The Laryngoscope

What Faces Reveal: Impaired Affect Display in Facial Paralysis

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Objectives/Hypothesis: To evaluate affect display in patients with facial paralysis as compared with normal subjects. We hypothesized that patients with facial paralysis would have impaired affect display and be perceived as displaying a negative affect as compared with normal subjects.

Study Design: Randomized controlled experiment.

Methods: Forty naive observers viewed pictures of patients with facial paralysis and normal faces. Observers classified the affect display of the patients and normal subjects by using a survey containing choices regarding primary emotions and personal attributes.

Results: An exploratory latent class analysis was performed on the survey results, and the faces were categorized into three types: positive, negative, and neutral. The probability of interpreting normal smiling faces as positive was 98%; the probability of interpreting those in repose as neutral or positive was 60%. The faces with facial paralysis were much more likely to be regarded as negative or neutral. The probability for classification into the negative class was 73% for the paralyzed faces in repose and 69% for the paralyzed smiling faces. In the latent class regression, smiling normal faces were six times more likely to be classified as positive, and smiling paralyzed faces were three times less likely to be in that class.

Conclusions: Patients with facial paralysis were classified as having a negative affect display the vast majority of the time. Antithetically, normal faces in repose were classified as neutral the majority of the time; they were classified as positive the majority of the time when smiling. These novel results demonstrate the impact of the facial paralysis defect on perception by observers.

Key Words: Facial paralysis, affect display, emotion.

***Laryngoscope,* 121:1138–1143, 2011**

INTRODUCTION

Our face speaks volumes about us before we ever say a word. Faces convey a wealth of information such as identity and gender. They also play a key role in affect display, the external display of one's emotions. As Darwin noted more than a century ago in *The Expression of the Emotions in Man and Animals*,[1] facial expressions of emotion are universal and highly conserved. Vitally important for verbal and nonverbal communication, facial expression is also fundamental to one's sense of well-being and ability to integrate into a social network.[2] "Emotional contagion" is the psychology term referring to the ability to communicate a certain mood on the one hand and to be empathic with people on the other hand.[3] In other words, it is our ability to get "in tune" with those around us. Impaired ability to form facial expressions therefore has the potential to result in dramatic social and emotional disruption.[4]

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Editor's Note: This Manuscript was accepted for publication January 26, 2011.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.21764

Patients with facial paralysis have impaired facial movement and facial asymmetry at rest. The muscles of facial expression are critically important for affect display and communication. This restriction of facial expression can have a dramatic impact on interpersonal relations.[4] Communication with others is disrupted when limitation of their facial actions prevents the cascade of emotional contagion. We have a reasonable understanding on how these impairments lead to a diminished quality of life from survey data completed by patients.[5] We have limited objective data on the impact of facial paralysis on affect display. The objective of the present study was to evaluate affect display in patients with facial paralysis as compared with normal individuals. We hypothesized that patients with facial paralysis would have impaired affect display as compared with normal individuals when they were attempting to perform the same facial expressions. Our subhypothesis was that the observers would assign negative emotional states and personal attributes to faces with facial paralysis. These hypotheses were explored with a latent class analysis.

MATERIALS AND METHODS

Participants

Institutional review board approval was received for this study. A group of 40 randomly selected subjects (17 females and 23 males) participated in the study from March to July 2010. An investigator stood at the entrance to the Johns Hopkins

Outpatient Center and asked every 10th individual if they would be interested in completing a survey. This entrance is one used by patients, employees, family, and friends of patients and thus was felt to be representative of the population of the city of Baltimore. Ages ranged from 18 to 61 years. Individuals were excluded as subjects if they had affective psychiatric conditions (schizophrenia, autism and related spectrum diseases) owing to established differences in the way individuals with those disorders view and direct attention toward a face, as well as how they convey and are able to infer emotional states from a person's face.[6]

