatomic regions of interest is not possible from the information they reported.

In the current study, we placed the eye-tracking spotlight precisely on lay observers' reflexive perception of periorbital aging, and the possible influence that a combined browlift and upper blepharoplasty has on gaze patterns. Previous work by us and others has clearly demonstrated that humans focus up to 50% of their early visual attention on the periorbital region of any face[5,16], again underscoring the aesthetic importance of this anatomic zone. Moreover, a series of eye-tracking studies within the past 5 years have shown that observers' attention is drawn towards outlier facial deformities, defects, and asymmetries such as cleft lip[16,18], skin lesions[12], and nasal deviation[13]. In this study we sought to determine whether natural aging changes around the eyes and brow would be interpreted similarly to other types of facial irregularities; that is, would they draw preferential visual attention? To the contrary, we discovered that the rejuvenative intervention of browlift and upper lid blepharoplasty *increased* observers' attention to the eye and brow region. While this may seem counter-intuitive at first, at odds with earlier findings, deeper analysis offers a likely explanation. Prior studies questioned whether different types of standing anatomic aberrations attract visual attention, and repeatedly confirmed that in fact they do; but the capacity of facial reconstruction to alter those eye-tracking patterns has not been extensively evaluated. The Frautschi study[17] did evaluate the impact of rhytidectomy, but the area of deformity in question was primarily the neck and jawline which are not normally high attention regions when a face is observed from the frontal view. That is, rhytidectomy therefore reduces deformity in a relatively lower attraction zone and encourages any distracted attention to return to the normal zone of maximal concentration (the eyes). In our study, in contrast, the area of change corresponded to the anticipated zone of maximal concentration zone. That is, the hooding effect associated with natural aging reduces fixation upon the surgical target region of the eyes and brows (median 14.5%), while the rejuvenative intervention *increases* attention on this focal zone of the face (median 15.5%). The resultant post-operative pattern of gaze upon the lookzone of the eyes and brow more closely approximates what we have found in an unpublished cohort of 9 eye-tracked faces between 20-40 years of age (23.07%).

After discovering that our surgical intervention increased the proportion of visual fixation within the eye and brow region, while diminishing it in the forehead zone, we examined the association between two-dimensional surface area and fixation within periorbital lookzones. A significant correlation was discovered between % of total facial surface area and % of total facial visual fixation time for both the forehead (ρ=0.53, p=0.003) and eye & brow (ρ=0.41, p=0.028) lookzones. The implication of this analysis is that surgical rejuvenation increases visual attention with the eye and brow principally by expanding its surface area. Similarly, as the brows are lifted, the surface area of the forehead is reduced in line with a reduction in % visual fixation of that lookzone.

Observers' personality ratings of the faces were also collected, serving as a measure of explicit response to periorbital aging changes. The personality rating protocol demonstrated a clear improvement in positive character attribution in all domains for both genders following blepharoplasty and browlift. Those chosen attributes (sociable, capable, trustworthy, attractive, healthy) are likely closely interrelated, much in the way that attractiveness has been shown to be linked to perceived health[1]. Facial rejuvenation procedures, in general, have been shown to impact attractiveness ratings and perceived age[1,2,4,6,7]. The current study, however, provides new information as it is the first to specifically consider periorbital aging (and rejuvenation) and the explicit appraisal of a broad range of character attributes. While a sample of 14 patients is not large enough to perform a correlation analysis with sufficient statistical power (especially when the variables considered are evaluated on a relative (% visual fixation time) and qualitative (character attribution) scale, and the data are not normally distributed), the statistically significant eye-tracking patterns that we observed were aligned directionally with the statistically significant change in character attribution that we measured.

The number and detail of lookzones considered in this study also enabled us to reveal the asymmetric eye-tracking pattern of a patient with unilateral brow ptosis and compensatory contralateral frontalis hyperactivity (Figure 7). The eye-tracking data was consistent with prior information showing that the human threshold for detection of asymmetry in eyelid position at rest is 2 mm, and in brow position is 3.5 mm[19]. As a reflection of the convergent validity of our eye-tracking methodology, we demonstrated reversion towards more equivalent bilateral visual fixation in the periorbital region following browlift and upper blepharoplasty of an asymmetric patient. Consistent with our overall findings, positively valenced character attribution also improved with the balancing rejuvenative intervention.

Taken together, the explicit and implicit categories of information reported here may help inform patient and surgeon decision-making, revealing as it does tangible consequences of both periorbital aging and its surgical correction.

