# On the Perceptual Salience of Features of Chernoff Faces for Representing Multivariate Data

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In order to assess the perceptual salience of features of Chernoff faces, a study was conducted in which subjects had to rate the similarity of pairs of Chernoff faces. It was found that the facial features differ considerably in perceptual salience. Highly salient features are the curvature of the mouth, the half-face height, the half-length of the eyes, and the length of the eyebrows, whereas the eccentricity of the lower ellipse of the face, the position of the center of the mouth, the separation and the slant of the eyes, and the height of the brows have little influence on the perception of Chernoff faces.

Chernoff (1973) suggested using cartoon-like schematic faces to represent multivariate data. Originally, the shape of the faces was determined by 18 parameters. Each of these parameters characterizes a facial feature, such as the length of the nose, the curvature of the mouth, the slant of the eyes, and so forth. Later H. Davis added two more features, namely, the nose width and the ears (cf. Bruckner, 1978). (A list of the 20 features is presented in Table 1.) To display a set of observations on, say, 12 variables by means of Chernoff faces, first each variable must be assigned to one of the 20 facial features. In addition, constants must be selected for the remaining 8 features. Then, a face for each of the multivariate observations can be produced.

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Using Chernoff faces for displaying multivariate data has many advantages (cf. Bruckner, 1978; Chernoff, 1973). First, schematic faces enable the user to detect and comprehend phenomena that would otherwise be noticed less easily. A study conducted by Jacob, Egeth, and Bevan (1976) showed that subjects could better cluster multivariate data when the observations were displayed by Chernoff faces than when they were presented numerically. Moreover, Chernoff faces were found to be more effective than glyphs and polygons (see Wainer, 1983, for a review of these and other graphical methods for displaying multivariate data). A second advantage of Chernoff faces is that they can serve as a mnemonic device for remembering major conclusions, especially when the facial features correspond somehow with the physical meaning of the variables. Finally, schematic faces provide a straightforward means for communicating results to others.

Because of these advantages, Chernoff faces have potentially many applications in psychology. Jacob (1978), for instance, utilized Chernoff faces for representing MMPI profiles, whereas Mezzich and Worthington (1978) graphically portrayed a patient's scores on the 17-variable Brief Psychiatric Rating Scale by means of Chernoff faces. For a discussion of applications in marketing research see Huff, Mahajan, and Black (1981).

In order to represent $k$-variate observations by Chernoff faces, each of the $k$ variables must be assigned to one of the 20 face parameters. This can be done in $20!/(20 - k)!$ ways. Usually an assignment is chosen at random. But, as Chernoff and Rizvi (1975) demonstrated, the way in which the variables are assigned to the facial features might very well affect the conclusions that can be reached by comparing the faces. To solve this problem, Jacob (1983) suggested to search for combinations of facial features for which the perceived similarities between the faces correspond closely to the Euclidean distances between the observations. This objective is, however, not only somewhat arbitrary but also difficult to accomplish. Instead of randomly assigning the variables to the face parameters, an assignment plan based on the cluster structure of the variables could be used, as suggested by Jacob (1981). Alternatively, as Huff et al. (1981) remarked, the variables can be assigned on the basis of the relative importance of the various facial features. This supposes that the relative importance, or perceptual salience, of the features is known. The purpose of the present study was to assess the perceptual salience of 15 of the 20 Chernoff face features. To study the impact of these 15 features on the perception of Chernoff faces, subjects were asked to judge the similarity of pairs of faces. Each pair consisted of a constant "modal" face and a face in which the 15 features were systematically varied.

## Method

### Subjects

Twenty-three first year students in psychology and education at the University of Ghent, Belgium, participated voluntarily in partial fulfillment of certain class requirements.

