Plastic and Reconstructive Surgery

Using Artificial Intelligence to Measure Emotional Expression Following Facial Reanimation Surgery

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Abstract:	Background : Social interactions are largely dependent on the interpretation of information conveyed through facial expressions. While facial reanimation seeks restoration of the facial expression of emotion, outcome measures have not addressed this directly. This study evaluates the use of a machine learning technology to directly measure facial expression before and after facial reanimation surgery. Methods: Fifteen study subjects with facial palsy were evaluated both before and after undergoing cross facial nerve graft and free gracilis muscle transfer. 8 healthy volunteers were assessed for control comparison. Video footage of subjects with their face in repose and with a posed, closed-lip smile was obtained. The video data was then analyzed using the Noldus FaceReader™ software application to measure the relative proportions of seven cardinal facial expressions detected within each clip. Results: The facial expression recognition application detected a far greater happy signal in post-operative (42%) versus pre-operative (13%) smile videos ($p<0.0001$), compared to 53% in videos of control faces smiling. This increase in postoperative happy signal was achieved in exchange for a reduction in the sad signal (15% to 9%, $p=0.092$) and the neutral signal (57% to 37%, $p = 0.0012$). For video clips of patients in repose, no significant difference in happy emotion was detected between pre-operative (3.1%) and postoperative (1.4%) states ($p=0.5$). Conclusion: This study provides the first proof of concept for the use of a machine learning software application to objectively quantify facial expression before and after surgical reanimation.
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Dr. Rod Rohrich April 11, 2019

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Plastic and Reconstructive Surgery

Dear Dr. Rohrich,

Please find enclosed our manuscript entitled "Using Artificial Intelligence to Measure Emotional Expression Following Facial Reanimation Surgery" by Boonipat *et al* to be considered for publication as an original article in Plastic and Reconstructive Surgery.

Given the rising presence of artificial intelligence in our society, and the increasing access to sophisticated techniques in surgical facial reanimation, we believe that our work that demonstrates a novel application of machine learning technology will be of broad interest to the readers of your journal.

We attest that the research described in this manuscript is original, has not been previously published, and is not currently being considered for publication elsewhere. The authors have no conflicts of interest to declare.

As Corresponding Author, I confirm that the manuscript has been read and approved for submission by all the named authors.

Thank you for your consideration.

Respectfully,

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Using Artificial Intelligence to Measure Facial Expression Following Facial Reanimation Surgery

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Short Running Head: AI to measure facial expressions

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Abstract:

Background: Social interactions are largely dependent on the interpretation of information conveyed through facial expressions. While facial reanimation seeks restoration of the facial expression of emotion, outcome measures have not addressed this directly. This study evaluates the use of a machine learning technology to directly measure facial expression before and after facial reanimation surgery.

Methods: Fifteen study subjects with facial palsy were evaluated both before and after undergoing cross facial nerve graft and free gracilis muscle transfer. 8 healthy volunteers were assessed for control comparison. Video footage of subjects with their face in repose and with a posed, closed-lip smile was obtained. The video data was then analyzed using the Noldus FaceReader™ software application to measure the relative proportions of seven cardinal facial expressions detected within each clip.

Results: The facial expression recognition application detected a far greater happy signal in post-operative (42%) versus pre-operative (13%) smile videos ($p<0.0001$), compared to 53% in videos of control faces smiling. This increase in postoperative happy signal was achieved in exchange for a reduction in the sad signal (15% to 9%, $p=0.092$) and the neutral signal (57% to 37%, $p = 0.0012$). For video clips of patients in repose, no significant difference in happy emotion was detected between pre-operative (3.1%) and postoperative (1.4%) states ($p=0.5$).

Conclusion: This study provides the first proof of concept for the use of a machine learning software application to objectively quantify facial expression before and after surgical reanimation.