Instrument

We created a survey to study affect display in normal and paralyzed subjects. Photographs for the survey were selected at random from our clinical archive of facial images by using keywords to locate the photographs. A random number generator was then used to select from that bank 48 photographs of 24 patients then used in the survey. Twelve of the patients had no lesions or paralysis and were considered normal controls. Twelve of the patients had upper and lower division facial paralysis. Seven of the facial paralysis patients had left-sided paralysis and five had right-sided paralysis. A smile photograph and a repose photograph were used for each patient. Survey questions were associated with each photograph. To mitigate repeated measure effects, the survey was evenly split, in a random fashion, into two mutually exclusive questionnaires that contained one photograph and associated questions from each of the 24 patients. That is, one questionnaire contained a smile photograph of a patient while the other contained a repose photograph, but none of the questionnaires contained both a smile and a repose photograph of the same patient; the smile and repose photographs were randomly assigned to the questionnaires. Each subject was randomly assigned to answer only one of the two questionnaires.

The survey questions were designed to measure how observers perceive affect display in faces with and without facial paralysis. For each picture, subjects were given 11 choices and were asked to pick the ones that best described the person in the photograph. Five of the choices were of primary emotions (happy, disgust, anger, sadness, and fear) for which facial expressions are universally characteristic of the human species, as described by Ekman et al.[7,8] The remaining six choices represented the following personal attributes: trustworthy, friendly, neutral, hostile, energetic, and tired. The choices were posed and recorded in a dichotomous fashion, that is, whether the photograph displayed a particular emotion or attribute or not.

Procedure

Informed consent was obtained from each subject. After successful enrollment, all subjects answered a brief demographic questionnaire to control for possible demographic covariant factors and to check consistency. Brief instructions were given to each subject, and then they were randomly assigned to answer one of the two questionnaires in an untimed fashion.

Data Analysis

Survey data were maintained in an Excel (Microsoft Corp., Redmond, WA) spreadsheet. Latent class regression analysis was performed in R (R Foundation for Statistical Computing, Vienna, Austria) using the poLCA package.[9,10] The poLCA estimates the latent class model using a modified[11] expectation-maximization algorithm.[12] This algorithm is subject to finding local rather than global maximum to the log-likelihood function. To avoid this issue, we estimated the latent class model 1,000 times with different randomly chosen initial conditions and used the model with the greatest log-likelihood for our analysis. The number of latent classes used in our analysis was determined by repeatedly fitting latent class models with increasing numbers of latent classes and choosing the model that minimized the Bayesian information criterion (BIC)[13] and the Akaike information criterion (AIC).[14] BIC and AIC are parsimony criteria that seek a balance between over- and underfitting a model by penalizing the log-likelihood function by the number of parameters being estimated. Two covariates were used to elucidate latent class membership: the presence of paralysis and smiling. These covariates were allowed to interact. Standard errors for the predicted latent class membership were obtained by estimating variances from resampled data; 1,000 bootstrap samples were used. Bias was negligible, and confidence intervals were obtained from the bootstrap results using the percentile method. Post hoc bootstrap hypothesis testing was performed to study the significance of the predicted probabilities of latent class membership. A total of 7,200 samples were used for each test. Multiple tests were performed; the tests were assumed to be dependent, so the Bonferroni procedure was used to control for the experiment-wide error rate. We set the significance level for our study at $\alpha = .05$.

RESULTS

Demographics

The population surveyed was heterogeneous in terms of age, income status, and racial distribution.

Latent Class Analysis

Forty subjects were enrolled in this study; each subject viewed 24 images and answered 11 questions per photograph. A total of 960 responses were thus collected; 96 responses were associated with incomplete data, that is, one or more of the 11 dichotomous questions were not answered or were answered incorrectly. These responses were removed from the data set. A χ^2 analysis of the 11-way contingency table showed that the manifest variables were too interrelated to attribute this pattern to chance alone; that is, the null hypothesis that the 11 variables were independent was rejected, $\chi^2(853) = 5984$; $P < .001$.

