Threshold of Visual Perception of Facial Asymmetry in a Facial Paralysis Model

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Objective: To determine the degree of facial asymmetry required to trigger conscious perception in the observer in a simulated model of facial paralysis.

Methods: A model of unilateral facial paralysis was created using the face of a participant without facial paralysis. Digital morphing software was used to create progressive asymmetry of the brow, oral commissure, and combined brow and oral commissure based on the typical sequelae seen in facial paralysis. Volunteers naive to the goals of the study repeatedly were shown a series of photographs of faces without facial paralysis, with the manipulated image interspersed within the series.

Results: At least 3 mm of facial asymmetry of the oral commissure, brow, or both was required before participants detected the asymmetry. With longer display intervals, participants tended to detect a smaller degree of asymmetry.

Conclusions: To our knowledge, this is the first study directed at determining the amount of facial asymmetry required to trigger conscious perception of patients’ facial paralysis in the naive observer. The pilot data and the discussion herein provide insight into the processes of visual perception of facial asymmetry and may be useful to surgeons for patient counseling and in setting surgical goals.


Facial paralysis is a potentially devastating injury with detrimental aesthetic, physiologic, and psychological effects. Unilateral facial paralysis results in facial asymmetry that can be present at rest and in motion. The flaccidly paralyzed side of the face may demonstrate absence of forehead rhytids, drooping of the eyebrows, ectropion, shallow melolabial folds, depression of the oral commissure (OC), and synkinesis. Potential functional complications include lagophthalmos with resultant exposure of the cornea that can result in keratitis, corneal ulceration, and eventual blindness. Oral incompetence may lead to speech deficits, drooling, and difficulties with feeding. Loss of the nasalis and dilator naris muscles, combined with the weight of the unsupported midface tissues, can result in nasal valve collapse and nasal obstruction. Additionally, the inability to effectively communicate emotions through facial expressions has been associated with decreased quality of life measures.

Mild asymmetries occur in the normal growth and development of the face and body. In fact, certain asymmetrical dimensions have been accepted as traits of beauty. However, as the degree of facial asymmetry progresses, it begins to be perceived as disfigurement. It is generally agreed that surgery cannot completely restore an asymmetric and disfigured face; however, it can dramatically reduce the degree of asymmetry and provide an approximation of a symmetrical appearance.

The psychologic sequelae of facial paralysis are well documented. Many people with disfigurements become preoccupied with their appearance and the possible effect it may have on others. They describe being the object of unwelcome attention from other people, leading to social isolation and a loss of self-esteem. Bull reported that these reactions are markedly influenced by the affected individuals’ understanding of how severe others consider their disfigurement. Therefore, it is important to provide an objective assessment of the ways that facial asymmetry secondary to facial paralysis is perceived by laypersons. Determination of the threshold for perception of facial asymmetry may provide data useful in patient counseling regarding the need for surgery and can also provide goals for reconstructive surgery by establishing a numerical goal for reduction of asymmetry. Ultimately, these results can help establish a more consistent management algo-
rhythm for this subset of patients whose cases present a clinical challenge.

A number of studies have evaluated the perception of facial symmetry and assessed the degree of asymmetry found with a number of conditions, including congenital, postsurgical, or postrumatic dentofacial and craniofacial deformities. However, to our knowledge, there have been no previous reports in the literature on studies that have attempted to measure the layperson’s visual threshold for perception of facial asymmetry owing to facial paralysis. In the study reported herein, we determined the threshold for visualization of facial asymmetry of the brow, OC, and brow and OC combined using layperson volunteers and a digitized model of unilateral facial paralysis that was serially morphed to demonstrate progressively greater asymmetry at the brow and OC.

**METHODS**

Informed consent was obtained from all participants for the use of their photographs. A model of unilateral flaccid facial paralysis was created by using digital image morphing software (Mirror Aesthetic Imaging Software, Canfield Scientific Inc, Fairfield, New Jersey). A digital photographic image of the face of a participant without facial paralysis at rest was manipulated to create progressive images of increasing asymmetry (Figure 1). This was performed on the (1) OC (1-mm increments, up to maximal asymmetry of 10 mm); (2) brow (0.5-mm increments, up to maximal asymmetry of 5 mm); and (3) OC and brow (for consistency, 1-mm increments were used in the brow and OC combination, with a maximum of asymmetry of 5 mm for both).