### Stimuli

Two sets of 16 pairs of Chernoff faces were constructed. The right stimulus of a pair was always the same "modal" face, of which the shape was determined by the medium values listed in Table 1. The left stimuli were constructed by vary-

Table 1
Features of the Chernoff Faces and Values of the Feature Parameters Used

| No. | Facial Feature | Low | Medium | High |
|---|---|---|---|---|
| 1 | Face width | | 0.45 | |
| 2 | Ear level | | 0.50 | |
| 3 | Half-face height | 0.55 | 0.75 | 0.95 |
| 4 | Eccentricity of upper ellipse of face | 0.55 | 0.75 | 0.95 |
| 5 | Eccentricity of lower ellipse of face | 0.55 | 0.75 | 0.95 |
| 6 | Length of nose | 0.18 | 0.28 | 0.38 |
| 7 | Position of center of mouth | 0.25 | 0.43 | 0.61 |
| 8 | Curvature of mouth | -3.20 | 0.80 | 3.20 |
| 9 | Length of mouth | 0.37 | 0.65 | 0.93 |
| 10 | Height of center of eyes | | 0.15 | |
| 11 | Separation of eyes | 0.35 | 0.55 | 0.75 |
| 12 | Slant of eyes | 0.24 | 0.40 | 0.56 |
| 13 | Eccentricity of eyes | 0.44 | 0.60 | 0.76 |
| 14 | Half-height of eye | 0.28 | 0.60 | 0.92 |
| 15 | Position of pupils | 0.26 | 0.50 | 0.74 |
| 16 | Height of eyebrow | 0.64 | 0.80 | 0.96 |
| 17 | Angle of brow | 0.10 | 0.50 | 0.90 |
| 18 | Length of brow | 0.37 | 0.65 | 0.93 |
| 19 | Radius of ear | | 0.55 | |
| 20 | Nose width | | 0.15 | |

ing the features numbered 3 to 9 and 11 to 18 in Table 1. Features 19 and 20 were omitted because they were not present in the original schematic faces proposed by Chernoff (1973). In order to limit further the number of independent variables, three more features were held constant, namely, features 1, 2, and 10. It was expected that these features would have relatively little influence on the facial perception. As values for the constant features, the medium values given in Table 1 were selected.

Features 3 to 9 and 11 to 18 were systematically varied according to an incomplete $2^{15}$ factorial design. More specifically, an orthogonal main-effect plan (Addelman, 1962, Basic plan no. 3) was adopted that permits uncorrelated estimation of the main effects of the 15 features on the basis of only 16 stimuli. Two independent realizations of the design were constructed in order to enable stability analysis of the results. For each stimulus set, the 15 facial features were randomly assigned to the factors of the design. Each factor had two levels, namely, the low and high values specified in Table 1. The resulting stimulus sets are described in Table 2. An "L" corresponds to the low value of the feature, while an "H" represents the high value of the feature. In addition to these two sets of 16 stimulus pairs, three trial pairs were constructed.

The faces were produced on a Calcomp plotter using Bruckner's (1978, pp. 115–120) Fortran program. Each face was drawn to fit in a square with sides of 10.8 cm. The faces of each pair were pasted next to each other on a separate sheet of 29.7 cm × 21 cm. The modal stimulus always occurred on the right.