Conclusion

Our study provides objective data evaluating the effect of surgery on the aging brow and upper lid. Importantly, we have combined explicit human ratings of character attribution with implicit information derived from reflexive eye-tracking patterns. These findings may be useful to patients and their surgeons, informing them about the impact of facial aging in this critical region of the face where aging is so acutely perceived, and the potential effects that surgical unveiling of the periorbital area may have on others' explicit and implicit perception of them, including an improvement in the perception of their character.

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Figures

Figure 1. Twenty aesthetic regions of interest ("lookzones") were hand-drawn post-hoc onto each image using pre-determined anatomic landmarks.

Figure 2. Two patients who underwent browlift and upper lid blepharoplasty. Fig. 2a and 2b, male pre-operative and post-operative photos. Fig. 2c and 2d, female pre-operative and post-operative photos. Fig. 2e-2h, heatmapping of observers' gaze of those same four images, demonstrating greater relative focus of attention on the region of the eyes and brows following surgery.

Figure 3. Visual fixation times across periorbital lookzones. Observers' attention to the eye and brow area of the face increased, and attention to the forehead and lower eyelid regions decreased, following periorbital rejuvenative surgery.

Figure 4. Demonstration of expansion of eye and brow lookzone, and reduction of forehead zone.

Figure 5. Correlation of percentage of total facial surface area with percentage of total visual fixation, by lookzone.

Figure 6. Effect of periorbital rejuvenation on character attribution. The surgical intervention resulted in an increase in all 5 positively-valenced attributes as per observer ratings -- all $p<0.05$ except "attractiveness" ($p=0.059$).

Figure 7. A patient with unilateral left brow ptosis and dermatochalasis who underwent a left endoscopic brow lift and upper lid blepharoplasty. Fig. 7a, Note the compensatory right brow and upper lid over-elevation preoperatively. Fig. 7b, Post-operative improvement in balance of the eye and brow lookzone is demonstrated. reflected in C.