Study participants were layperson volunteers naive to the goals of the study. A total of 30 volunteers were recruited for each group and subgroup. Participants were repeatedly shown a series of 10 images, including 9 control images, with the manipulated image interspersed within the series. With each iteration, the manipulated image was subject to progressively increasing asymmetry. Control images were digital photographs of the faces of men and women between 30 and 60 years of age without facial paralysis at rest. Images were presented to the participants at 10-second or 2-second intervals using a 19-inch monitor and were calibrated to be life-sized. Participants were asked to write down general comments about each face before the next image was presented.

We considered asymmetry as being identified if there was specific mention of the morphed side of the face being different from the contralateral, unaltered side. Specific mention of the brow or OC area was not required; written indication that the participant perceived a difference between the morphed and control side of the image was sufficient. For the isolated OC and isolated brow asymmetry groups, after the detection threshold was identified, participants were shown the study image again at baseline and with successively less asymmetry and were asked at what point they believed the amount of facial asymmetry was unacceptable and would merit surgery.

Stata/IC 10 (StataCorp LP, College Station, Texas) was used for statistical analysis. Data analysis was performed for the 2 basic sets of experiments. The first experiment was designed to study the effect that visualization time and defect location have on threshold detection. We studied 2 factors: time and location, with 2 categories in each factor. The 4 groups were OC for 2 seconds (OC-2), OC for 10 seconds (OC-10), brow for 2 seconds (B-2), and brow for 10 seconds (B-10). The individual groups’ threshold distributions were tested for normality using the Shapiro-Francia W’ test for normality. The OC-10 group was found to be not normally distributed; therefore, a Kruskal-Wallis 1-way analysis of variance test, a non-parametric technique, was used to determine the effects of asymmetry location (OC or brow) and time (2-second or 10-second) on threshold (mm). We had insufficient power to perform a factored nonparametric analysis, so the 4 groups were compared directly.

The second experiment investigated whether a participant’s ability to detect a facial asymmetry was dependent on observation time. Three possible types of asymmetry—OC only, brow only, and brow and OC combined—were shown to independent groups for 2 and 10 seconds. The data yielded a 3 × 2 contingency table (Table 1). Because some of the values in the table were small, the Fisher exact test was used to test whether the area of asymmetry detected first was independent of the observation time. The table was then partitioned to determine whether differences in the 3 groups were statistically significant. In the first partition, the χ² test was used to compare the detection of OC asymmetry first with the detection of brow asymmetry first, at 2 and 10 seconds. The next partition collapsed the original table by combining the independent OC and brow categories, ie, detecting an OC or OC-10 group was found to be not normally distributed; there-

Table 1. Location of Facial Asymmetry Noted First in an Image With OC and Brow Asymmetry Presented at 2-Second and 10-Second Intervals

<table>
<thead>
<tr>
<th>Location</th>
<th>Seconds, No. (%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC</td>
<td>9 (30)</td>
<td>13</td>
</tr>
<tr>
<td>Brow</td>
<td>18 (60)</td>
<td>21</td>
</tr>
<tr>
<td>OC and brow</td>
<td>3 (10)</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>60</td>
</tr>
</tbody>
</table>

Abbreviation: OC, oral commissure.

Figure 1. Facial asymmetry model of oral commissure. A, Symmetrical, unaltered image. B, One mm of right oral commissure depression. C, Two mm of right oral commissure depression. D, Three mm of right oral commissure depression.
brow asymmetry, so they could be compared with the simultaneous detection of brow and OC asymmetry. This comparison was made at 2 and 10 seconds. A similar analysis was performed to study the dependence of detection threshold on observation times. Three detection thresholds (3, 4, and 5 mm) were compared at 2 and 10 seconds (Table 2). We used the Fisher exact test to reject the null hypothesis that detection thresholds are independent of observation times. The table was then partitioned to determine whether there was a difference between threshold values of 3 and 4 mm at 2 and 10 seconds.