### Procedure

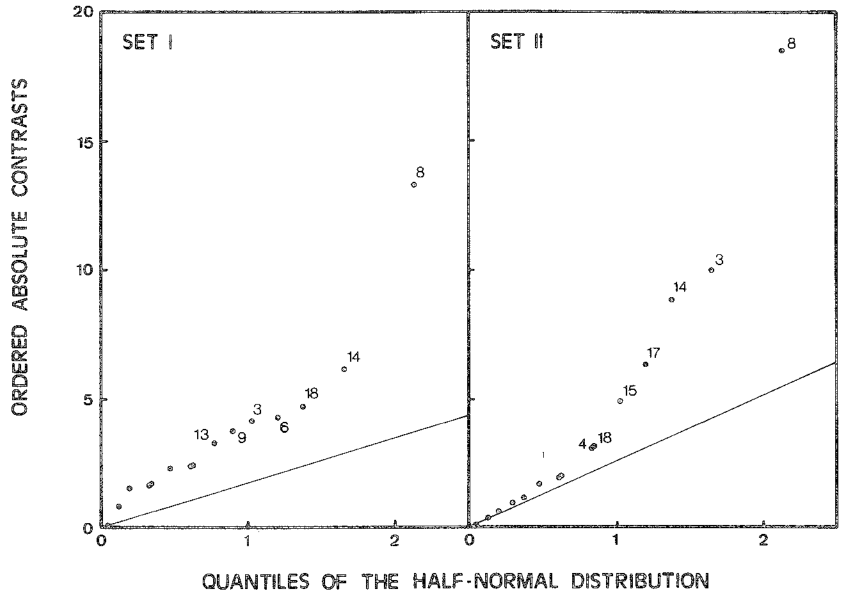
The subjects were run in groups. Every subject received a booklet containing the stimulus pairs. The subjects were asked to indicate the similarity between the two faces of each pair on a rating scale ranging from 1 (very dissimilar) to 9 (very similar).

After the three trial pairs, the two sets of 16 stimulus pairs were presented. The order of the stimuli within each set was randomized. These 35 stimuli were presented twice. The data analysis reported below is based only on the data obtained on the second presentation. On the average, the entire task took about 20 minutes to complete.

Table 2
Design of the Stimulus Sets

| Facial Feature in Set I | Facial Feature in Set II | Stimulus Pair Numbers | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 13 | 3 | L | L | L | L | L | L | L | L | H | H | H | H | H | H | H | H |
| 12 | 17 | L | L | L | L | H | H | H | H | L | L | L | L | H | H | H | H |
| 3 | 9 | L | L | L | L | H | H | H | H | H | H | H | H | L | L | L | L |
| 7 | 13 | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H |
| 6 | 7 | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H |
| 4 | 12 | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L |
| 11 | 14 | L | L | H | H | L | L | H | H | H | H | L | L | H | H | L | L |
| 5 | 8 | L | H | L | H | H | L | H | L | L | H | L | H | H | L | H | L |
| 18 | 16 | L | H | H | L | H | L | L | H | H | L | L | H | L | H | H | L |
| 8 | 4 | L | H | H | L | L | H | H | L | H | L | L | H | H | L | L | H |
| 9 | 6 | L | L | H | H | H | H | L | L | L | L | H | H | H | H | L | L |
| 16 | 5 | L | H | L | H | H | L | H | L | H | L | H | L | L | H | L | H |
| 14 | 15 | L | H | L | H | L | H | L | H | H | L | H | L | H | L | H | L |
| 15 | 18 | L | H | H | L | H | L | L | H | L | H | H | L | H | L | L | H |
| 17 | 11 | L | L | H | H | H | H | L | L | H | H | L | L | L | L | H | H |

**Figure 1**
Half-Normal Probability Plot of the Ordered Contrasts for the Two Data Sets




## Results

A separate repeated measures analysis of variance, in which the 16 stimulus pairs were treated as levels of a single factor, was performed on the data obtained for each set of faces. As could be expected, the effect of the stimulus pair factor is highly significant in both data sets ($F[15,330]$ = 12.01 and 16.01, respectively, both $p < .001$), showing that the perception of Chernoff faces is affected by changes in the facial features.

Next, orthogonal single degree of freedom contrasts corresponding to the 15 face parameters that were varied according to the design given in Table 2, were computed. The coefficients of the contrasts were chosen such that the variance of each contrast equals the residual within-subjects variance. To assess the differential perceptual salience of the facial features, a half-normal probability plot of the absolute contrasts was constructed, as suggested by Wilk and Gnanadesikan (1968) and Gnanadesikan (1980). This amounts to plotting the ordered absolute contrasts against the corresponding quantiles of the standard normal distribution folded about its mean. The resulting plot is displayed in Figure 1.