Figure 1

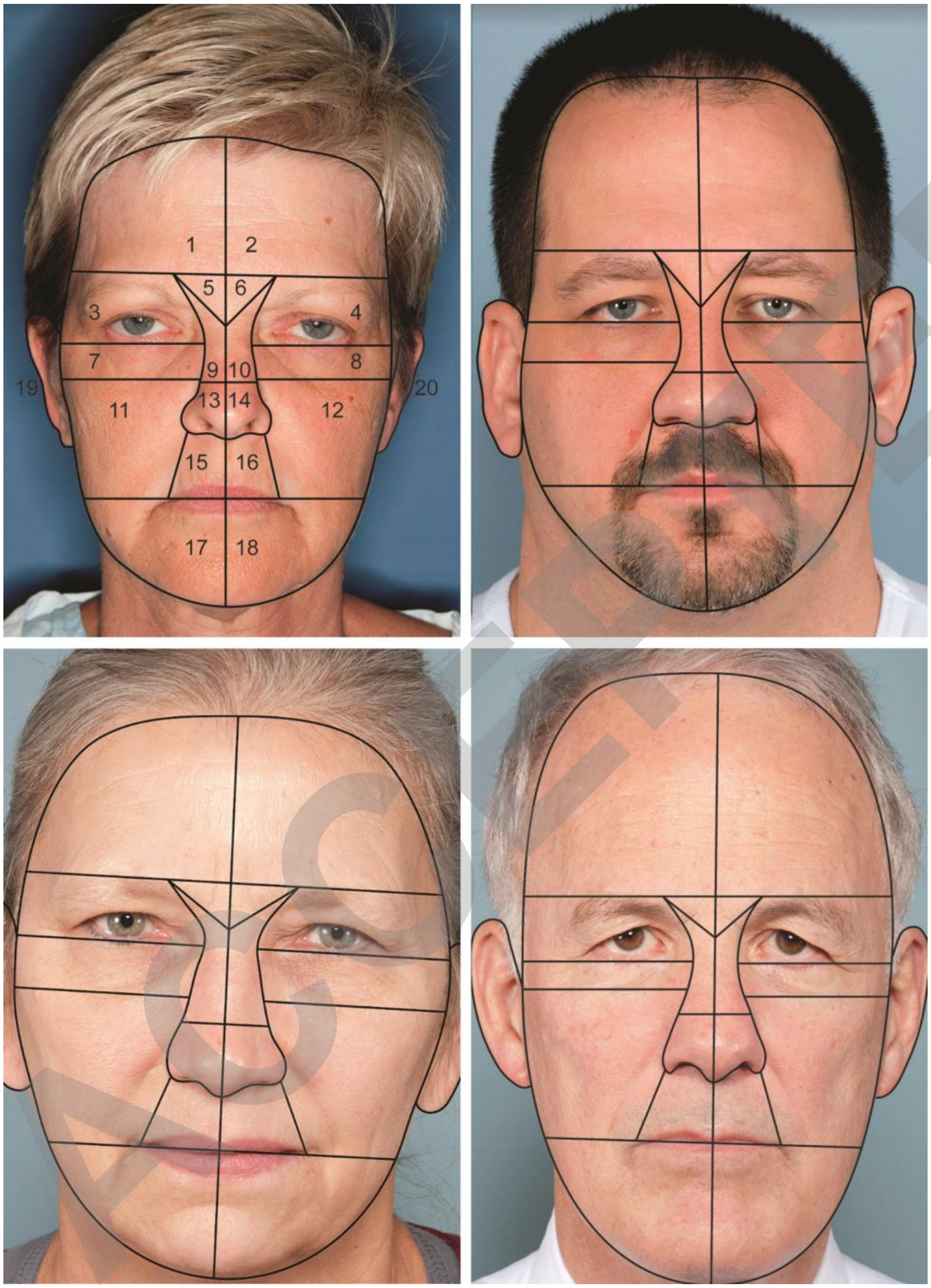
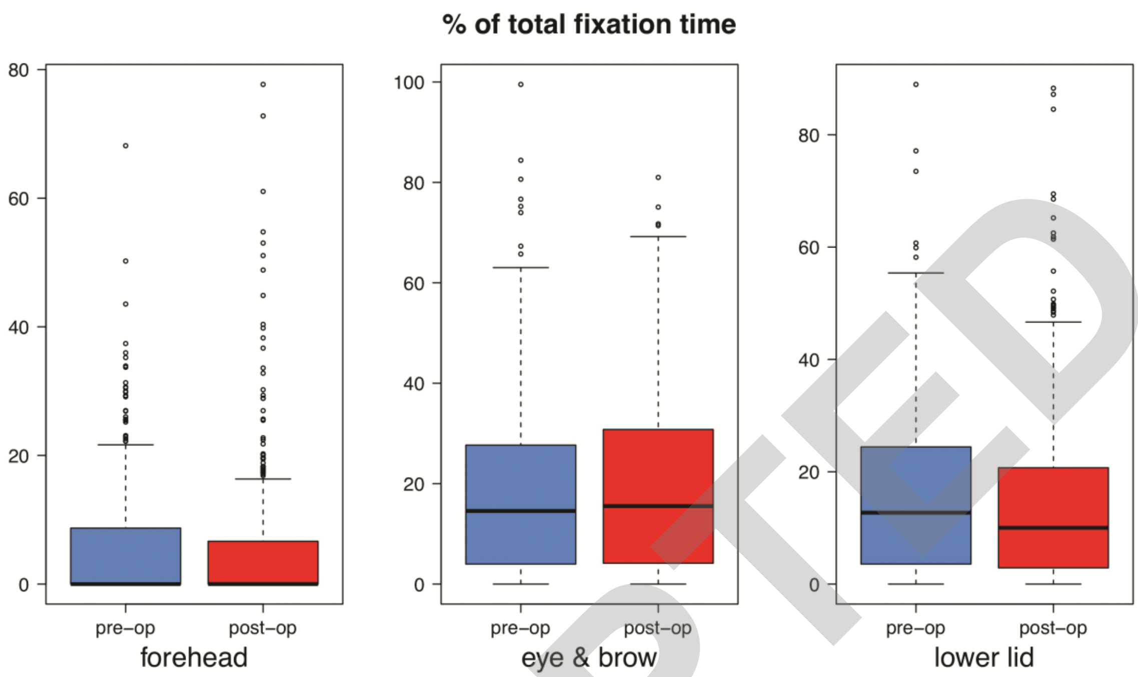