INTRODUCTION

Social interactions are largely dependent on the interpretation of information conveyed through facial expressions.[1] Humans have a uniquely broad and complex array of facial mimetic movements that allow for the delivery of non-verbal cues ranging from dramatic to nuanced. Seven cardinal facial movement patterns have been detected universally, corresponding to the emotions of happiness, sadness, anger, surprise, fear, disgust, and neutral[2]. Any impairment in the ability to legibly and appropriately express these emotions represents a significant social disability.[3-5] The attenuated or incongruous facial expressions that are associated with facial palsy[4,6] can lead to stress, social misinterpretation, embarrassment and the ultimate avoidance of social engagement.[3-5,7,8] The evaluation of facial palsy and surgical reanimation, therefore, must not only consider static and dynamic measures of movement, vector, and power, but also be able to quantify emotional expression.[9,10]

We tested a commercially available artificial intelligence system trained and validated using the Amsterdam Dynamic Facial Expression Set,[11] a highly standardized set of images containing the different emotional expressions. This machine learning application is able to analyze video data and provide an objective measure of facial expression, generating a relative breakdown of each of the 7 basic emotions. We employed this system to measure the impact of facial reanimation surgery on the detection of happiness contained within a smile. To our knowledge, this is the first report on the use of an artificial intelligence method to read the faces of plastic surgical patients.

METHODS

After obtaining Institutional Review Board approval, we retrospectively identified all patients who underwent cross facial nerve graft and free gracilis muscle transfer for facial reanimation at our institution between 2011 and 2018. Pre and post-operative video clips were obtained

for all patients, and they were asked to first assume a neutral repose position and then smile naturally without teeth showing. Recording was performed using a Canon XH-A1S 3CCD HDV Camcorder positioned 1.5 meters away from the patient.

Patients were excluded if no video clips were available for them at least four months after the final facial reanimation procedure. For patients with multiple postoperative video clips, the most recent one was chosen for analysis of facial expression. Video recordings of (n=8) healthy volunteers both smiling and in repose were also collected. Each clip was 1 to 3 seconds in duration.

Videos were analyzed using a commercially available facial expression recognition software package (FaceReader™, Noldus Information Technology BV, Wageningen, Netherlands). The data generated reflects the proportion of each emotion expressed for any given facial movement.

The capability of the software to classify facial expressions was achieved by training an artificial neural network, using over 10,000 images that were manually annotated by trained experts.[11-16] The system assesses the movements of more than 500 facial landmarks on each face to perform the classification.

Differences between paired continuous variables were assessed using the nonparametric Wilcoxon signed-rank test comparing facial emotions detected by the facial expression recognition technology pre- and post-operatively. All statistical analysis was performed using JMP (SAS Institute Inc.). A value of $p < 0.05$ was considered statistically significant.

RESULTS

We identified 15 patients who underwent cross facial nerve graft (CFNG) and free gracilis muscle transfer. Average age was 36 years, and shortest time interval between the reanimation procedure and the postoperative video was 10.2 months.

The average happy emotion detected in smile videos increased significantly from a rating of 13% pre-operatively to 42% post-operatively ($p<0.0001$), while in the control group happy emotion with smiling was rated at 53% (**Figure 1A**). For the neutral (repose) videos, no significant difference was found in average happy emotion between pre-operative (3.1%) and postoperative (1.4%) videos ($p=0.5$) (**Figure 1B**).

The increase in the "happy" signal postoperatively was achieved at the expense of the "sad" signal (15% to 9%, $p=0.092$) and the "neutral" signal (57% to 37%, $p = 0.0012$). The predominant alternative emotion detected during smile was *neutral* (57% preoperatively, 37% postoperatively) (Supplemental Digital Content 1 and 2 represents result for a representative patient).