We note that primary emotions and our chosen attributes can be separated into positive, neutral, and negative dimensions,and we speculate that normal smiling and repose faces emote positive and neutral to negative feeling, respectively.[7] We further assume that affect display is unimpaired in nonparalyzed faces and that normal observers will naturally and correctly assign faces to their appropriate emotive class. We conjecture that affect display is impaired in paralyzed faces and that normal observers will incorrectly interpret the emotional status of faces but still classify them into a positive, negative, or neutral class. We therefore hypothesize that the dependencies between the 11 variables can be explained by a smaller class of latent variables, such that the 11 variables are conditionally independent based on the states of the latent variables, and that the latent variables will at the very least

TABLE I.
Fit and Parsimony Criteria for Latent Class Models as a Function of Class Number.

No. of Latent Classes	Ln(*L*)	AIC	BIC	Pearson c^2	dF	*P* Value
1	−3783.6	7589.2	7641.6	5984.5	853	<.001
2	−3168.5	6389.1	6512.9	1115.0	838	<.001
3	−3041.0	6166.0	6361.2	810.1	823	.619
4	−3030.1	6172.2	6438.8	577.6	808	~1

Ln(*L*) = log likelihood; AIC = Akaike information criterion; BIC = Bayesian information criterion; dF = degrees of freedom; *P* value = *P* value for c^2.

include three constructs to represent the positive emotion/attribute class, the neutral attribute class, and the negative emotion/attribute class. Because we expect affect display is hindered in paralyzed patients, we anticipate class membership probabilities will be different for the normal and paralyzed faces.

We performed exploratory latent class analysis to test these hypotheses. We fit four latent class models: a null model, which assumed all 11 variables were independent, and three models with increasing (2, 3, and 4) numbers of latent classes. Two covariates, smile and paralysis, were also included in the model. Measures of fit and parsimony for all models are shown in Table I. Based on the two parsimony measures, AIC and BIC, the three latent class model was the most parsimonious, so we chose it for our analysis. The conditional and latent class probabilities for the three-class model are shown in Table II. The conditional probabilities are also displayed graphically in Figure 1. The first latent class is dominated by negative emotions and attributes, so we term this the negative class. This class accounted for 44% of all the responses. In other words, 44% of the faces shown were considered negative. The second class was dominated by happy emotion and energetic, friendly, and trustworthy attributes, so we denoted this as the positive class; 33% of responses fit this category. The final class was dominated by the neutral attribute and was therefore named the neutral class; 23% of the responses were neutral. These classification percentages were for the model as a whole. To understand how paralysis and smiling affected class membership we turned to our regression results.

The latent class regression coefficients are shown in Table III. Because the negative latent class was used as a reference, its coefficients were by definition equal to zero. The regression coefficients are related to the mixing probabilities, i.e., the predicted probabilities of latent class membership, by the following equation:

$$p_{r,i}(\mathrm{X}_i;\beta) = \frac{e^{\mathrm{X}_i \bullet \beta_r}}{\sum_{q=1}^{R} e^{\mathrm{X}_i \bullet \beta_q}}, \qquad (1)$$

where $p_{r,i}$ is the mixing probability for class r^{th} class and i^{th} response, β_{r} is the coefficient vector for the r^{th} class, X_i is the covariate vector for response i, and R is the total number of latent classes. The latent class probabilities were obtained by averaging Equation 1 over all responses. We plotted the predicted probabilities of latent class membership as a function of the smile and paralysis covariates in Figure 2 and Figure 3. The predicted probabilities, standard errors, and 95% confidence intervals are listed in Table IV. All of the coefficients for the positive class were significant; only the paralysis coefficient was significant in the neutral class.

We note that Equation 1 imposes a constraint on the predicted probabilities, that is, the predicted probabilities for all three classes are defined by the coefficients listed in Table IV; nonetheless, it is still informative to formally test whether the predicted probabilities for the negative class vary as a function of the covariates. Because the probability distributions for the differences of predicted probabilities were not normal, we performed these comparisons by estimating the distribution of the differences using 7,200 bootstrap samples per test. A test was considered significant if the adjusted confidence intervals did not include zero. The

TABLE II.
Conditional and Latent Class Probabilities for the Three-Class Model.