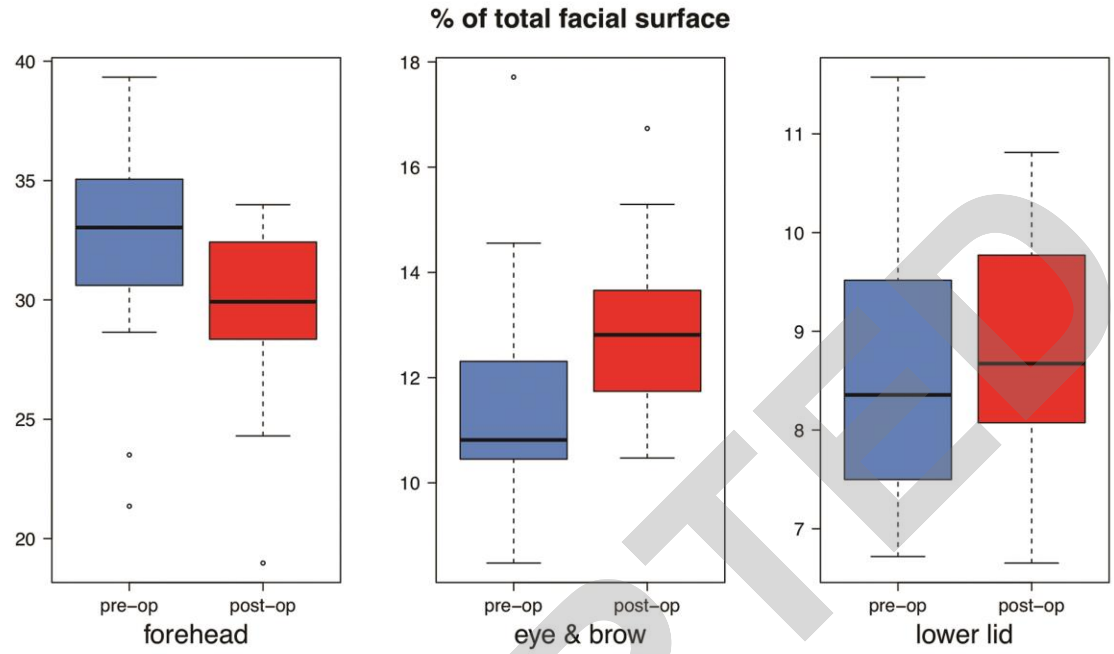
Figure 2

Figure 3



% of total fixation time
80
60
40
20
0
pre−op
post−op
forehead
100
80
60
40
20
0
pre−op
post−op
eye & brow
80
60
40
20
0
pre−op
post−op
lower lid

Figure 4


% of total facial surface
40
35
30
25
20
pre–op
post–op
forehead
18
16
14
12
10
pre–op
post–op
eye & brow
11
10
9
8
7
pre–op
post–op
lower lid