DISCUSSION

For decades, researchers have studied expression by manually annotating and measuring facial anatomic landmarks, looking for various patterns and associations[2]. With the advent of techniques in artificial intelligence, software applications now exist that greatly facilitate that process, and facial recognition systems have thus been ushered into the cultural mainstream such as the FaceID on Apple's iPhones and Biometric face recognitions in airports.[17,18] The system that we utilized in this study was designed specifically to integrate facial movement combinations in order to quantify the proportion of different emotions conveyed during active facial expression.[11,14,15,19] The use of a machine learning system to read facial emotional expression – and to quantify the legibility of intended expressions – could represent a paradigm shift in the evaluation of facial palsy and its surgical management. Our study analyzed the faces of patients with unilateral facial palsy before and after two-stage facial reanimation surgery both in repose as well as when posing with a closed-lip smile. The testing method detected an alteration in the happy expression of smiling patients with facial

palsy. This difference was significantly reduced following facial reanimation surgery but did not match normal levels.

Interestingly, the increase in happiness measured in postoperative versus pre-operative smiles was achieved mostly in exchange for a reduction in sad and neutral signals, suggesting the inappropriate conveyance of a blunted or sad expression with facial palsy.

There are important implications of this work. Most notably, the study represents a proof of concept for the use of artificial intelligence as an objective means of analyzing facial expression in a condition characterized by facial expressive dysfunction. It offers a novel approach for the evaluation of reconstructive intervention by quantifying both surgical benefits as well as residual deficits. Moreover, the impact of other facial conditions and corrective procedures can be assessed using the same artificial intelligence technology.

One notable limitation of this study is that we tested only the closed-lip smile which more closely reflects the reanimated movement that is achieved surgically. The software application that we utilized is designed to detect natural smiles involving upper lip elevation and dental show. That is the likely explanation for why our control group scored a modest 53% happy emotion rating.

The method we describe, by considering the effectiveness of a facial expression in a holistic manner, integrates an assessment of symmetry, excursion, and timing in all regions of the face. It eliminates intra- and inter-observer variability that is unavoidable with human evaluation[20], and may impact patient-reported outcome measures and observer evaluations.

CONCLUSION

This study proposes a paradigm shift in the clinical evaluation of facial palsy, implementing an existing facial emotion recognition application to quantify changes in expression associated with facial reanimation surgery.

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Figure Legends:

Figure 1. a) Percent of emotion detected in smiles, pre-operatively and post-operatively; b) Percent of emotion detected in neutral, pre-operatively and post-operatively.

Figure, Supplemental Digital Content 1 and 2:

Screenshots of the output from the software application of a female patient: a) Pre-operatively; b) Post-operatively.

Figure 1A

Click here to access/download;Figure;Figure 1a smile summary bar charts smile.jpg

