Quantitative comparison of computerized discrete and animated profile preferences

Donald B. Giddon, DMD, PhD; Regina Sconzo, DMD; Jason A. Kinchen, BA; Carla A. Evans, DDS, DMSc

The purpose of this study was to determine how changes in the physical dimensions of the facial profile are related to subjective judgments of acceptable or unacceptable appearance; that is, how much change in morphology is associated with increments or decrements in acceptability, preference, beauty, etc. In holistic terms, how much physical change must there be in a particular feature before the Gestalt of an acceptable, attractive, or beautiful face is rejected, or conversely, how much change in shape or size of an unattractive feature before an acceptable Gestalt is achieved?

To accomplish this task, computer software was developed for assessing subjective responses to manipulated changes in selected physical dimensions of the facial soft-tissue profile (STP), using the methods developed by Giddon and associates.[1-3]

Previous authors have attempted to rank or classify faces on the basis of attractiveness, and considerable agreement has been found among

Abstract

To determine the physical bases of subjective judgments of facial appearance, two computer presentations of discrete soft tissue profile (STP) images were compared with the same images appearing in an animated format. The images were judged by 24 volunteers. The influences of the number and order of faces presented, gender, and dental knowledge were evaluated. Fifteen to eighteen digitized distortions of the chin, upper lip, mandible, bimaxillary relationship, and lower face height were prepared from STPs of four faces (two males and two females) representing Class I, Class I with microgenia, Class II division 1, and Class III. The judges responded to each discrete alteration as acceptable or unacceptable and with a separate rating from 1 to 6. Each feature was then "animated" by presenting the distortions serially at 1.25 frames/sec in counterbalanced order six times, from both the extreme protrusive (P) and retrusive (R) distortions. The judges indicated an acceptance zone by pressing a button when the face became acceptable and releasing it when no longer acceptable. The rating responses were more favorable than the simple acceptable/unacceptable dichotomy. Neither of the discrete methods was found to be as reliable as the animated method. Significant differences were found for the animated responses between the aggregate midpoint of acceptability of Class II division 1 and Class III for all features except bimaxillary relationship, thus providing a criterion-based validation of the animated method. The dental judges had a greater tolerance of feature variations than did the nondental judges. By establishing a zone of acceptability in addition to a single midpoint of acceptability, the animation technique may be more clinically useful than discrete presentation for determining individual as well as group perceptions of physical change.

Key Words

Computer imaging • Facial esthetics • Psychophysics

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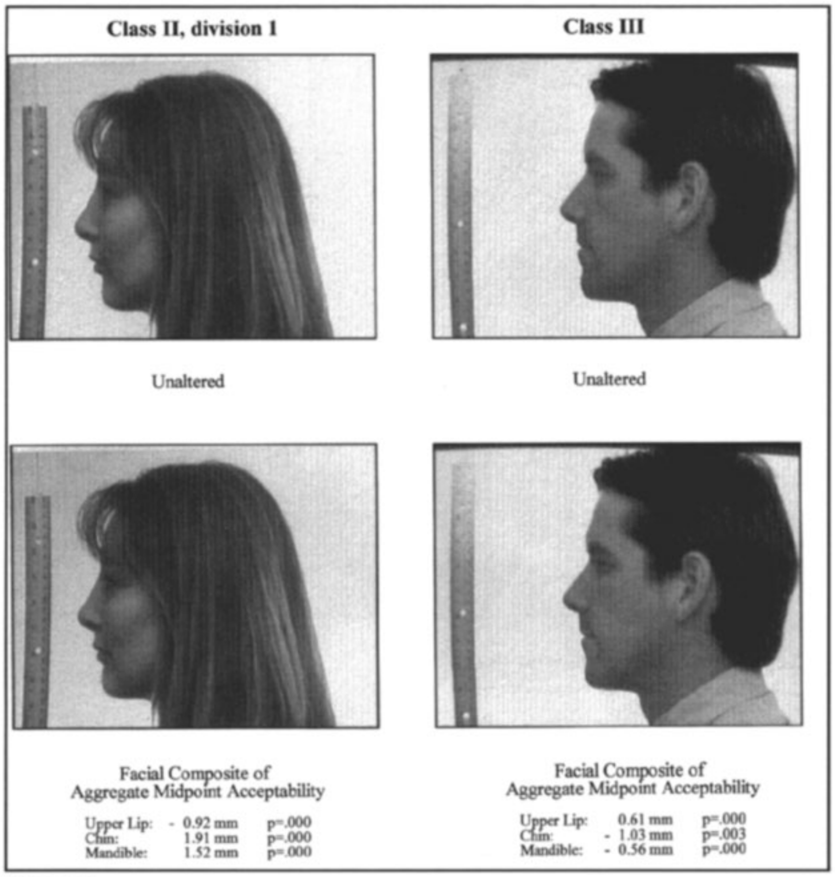