	Class 1: Negative	SE	Class 2: Positive	SE	Class 3: Neutral	SE
Angry	0.188	0.022	<0.001	<0.001	<0.001	<0.001
Disgusted	0.246	0.024	<0.001	<0.001	0.026	0.016
Energetic	0.019	0.008	0.216	0.028	0.011	0.008
Friendly	0.044	0.013	0.553	0.035	0.098	0.023
Happy	<0.001	<0.001	0.749	0.030	0.017	0.011
Hostile	0.138	0.020	0.023	0.001	0.016	0.012
Neutral	0.095	0.030	0.034	0.013	1.000	<0.001
Sad	0.036	0.028	<0.001	<0.001	0.072	0.026
Scared	0.177	0.021	0.010	0.007	0.007	0.010
Tired	0.272	0.025	0.060	0.015	0.120	0.027
Trustworthy	0.029	0.010	0.213	0.028	0.041	0.015
Latent class probabilities	0.437	0.019	0.330	0.011	0.233	0.018

SE = standard error.

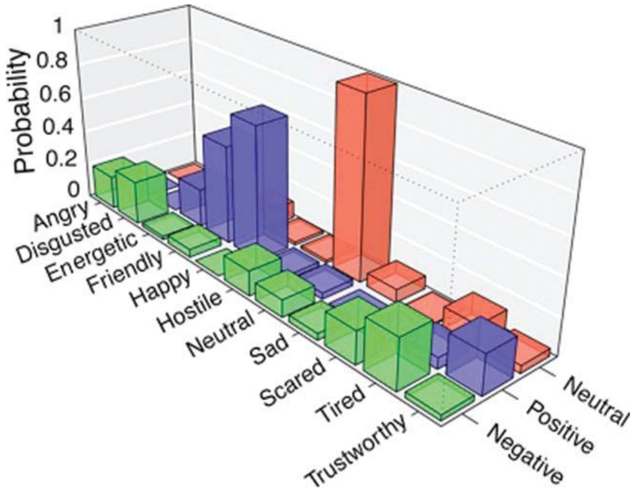

Fig. 1. Conditional probabilities for the negative, positive, and neutral latent classes as a function of manifest variables. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

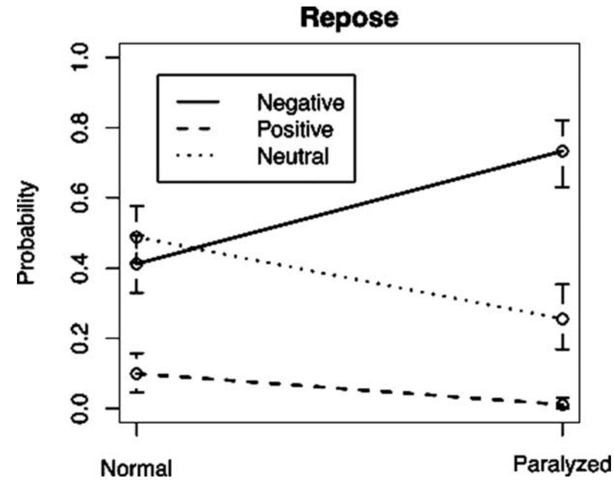

Fig. 2. Predicted probabilities of latent class membership as a function of the paralysis covariate for the repose photographs. The 95% confidence intervals are plotted as well.

confidence intervals were adjusted for multiple comparisons by using the Bonferroni procedure, i.e., $CI = 1 - a/m$, where CI denotes confidence intervals, "a" is the size of type I error, and "m" is the number of comparisons—in our case equal to 6. The results are shown in Table V. All of the comparisons except for that of smile paralysis to repose paralysis were significant.