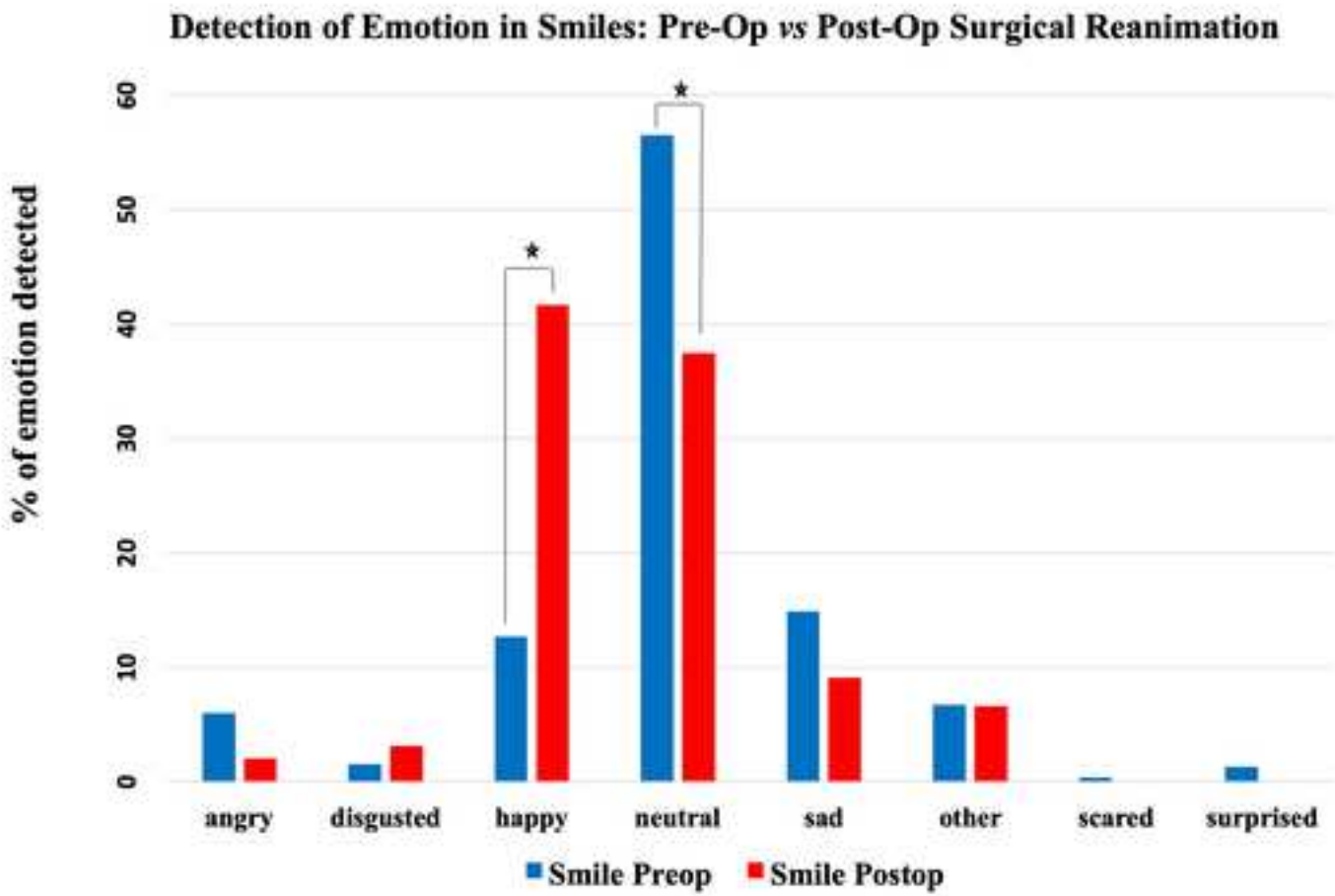