Figure 1

Figure 1
Unaltered photographs and composite changes in soft-tissue profiles of Class II division 1 and Class III clinical orthodontic classifications.

judges and societies.[4-6] Others have tried to identify physical features that can differentiate attractive from unattractive faces.[7-18] Some characteristics specifically identified with attractiveness are symmetry[10,19,20] and exaggeration of selected features,[17] or conversely, averageness of facial features[15] and neoteny.[11,21] The precise relationship between morphological changes and subjective esthetic judgments of features, however, has not been adequately defined. One can only infer from responses to psychophysical and related methods of stimulus presentation the ideational representation or mental image that an individual has of his or her own or another person's face or body. Unfortunately, clinicians do not always realize that it is the perception and not the actual physical characteristics to which the individual is responding, and often without an ability to communicate his or her cognition, feelings, or even expectations of treatment.[22,23]

The perception of the face in particular is a complex experience encompassing cognitive, affective, and related physiological changes as well as behavioral responses.[4,24] It is thus extremely difficult to determine whether the observer is actually responding to isolated components of the face or to Gestalt-like configurations.

The objective of this study was to establish the usefulness of a new animated method of stimulus presentation by demonstrating that:

1. Computer-animated presentation of feature distortions yielded a more reliable indication of the ideational representation or mental image of soft tissue profiles (STP) than more conventional methods of presenting the same distortions discretely;
2. Judges' abilities to use the animation procedure to correctly identify the appropriate post-treatment outcomes of four disparate clinical orthodontic classifications provided evidence of criterion-based validity of the method.

Materials and methods

Soft tissue profile images of two male and two female orthodontic patients were obtained photographically and standardized by positioning patients 5 feet from the camera, with the head in a natural position next to a calibration ruler. These stimulus faces were selected as representatives of the major Angle classifications of orthodontic patients: Class I; Class I malocclusion with microgenia; Class II division 1 malocclusion; Class III malocclusion. Although shown here in black and white (Figure 1), the actual stimulus faces were presented in full color. To simplify the comparison of methods, only the responses to the clinically disparate Class II division 1 and Class III malocclusions will be used for presentation of results.

Using the method of Kitay et al.,[25,26] profile soft-tissue distortions were created using the TrueVision Image Processing Software (TIPS; Indianapolis, Ind: Truevision, Inc., 1992) for five components of the lower third of the face: upper lip, bimaxillary position, chin, mandible, and lower face height. For each feature, approximately 16 distortions of the unaltered face were created, 1.0 to 1.5 pixels apart, from retrusive/short to protrusive/long extremes. The number of distortions per feature was established in preliminary trials to ensure a quantifiable gradient of changes in physical dimensions between the extremes of perceived acceptability and unacceptability. Color and blending were adjusted to provide as natural an appearance as possible to minimize distracting discontinuities between discrete distortions.

Two computer programs were developed for presenting the profile distortions. The first program was designed to present each distortion discretely in random order. In the second program, the same distortions were presented sequentially in a continuous or animated fashion, much like a flower blossoming in slow motion. The rate of presentation was 1.25 frames per second, determined in preliminary trials to maximize discrimination with minimal variance.

Fourteen female and 10 male volunteers (of varying familiarity with dentofacial esthetics) from the Harvard Medical area and ranging in age from 21 to 45 years with a mean of 27.0 ± 5.2 years served as judges.