These findings show that paralysis significantly affects affect display. Paralyzed faces are most likely to be viewed as displaying negative emotions and attributes. Paralyzed faces in repose have a roughly 1% chance of being viewed positively, compared to a 10% chance for a normal face in repose. Smiling increases this probability to 23% for paralyzed faces compared to 98% for normal faces. In our study, smiling did not change the likelihood of being viewed negatively or neutrally in paralyzed patients as opposed to normal faces.

DISCUSSION

This experiment revealed multiple interesting findings about affect display in patients with facial paralysis as compared to normal individuals. There were distinct differences in affect display between patients with facial paralysis and normal individuals as perceived by casual observers. From the patterns of associations of the 11 emotions and attributes, the exploratory latent class analysis identified three independent latent variables, positive, negative, and neutral. As a group, normal faces were most likely to be classified as either positive or neutral. Within that group, the probability for observers to interpret normal smiling faces as positive was 98%, and the probability for observers to interpret normal faces in repose as neutral or positive was 60%. On the contrary, as a group, faces with facial paralysis were much more likely to be regarded as negative or neutral. The probability for classification into the negative class was 73% for the paralyzed faces in repose and 69% for the paralyzed smiling faces. In the latent class regression, smiling normal faces were six times more likely to

TABLE III.
Estimated Coefficients of Covariates.

	Coefficients (b_2)	Standard Error	*t* Value	*P* Value
Positive Latent Class				
Intercept	−1.422	0.294	−4.825	<.001
Smile	6.257	1.009	6.204	<.001
Paralysis	−2.771	0.775	−3.574	<.001
Smile*paralysis	−3.019	1.258	−2.400	.017
Neutral Latent Class				
Intercept	0.167	0.169	0.992	.322
Smile	0.103	1.319	0.078	.938
Paralysis	−1.221	0.241	−5.070	<.001
Smile*paralysis	−0.246	1.348	−0.183	.855

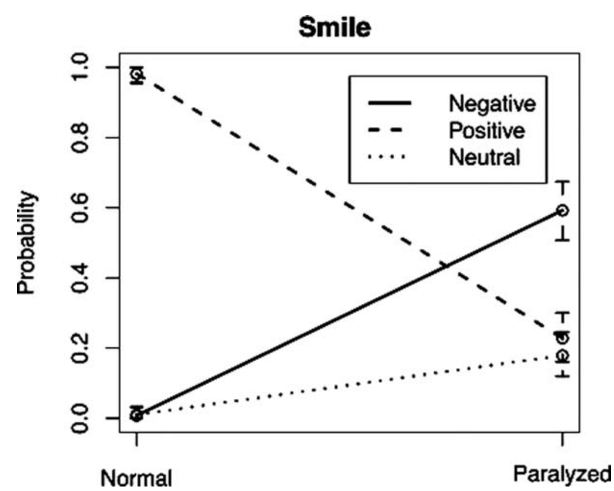

Fig. 3. Predicted probabilities of latent class membership as a function of the paralysis covariate for the smiling faces. The 95% confidence intervals are plotted as well.

be classified positive, but smiling paralyzed faces were three times less likely to be in that class.

Despite the established impact of facial paralysis on patients themselves, the perception of the facial paralysis deformities has been incompletely studied from the observer's point of view. It was previously shown objectively that observers allocate attention differently when gazing on faces with deformity as compared to those without deformity.[15] However, to the best of our knowledge, until now we have had a very limited understanding of how this altered attention allocation affects the perception of the face by the casual observer.

In one previous study of emotion expression, the significant others of patients with facial paralysis were asked to rate the ability of their partner to express emotion. They rated their partner as having limited ability to express primary emotions, which was consistent with the assessment by the patients themselves.[5] In the current study we showed that patients with upper and lower division facial paralysis experience impaired affect display as compared with normal subjects and further that their visage is routinely negatively perceived by casual observers as compared with normal subjects.