RESULTS

ISOLATED OC

For the 10-second interval, most participants (73% [22 of 30]) detected asymmetry of the OC at 3 mm (Figure 2A) and most of the 2-second-interval cohort detected asymmetry at 5 mm (53% [16 of 30]) (Figure 2B). After the OC asymmetry was identified, 60% of the participants in the 10-second interval group considered the asymmetry unacceptable at 5 mm and would recommend reconstructive surgery at that point (Figure 3).

ISOLATED BROW ASYMMETRY

Figure 4 demonstrates the threshold of detection of facial asymmetry at the 10-second (Figure 4A) and 2-second (Figure 4B) intervals. At both time intervals, most participants detected the brow asymmetry at 3.5 mm. Half the participants in the 10-second group believed reconstructive surgery was indicated when the brow asymmetry reached 4.0 mm (Figure 5).

COMBINED OC AND BROW ASYMMETRY

Figure 6 illustrates the location where asymmetry was first noted in the combined OC and brow asymmetry model by site and time interval. Most participants recognized the brow and OC asymmetry simultaneously...
when using the 10-second interval, while the brow asymmetry was noticed first by most participants when the 2-second interval was used.

**STATISTICAL ANALYSIS**

With use of the Kruskal-Wallis test, statistical significance was set at \( P < .001 \); this showed differences in the 4 group medians (OC-2, OC-10, B-2, and B-10) to be statistically significant. To further determine whether group medians differed significantly, post hoc paired tests were performed. This method controls for multiple comparisons. The comparisons found to be statistically significant \( (P < .001) \) were OC-2 vs OC-10, OC-2 vs B-2, and OC-2 vs B-10. The results show that 60% of the participants saw brow asymmetry first when viewing the image for 2 seconds, but when given 10 seconds to view the images, 77% were able to detect the brow and OC asymmetry simultaneously.

When the table was partitioned to determine whether differences in the 3 groups were statistically significant, the \( \chi^2 \) value was 0.87, which did not exceed the critical value for the \( \chi^2 \) distribution with 1 degree of freedom with \( \alpha = .05 \). This suggested that there is no preference for seeing 1 type of asymmetry more than the other. In the next partition, where the table was collapsed to combine brow or OC and compare that group with brow and OC combined for viewing at 2 and 10 seconds, 90% of the participants detected asymmetry at the OC or brow when viewing the image for 2 seconds, but 76% detected asymmetry at both areas when viewing the image for 10 seconds. These values were statistically significant because the \( \chi^2 \) value exceeded the critical value for \( \alpha = .001 \).

When the dependence of detection threshold on observation time was checked at the 2-second interval, 67% of the people detected the asymmetry at 4 mm, but at the 10-second interval, 87% of the people detected the asymmetry at 3 mm. The Fisher exact test probability was \( P < .001 \), suggesting that the observed differences between categories were significant. The table was then partitioned to determine whether there was a significant difference between threshold values of 3 and 4 mm at 2 and 10 seconds. The differences were significantly different \( (\chi^2 \text{ value }= 24.4) \), which exceeded the critical level for \( \alpha = .001 \). Collapsing the original partition table by combining the 3- and 4-mm threshold categories and comparing them with the 5-mm categories at 2 and 10 seconds shows that the differences between the collapsed categories were also significantly different \( (\chi^2 \text{ value }= 5.45; \alpha = .02) \).

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**COMMENT**

Patients are often concerned about the social stigma associated with facial asymmetry secondary to facial paralysis. Reconstructive surgeons, in addition to attempting to restore function, must also counsel patients on the need for surgery and provide guidance on appropriate expectations. Nevertheless, no previous studies, to our knowledge, have sought to ascertain the threshold at which facial asymmetry is noted by laypersons. In this pilot study, we used digital morphing software to make progressively more asymmetric images in a uniform stepwise fashion, focusing on areas of the face typically affected by facial paralysis. Images were viewed at 2 and 10 seconds in an attempt to simulate real-world situations of prolonged observation vs quickly glancing at an individual in passing.