The judges were asked to complete two tasks in random order, as depicted schematically in Figure 2. In one task, judges were asked to indicate whether each profile distortion was acceptable by pressing the left computer mouse button, or unacceptable, by pressing the right button. In the other task, judges were asked to use the keyboard for rating each of the same discrete profile images on a 6-point rating scale. A rating of 1 indicated the highest acceptability while 6 indicated the lowest acceptability.

Using the classic psychophysical method of adjustment for evaluation of the animated distortions,[27] the shape of each feature slowly changed. Beginning with the most extreme unacceptable protruded or retruded distortion, the feature appeared to move in a horizontal direction until the respondent pressed the left computer mouse button to indicate that an acceptable position of the feature had been achieved. The mouse button was held down until the moving image was no longer acceptable, thus creating protrusive and retrusive boundaries of acceptability. The same procedure was followed for lower face height by moving it vertically between longer and shorter positions. To counterbalance practice and order effects, each feature was presented in random order and displayed three times from the retrusive or shorter face height (R) to protrusive or longer face height (P) and three times from the P to the R extremes; viz.: R→P, P→R, P→R, R→P, R→P, P→R, as shown in Figure 2.

Results

Data reduction and analysis

For ease of comparison with the simple binary acceptable/unacceptable task, the data for the rating and animated responses were reduced to a dichotomous percent acceptable for each distortion. The 1-6 rating scores were transformed to a dichotomous variable by splitting the rating scores at the grand median across all features for each judge separately; that is, responses less than each judge's median were considered acceptable. Frame numbers of the feature distortions for each face were converted to mm of distance from the

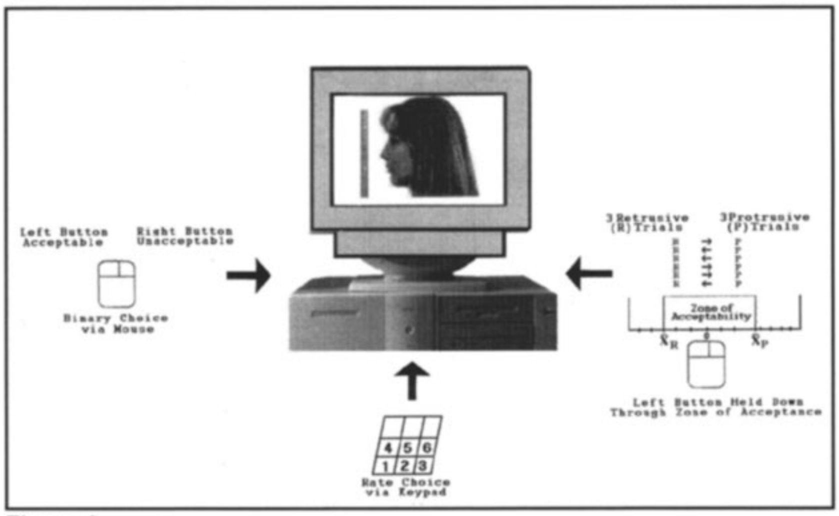

Figure 2

unaltered image and corrected for the very small differences among the head sizes of the four faces (0.67-0.72); for example, the computer image of the Class II division 1 face was .67 of the actual head size.

Figure 2
Schematic representation of three tasks and computer interface. The boundaries of the zone of acceptance are determined by the difference between the averages of six retrusive and six protrusive trials.

From the responses to the animated displays, the average across six trials for the retrusive/shorter and protrusive/longer boundaries in mm was determined for each judge. The difference between these mean boundaries ($\bar{X}_P$ - $\bar{X}_R$) determined each judge's zone of acceptability (ZA). As a measure of central tendency, the midpoint of acceptability (MA) was then defined as: $[(\bar{X}_P - \bar{X}_R)/2 + \bar{X}_R]$. An aggregate ZA and MA were then computed across all judges.

For graphic comparison with the responses to the two discrete methods of presentation, the animated data were reduced to a dichotomous variable by determining the proportion of judges accepting each increment of distortion; that is, once the respondent entered the ZA from either direction by pressing the mouse button, all subsequent responses were considered acceptable until the mouse button was released. Thus, the proportion of subjects accepting each distortion or frame (converted to mm) on the abscissa appears as a cumulative percentage acceptability on the ordinate, as shown in Figures 3 and 4.