Patients with facial paralysis consistently describe feeling that they are negatively perceived.[16] In fact, until now there were no assessments of affect display by patients with facial paralysis as regarded by the casual observer. The latent class analysis revealed that the faces with facial paralysis were regarded as presenting a negative affect display both when in repose and when smiling the vast majority of the time, 73% and 59%, respectively. On the contrary, the normal faces were regarded more appropriately, with neutral affect display the vast majority of the time when in repose (49%) and positive affect display 98% of the time when smiling. The change in affect display for normal faces went from 10% of faces classified as a positive display when in repose to 98% classified as a positive display when smiling. Antithetically, for patients with facial paralysis, these same changes were from 0% to 23%, respectively. Similarly, the prediction probability of negative affect display changed from 40% in repose to 0% smiling in normal patients, and the same changes for paralyzed patients were 70% to 60%, respectively. In other words, even when patients with facial paralysis tried to display positive emotions through smiling, it was still remarkably difficult for them to achieve.

TABLE IV.
Prediction Probabilities for Latent Class Membership.

Class	Probability	Standard Error	95% Confidence Interval
Negative latent class			
Repose-normal	.407	0.045	(0.330–0.492)
Repose-paralysis	.727	0.069	(0.630–0.821)
Smile-normal	.011	0.063	(0.000–0.027)
Smile-paralysis	.589	0.048	(0.507–0.674)
Positive latent class			
Repose-normal	.100	0.0368	(0.046–0.158)
Repose-paralysis	.014	0.0445	(0.000–0.029)
Smile-normal	.978	0.0701	(0.956–1.000)
Smile-paralysis	.229	0.0382	(0.161–0.300)
Neutral latent class			
Repose-normal	.493	0.433	(0.415–0.576)
Repose-paralysis	.259	0.052	(0.169–0.354)
Smile-normal	.011	0.032	(0.000–0.032)
Smile-paralysis	.181	0.034	(0.120–0.246)

TABLE V.
Hypothesis Tests for Negative Latent Class.

Comparison	Adjusted Confidence Intervals
Repose:normal—repose:paralysis	(−0.479, −0.167)
Repose:normal—smile:paralysis	(−0.330, −0.368)
Repose:normal—smile:normal	(0.281,0.509)
Repose:paralysis—smile:paralysis	(−0.024, 0.293)
Repose:paralysis—smile:neutral	(0.589, 0.858)
Smile:paralysis—smile:normal	(0.472, 0.693)

Confidence intervals adjusted for multiple comparisons.

Although the results are statistically sound, we recognize the study has limitations. These limitations include the number of faces (normal subjects and those with facial paralysis) considered for evaluation by viewers and the number of viewers themselves. Confirmatory studies would require larger groups of both to render the data more generalizable.

Despite the limitations, these provocative results provide new insight on the impact of facial paralysis on interpersonal communication. They highlight the significance of the facial paralysis deformity in diminishing emotional contagion and contributing to social isolation and validate the concerns expressed by patients with facial paralysis. The patients have an impaired ability to induce emotional contagion or "infect" their observer with the emotion they are experiencing. In an era of limited healthcare dollars and demand for evidence-based medicine practices, surgical efforts must be focused on areas of greatest impact. These data support efforts to continue to identify effective reconstructive methods for patients with facial paralysis to maximize the restoration of affect display.

These results further suggest that comprehensive treatment paradigms should include counseling about communication limitations and their effect. Ideally patients and their family members would receive information about the impact of impaired affect display in interpersonal relationships. The goal would be to generate an awareness of the problem to minimize frustration and misunderstanding between patients and their family and friends.

CONCLUSION

This study was performed to evaluate the impact of facial paralysis on affect display with an exploratory latent class analysis. From the patterns of associations of the 11 emotions and attributes, the exploratory latent class analysis identified three independent latent variables, positive, negative, and neutral. Normal faces were classified as positive or neutral the majority of the time, depending on smiling or repose status, but faces with facial paralysis were classified as negative the majority of the time, whether smiling or in repose. These data provide evidence that faces with paralysis have impaired affect display as compared to normal subjects.

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