If none of the features has an effect, all points should fall on a straight line through the origin with a slope equal to the square root of the residual within-subjects variance. In Figure 1, this null line is shown for each data set. In the figure, only the points corresponding to significant contrasts ($p <$ .05) are labeled. As can be inferred from Figure 1, the perceptual saliences of the 15 facial features clearly differ. Features 3, 8, 14, and 18 have a significant effect in both stimulus sets, while features 5, 7, 11, 12, and 16 fail to reach significance in both data sets.

To demonstrate the differential perceptual salience of the features of Chernoff faces, two pairs of faces are presented in Figures 2 and 3. The face on the left in Figure 2 has low values for features 3, 8, 14, and 18, and medium values for the remaining features. The face on the right, on the other hand, has high values on the highly salient features 3, 8, 14, and 18, and medium values on the other features. The faces in Figure 3 were constructed in the same way, except that now the faces differ on the nonsalient features 5, 7, 11, 12, and

16. Clearly, the faces displayed in Figure 2 are much more dissimilar that those depicted in Figure 3.

## Discussion

The present study confirmed that the features of Chernoff faces differ in perceptual salience. Moreover, it was found that of the 15 features studied, the curvature of the mouth (feature 8) is the most salient one. Consequently, when using Chernoff faces to represent multivariate data, differences on the variable represented by the mouth curvature will be much better perceived than differences on the other variables. Therefore, in order to highlight a variable's effect, it would make sense to assign that variable to the mouth curvature parameter. Other highly salient features are the half-face height (feature 3), the half-length of the eyes (feature 14), and the length of the brows (feature 18). Features that have little influence on the perception of Chernoff faces are the eccentricity of the lower ellipse of the face (feature 5), the position of the center of the mouth (feature 7), the separation and the slant of the eyes (features 11 and 12), and the height of the eyebrows (feature 16). If possible, use of these features to represent variables should be avoided.

The present study suffered from two limitations that were necessary in order to retain a manageable number of stimulus pairs. First, only 15 of the 20 Chernoff face features were varied. In addition, a design was adopted that allowed only for estimation of main effects. It would be interesting to replicate the experiment using a different subset of features, and to investigate the extent to which the facial features interact with each other.

**Figure 2**
Two Chernoff Faces that Differ on the
Four Most Salient Features

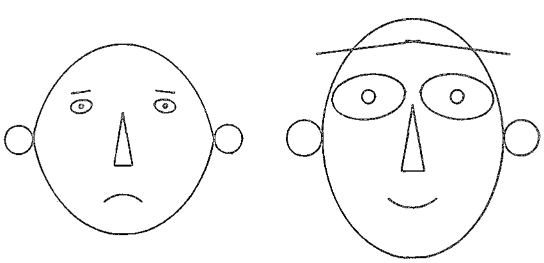
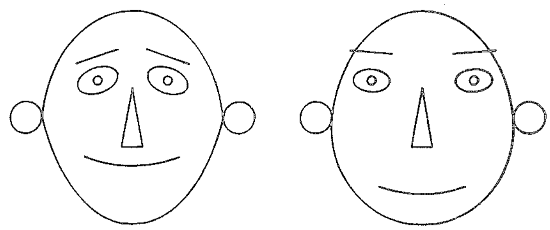


**Figure 3**
Two Chernoff Faces that Differ on the
Five Least Salient Features



A drawback of Chernoff faces is that interdependencies exist among some of the parameters. When certain parameters take on extreme values, other parameters may lose their effect. In an attempt to overcome this shortcoming, Flury and Riedwyl (1981) suggested an alternative kind of schematic faces for representing multivariate data. It would be worthwhile to replicate the present study using the Flury and Riedwyl type of faces instead of the original Chernoff faces.

The finding of a differential perceptual saliency of the Chernoff face features illustrates that in order to improve graphical communication, it is necessary to study the perceptual processes on which graphical methods for data display call. Ultimately, this should result in a comprehensive psychological theory of graphical perception. A first attempt to formulate such a theory has recently been undertaken by Cleveland and McGill (1984, in press).

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