Comparison of methods

A comparison of results of the two discrete methods with the animated method of presentation of each of the five features can be seen in Figure 3 for the clinically opposite Class II division 1 and Class III facial STPs. In addition to the obvious differences between responses to the discrete and animated methods, there were some differences between the responses to the simple binary and rating tasks dichotomized at the

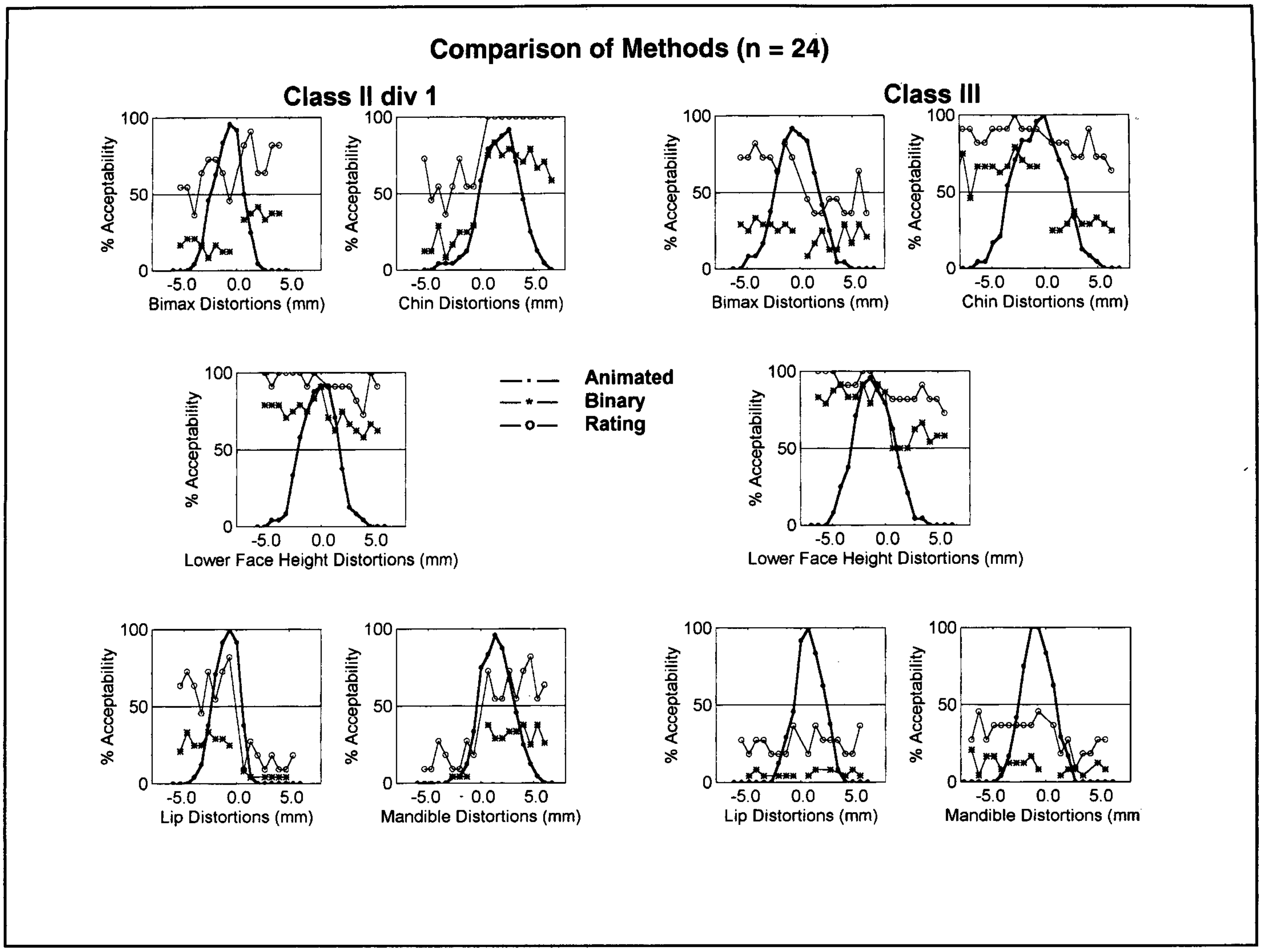

Figure 3

Figure 3
Comparison of animated method with discrete binary and rating tasks. Abscissa indicates the mm of distortion of feature change from the unaltered (0.0 mm) features of the two test faces (x-axis). Percent acceptability for each mm of distortion is shown on the ordinate (y-axis). For comparison, ratings have been dichotomized at the grand median.