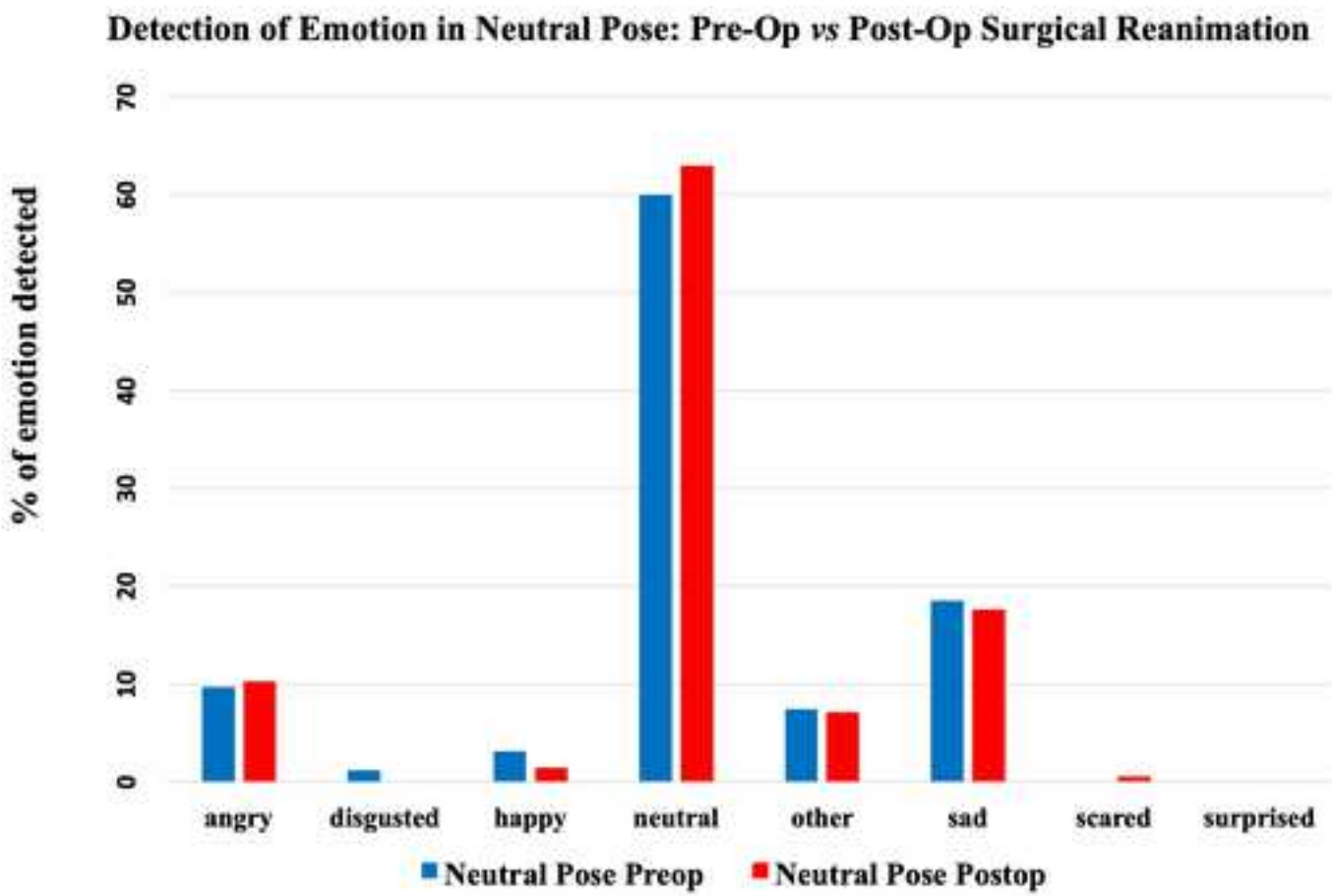
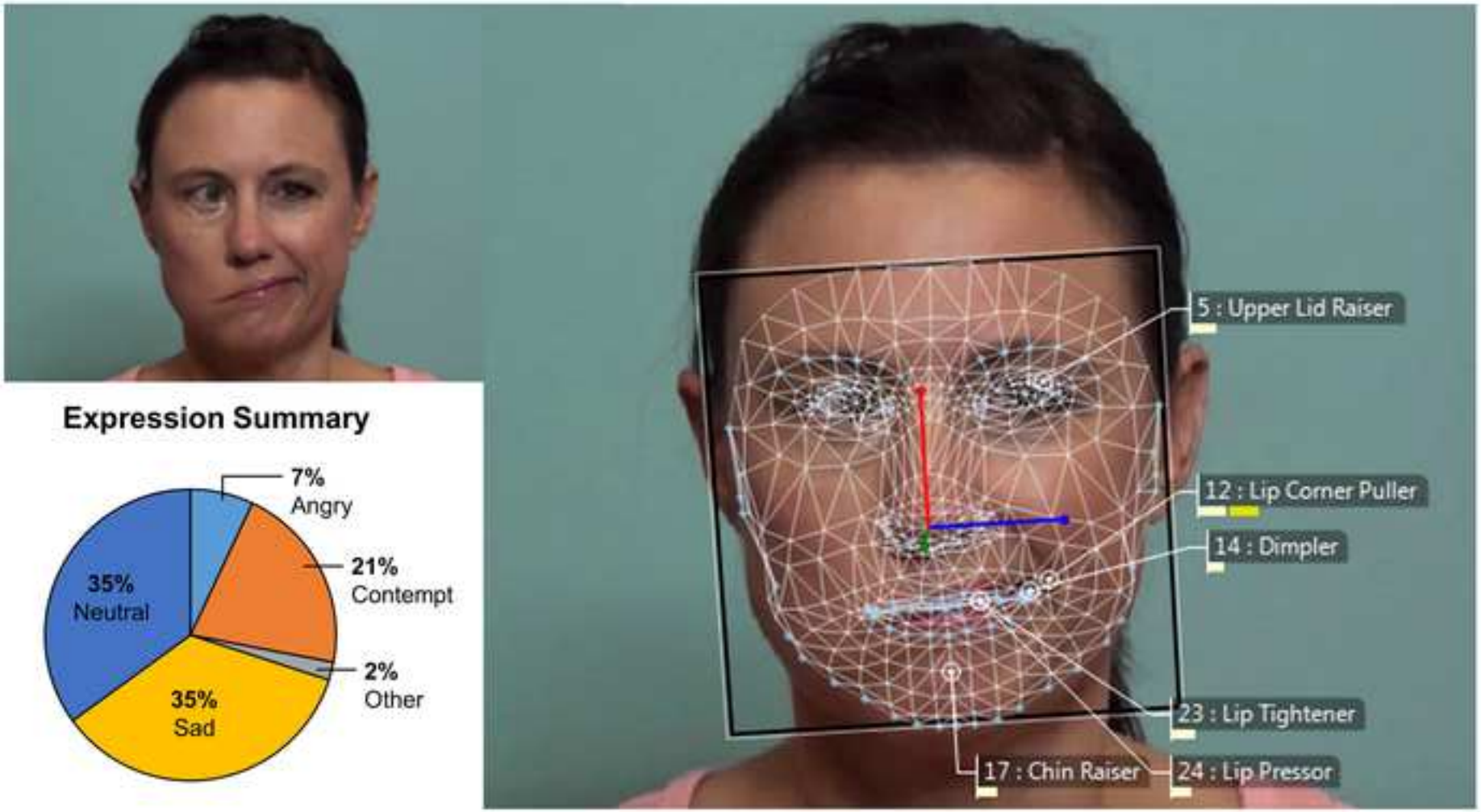