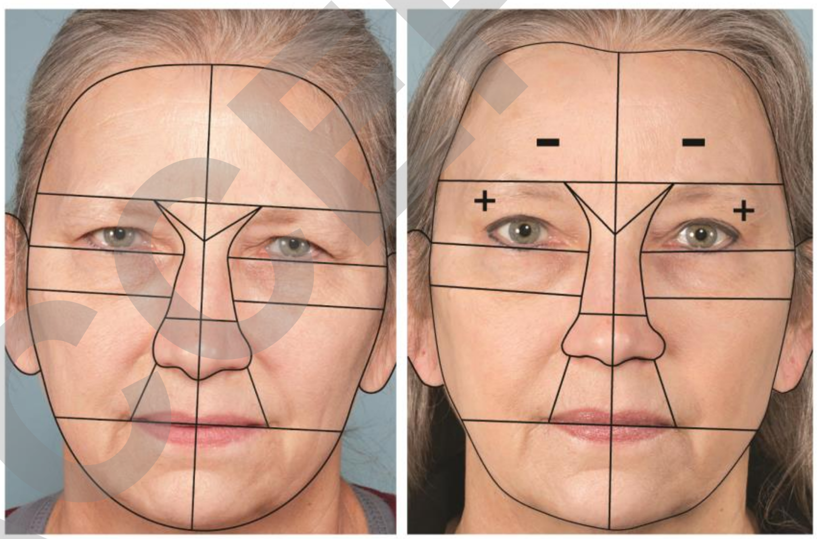

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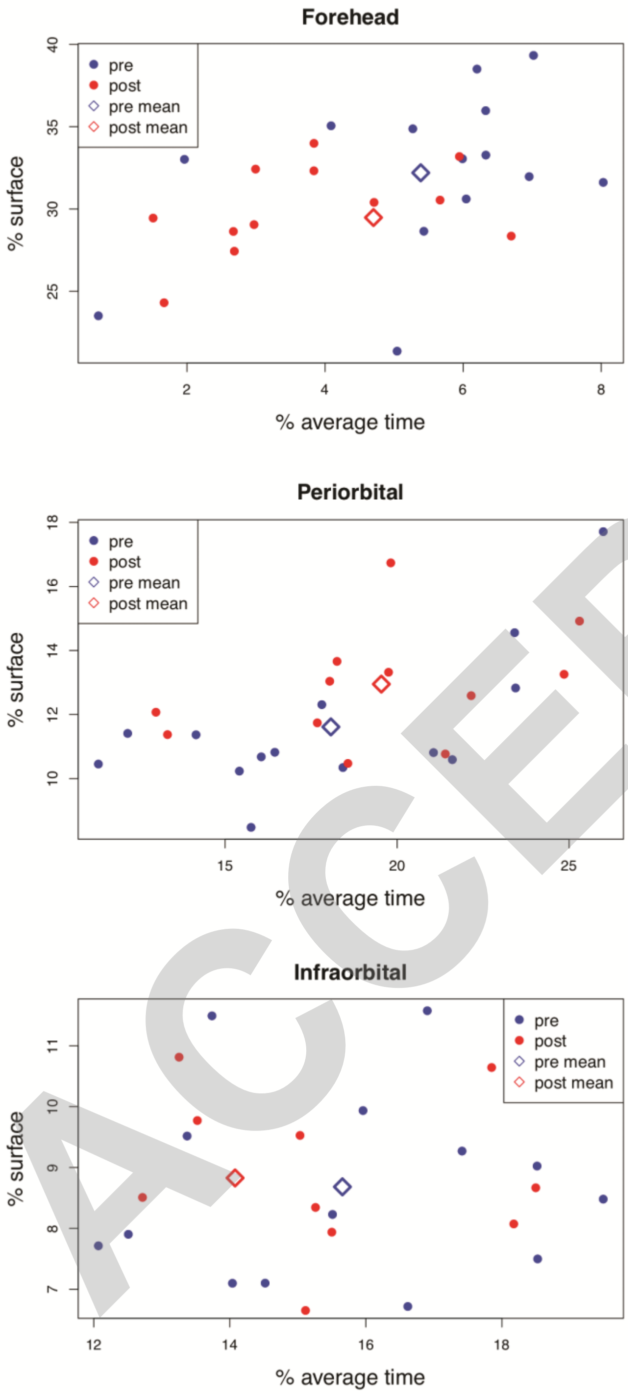
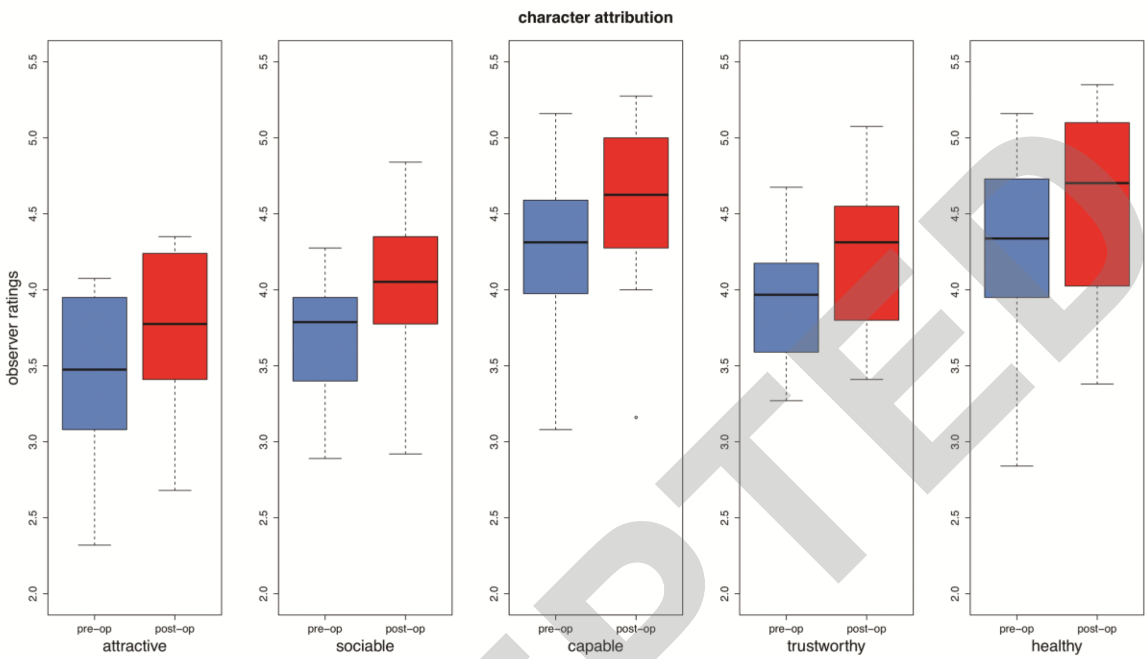
Figure 5



Forehead
pre
post
pre mean
post mean
% surface
% average time
Periorbital
pre
post
pre mean
post mean
% surface
% average time
Infraorbital
pre
post
pre mean
post mean
% surface
% average time

Figure 6



character attribution
observer ratings
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
pre–op
post–op
attractive
sociable
capable
trustworthy
healthy

Figure 7