grand median. With few exceptions, the percent acceptability of the dichotomized rating was higher than the responses to the simple binary tasks. Using logit regression analyses,[28] the slopes of the two dichotomized discrete response methods were essentially similar to each other, but statistically significantly different from the animated method. Although acceptability appeared to increase as the distortions approached the unaltered feature from the R and P extremes, the discrete methods were generally less discriminating than the animated methods (that is, the slopes were smaller); for example, the acceptability of almost all facial height distortions and unacceptability of all but the unaltered upper lip distortions. The net statistical result was that the slopes for the regression equations for the dichotomous responses to the discretely-presented distortions across all four faces were essentially 0. The slopes for the responses to the animated presentation ranged from 0.6 to 1.6 and were all significantly different from 0.

Differences among faces

Examining the responses to each feature reveals considerable differences among faces for all three methods. In addition to the differences noted above for the discrete methods, there was considerable spread in the aggregate ZA as well as in the central tendency or MA between the faces in the animated program. These differences between the Class II division 1 and Class III malocclusions, as representative of extremes of clinical classification of STPs, essentially establish the criterion-based validity of the animated method of presentation. As shown in Figure 4, the preferred positions or aggregate MA for the female Class II division 1 malocclusion were for greater protrusion of the mandible, chin, and bimaxillary relationship, a more retrusive upper lip, and a preference for shorter face height. For the male Class III, only the chin and mandible were preferred in a more retrusive position with

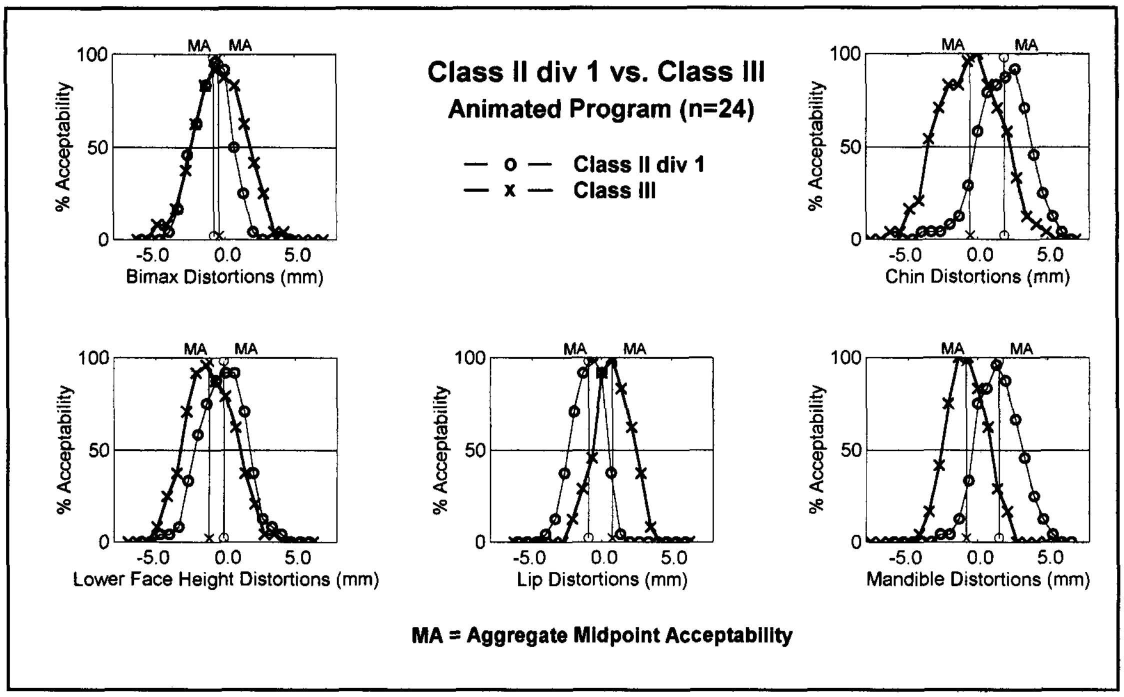

Figure 4
Comparison between percent acceptability of each feature for Class II division 1 and Class III faces. Ordinate (y-axis) indicates percent acceptability for mm of change of each feature from unaltered (0.0 mm), shown on the abscissa (x-axis). Aggregate MA across all judges defined as:

$$\bar{X}_{MA} = \sum_{J=1}^{24} [(\bar{X}_P - \bar{X}_R)/2 + \bar{X}]/24$$

a preference for a shorter lower face height.

The differences between the aggregate MAs of the responses to the animated features were highly significant, except for the retrusive bimaxillary relationship, as shown in Table 1. For the aggregate ZA, only the differences between the faces for the bimaxillary relationship and chin were significantly different. Most important, the changes in MA from the unaltered feature (0.0 mm of distortion), shown in Figure 1 as a composite reconstruction of preferred positions, were all statistically significantly different and were consistent with expectations of clinical outcome of orthodontic or surgical intervention.

Influence of respondent or judge variables

The same pattern of differences between orthodontic classifications was found for all three methods with dental judges showing a greater tolerance (larger ZA) for changes than the nondental judges. Moreover, no consistent age or gender differences were found with any of the methods.

Reliability

Using intraclass correlation(s),[29] the interjudge agreement or reliability across two faces of the unconverted rating responses of the discretely presented dichotomous stimuli was moderate at best, compared with the highly reliable responses to the animated distortions (see Table 2).

Discussion

New user-friendly computer-animation technology has been developed for relating proposed changes in physical dimensions of the face to measurable subjective judgments. In agreement with other research showing that both rigid and nonrigid motions typically enhance the perception of shape,[30] our use of movement or simulated animation has been found to be more sensitive, reliable, and valid than more conventional methods of evaluating discrimination of morphological changes.

Several factors may have accounted for the differences between the discrete and animated methods. Ideally, the animated face method would have been compared with the similar but time-consuming method of paired comparisons in which each discrete image distortion is compared with every other distortion to yield the relatively preferred image.[31] In the present experiment, the discrete methods required only an absolute judgment; that is, the respondent could accept or reject any or all of the discrete distortions. In fact, as shown earlier, there were several examples of feature distortions that were almost all unacceptable, except for the unaltered frame, which possibly may be because of its more natural look. The animated or moving face, on the other hand, required only a relative judgment. The respondent judge had to accept the changing distortion at some point and had to reject it at a subsequent point; in other words, enter and leave the ZA for both the extreme retrusive and protrusive positions.

Other reasons for the differences among meth-

Table 1
Aggregate measurements of zone of acceptability and midpoint acceptability for animated data (mm)

N=24	Class II division 1 Aggregate zone of acceptability (ZA)	Class II division 1 Aggregate midpoint of acceptability (MA)	Class III Aggregate zone of acceptability (ZA)	Class III Aggregate midpoint of acceptability (MA)	P (*t*-test) ≤ ZA	P (*t*-test) ≤ MA
Bimaxillary relationship	3.1±1.2	-0.8±0.6	4.3±1.7	-0.5±1.0	.01	NS
Chin	3.9±1.7	1.9±1.0	5.6±2.4	-0.6±0.8	.01	.001
Lower face height	3.9±1.2	-0.1±0.9	4.4±1.5	-1.2±0.9	NS	.005
Upper lip	2.9±1.0	-0.9±0.4	3.2±1.2	0.8±0.6	NS	.001
Mandible	3.6±1.5	1.5±0.8	3.7±1.3	-0.8±0.6	NS	.001

Table 2
Inter-judge agreement across Class II division 1 and Class III faces for rating and animated methods

	Intraclass correlations: Rating n=11 Retrusive	Rating n=11 Protrusive	"Animated" n=24 Retrusive	"Animated" n=24 Protrusive
Bimaxillary relationship	.35	.68	.39	.92
Chin	.86	.80	.99	.98
Lower face height	.00	.00	.95	.83
Upper lip	.82	.00	.99	.99
Mandible	.00	.80	.99	.99

ods may be related to the panel of judges, who varied in gender and dental sophistication. Dental/esthetic sophistication may, in fact, have been too broadly defined in this study by including anyone from dental assistants to postdoctoral orthodontic graduate students. In agreement with Tedesco[32,33] and Phillips et al.,[34] the dental judges in this study were more tolerant or less discriminating than the nondental judges.