In naive participants, we determined the threshold for noticing asymmetry of the OC and brow. Not surprisingly, the threshold was statistically significantly lower for each group when a longer time was allowed for viewing the image (10 vs 2 seconds). For OC and brow asymmetry, the level (mm) of asymmetry at which most participants considered the facial asymmetry unacceptable and would recommend surgery exceeded the level at which most participants initially identified any asymmetry.

Between the B-2 and OC-2 groups, there were statistically significant differences in threshold for detection.
of asymmetry. This indicates that at the shorter viewing interval, a given amount of facial asymmetry was more noticeable in the brow commissure than the OC. However, this was not true for the longer viewing interval because there was not a statistically significant difference in the thresholds for detection of asymmetry at the OC and brow when the asymmetries were presented for 10 seconds.

Brow and OC asymmetries were presented simultaneously in an attempt to study how the presence of multiple sites of asymmetry may affect detection thresholds. These results also varied based on the duration of screening. When looking at the altered images for 2 seconds, 90% of the viewers detected an individual defect first, but when viewing the images for 10 seconds, 77% of the participants detected both defects simultaneously—this difference was statistically significant. This study, however, was unable to detect a statistically significant difference in detection of OC or brow asymmetry when they were displayed together at either time interval; this may be owing to a lack of power of the study. Nevertheless, our results suggest that at 2 seconds, brow asymmetry, as compared with OC asymmetry, was detected first. This corroborates our finding, stated previously, that a given amount of facial asymmetry was more noticeable in the brow than OC when OC or brow asymmetry images were displayed independently.

Similar to the studies evaluating OC and brow asymmetry independently, longer viewing times of the combined asymmetries resulted in a decrease in the threshold of detection. Statistically significant differences in the detection threshold were found between the 2-second and 10-second intervals, with longer viewing periods allowing for a lower threshold of detection. When viewers saw the altered faces for only 2 seconds, the vast majority detected the OC or brow asymmetry at 4 mm, but this decreased to 3 mm when they saw the asymmetry for 10 seconds.

Ishii et al13 performed a novel study tracking the eye movements (scan paths) of naive observers viewing images of symmetrical faces and those with peripheral surgical deformities. Confirming the results of a previous study,14 the investigators found that when viewing symmetrical faces, observers performed fixations on the central triangle of the eyes, nose, and mouth. When peripheral facial deformities were presented, scan paths were deviated such that observers would redirect their attention to the region of the face with the defect and spend less time gazing at the central triangle. One possibility to account for our combined asymmetry results would be that the eye is viewed first within the typical scan path; thus, during quick gaze, in which the whole central scan path is not completed, relatively more attention is focused on the eye than on the mouth.

The pilot data herein may be useful for patient counseling and surgical planning. Patients with minimal asymmetry may take comfort in knowing that in our model, most participants did not notice asymmetry of the brow or OC until 3 mm or more of asymmetry was apparent. Likewise, as a goal, surgeons may attempt to reduce asymmetry of the brow or OC to within less than 3 mm such that most participants would not have noticed the subtle differences between facial hemispheres. While patients are unique and treatment will ultimately need to be individualized, our results provide a framework on which to base a discussion of the need for surgery and goals of surgery.

One of the main limitations of this initial study was the static nature of the presented images. Real-world situations generally involve dynamic movement, and a complete assessment of the sequelae of facial paralysis requires an assessment of the mimetic action of the facial musculature. Nevertheless, we believe the static images presented at the 10-second and 2-second intervals provide some useful information because they mimic the images seen in some real-world situations, such as the prolonged observation of the listener in a conversation or a casual glance at a bystander.

CONCLUSIONS

To our knowledge, ours is the first study directed at determining the threshold of facial asymmetry in patients with facial paralysis necessary to trigger conscious perception in the lay observer. These results may provide insight into the processes of visual perception of facial asymmetry and guidance for surgeons and patients sorting through the myriad options for surgical intervention and physical therapy. Further efforts are underway to pursue these concepts in 3-dimensional dynamic faces.

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REFERENCES