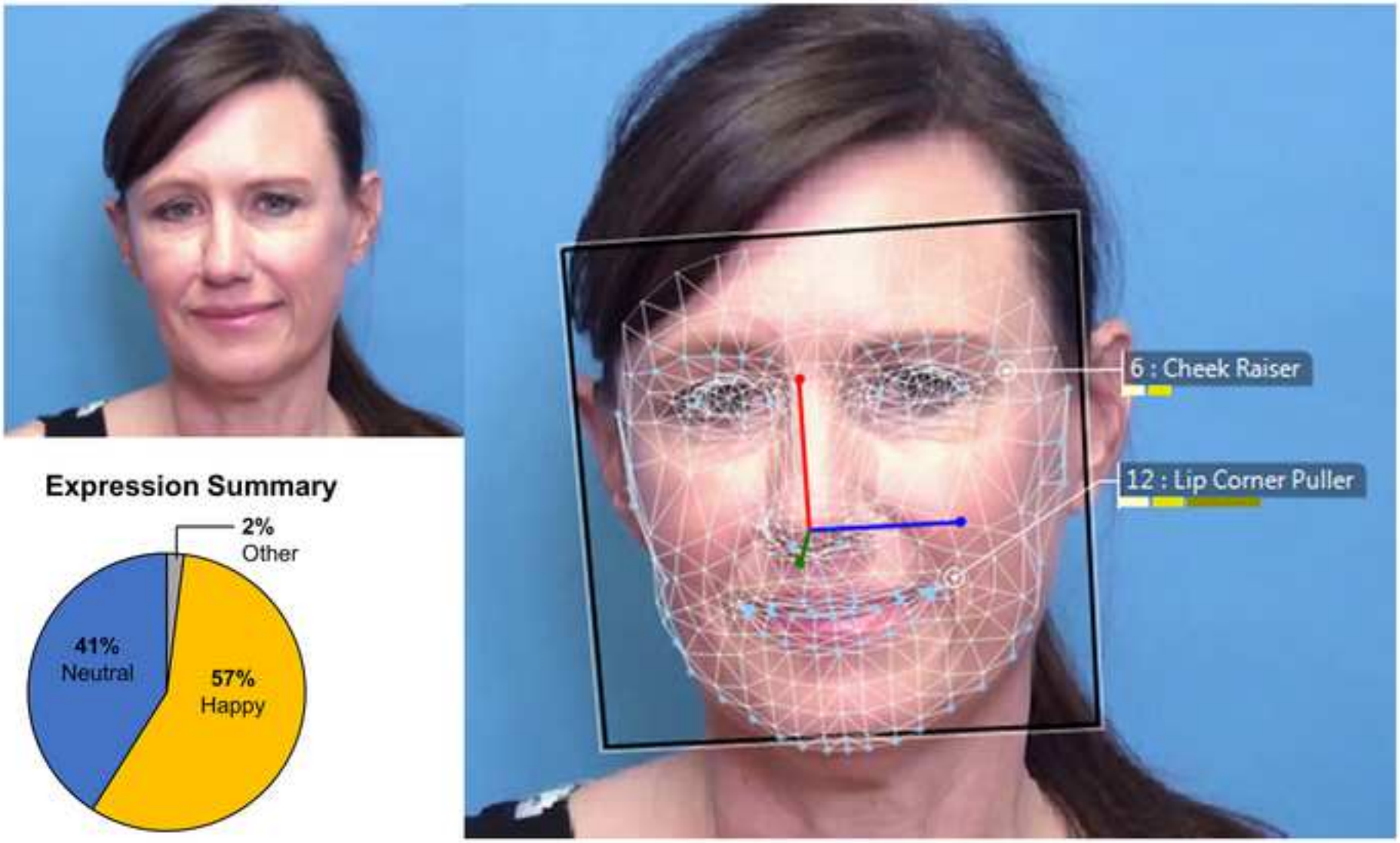