Although most of the preferred positions of the five features for the test faces were congruent with clinical expectations of treatment outcome, there was considerable variability in the response to some features; for example, the relatively larger variance for lower face height indicates that vertical changes are harder to discern than horizontal ones, a finding which is consistent with the dental[35] as well as the psychological literature.[36] It was also noteworthy that the greatest changes and variances were found in the responses to the chin, particularly in the more retrusive position. This finding reflects clinical observations and some experimental findings that less dentally-sophisticated observers often have difficulty in agreeing on a preferred position for a retrognathic chin.[35]

In the present experiment, only one feature at a time from the lower third of the STP was manipulated. To determine the true interaction among all features in formulating judgments of STP acceptability, it is essential to evaluate each changing feature relative to more than one position of every other feature used in this program. Other factors to be considered in further studies of this method are size and location of the image on the monitor; the influence of color, texture, shading, and other visual cues; interaction among features; and inclusion of profile features other than those in the lower third of the face.

Other characteristics of the judges may also have an influence on judgments of acceptability, such as the gender of the judge in relation to the gender of the stimulus face; judge's handedness or eye dominance; side of the stimulus faces being presented; and differing psychomotor ability of judges to cope with the task requirement. Because of differences in hand or eye dominance, pressing the left computer mouse button may not be the most user-friendly method for assessing perceptual discrimination.

Only the words "acceptable" and "unacceptable" were used as outcome measures in the present study because they include all possible positive or negative value-laden words. As can be inferred from other authors,[37,38] more commonly-used words in esthetic research, such as "beautiful" or "attractive," may well have yielded different results. Moreover, as has been shown by Langlois,[39] words such as "youthful" or "healthy" may also modify judgments of attractiveness to the same stimulus.

The task now remains to develop a clinically practical instrument for assessment of all features of the full profile as well as the frontal face. Manipulation of at least the lips in the frontal face has in fact been demonstrated successfully with this program.[40] A new, reliable morphing program has been developed and validated that is capable of creating multiple transitional images between the two discrete extreme distortions without being anchored by the unaltered image.[3]

Conclusion

The animation method of presenting facial stimuli was found to be superior to more conventional methods of presenting discrete stimuli. Criterion-based clinical validation of this animation technique was achieved by demonstrating highly significant differences among responses to clinically disparate stimuli; i.e., Class II division 1 vs. Class III malocclusions. The method also appears to be extremely sensitive, as indicated by judges' ability to differentiate ≤ 1.0 mm of change in physical dimensions.

In summary, the use of an animated stimulus permits the establishment of a more realistic range or zone of acceptability in addition to a single measure of the most preferred configuration of proposed profile morphology. For both individuals and groups of patients, clinicians will be able to determine how much physical change in a feature or features must be made before an unacceptable facial appearance becomes acceptable; or conversely, how much change in a single feature or features will be tolerated before the facial profile is rejected. One major advantage of the animated method over other computer-based video imaging programs, which provides the patient with an immediate range of possible outcomes,[41] is the relatively disguised nature of the task; that is, the patient is essentially unaware of his or her response to the animated stimulus face. Moreover, the clinician can review the patient's preferences to avoid presenting an unrealistic treatment plan. The use of this new methodology can thus spare both clinician and patient confrontations over discrepancies between clinical ability to provide a specific result and patient expectation of outcome.

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Author Address

Dr. Donald B. Giddon
277 Linden Street
Wellesley, MA 02181

Donald B. Giddon, Harvard School of Dental Medicine and University of Illinois at Chicago.

Regina Sconzo, Boston University.

Jason A. Kinchen, Mathworks, Natick, Mass.

Carla A. Evans, University of Illinois at Chicago.

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