Figure 1B







Dr. Rod Rohrich

December 2, 2019

Editor-in-Chief

Plastic and Reconstructive Surgery

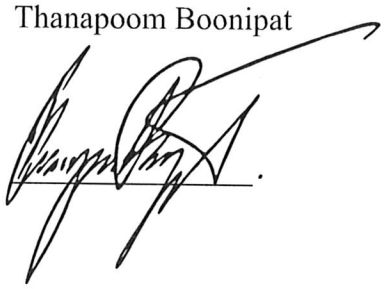
Dear Dr. Rohrich,

I am writing to kindly request that Dr. Mitchel Stotland and Dr. Samir Mardini be listed as co-senior authors in our accepted manuscript "Using Artificial Intelligence to Measure Emotional Expression Following Facial Reanimation Surgery"" PRS-D-19-01135. The author order would remain the same:

Thanapoom Boonipat, M.D.; Malke Asaad, M.D.; Jason Lin, BS; Graeme E. Glass, M.D.; Samir Mardini, M.D.; Mitchell Stotland, M.D.

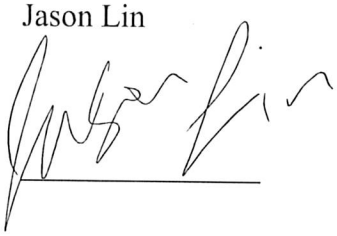
All authors have agreed to the above-mentioned changes and provided their signatures accordingly:

Thanapoom Boonipat



Malke Asaad

Jason Lin



Graeme Glass

Samir Mardini

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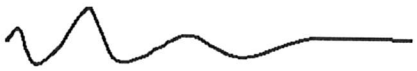

Respectfully,

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