Journal of the World Federation of Orthodontists xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of the World Federation of Orthodontists

journal homepage: www.ejwf.org

Quantitating the art and science of esthetic clinical success

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ARTICLE INFO

Article history:
Received 31 December 2020
Revised 23 March 2021
Accepted 23 March 2021
Available online xxx

Keywords:
Esthetics
Neurophysiology
Orthodontics
Perception
Psychophysics

ABSTRACT

Background: Beginning with the biobehavioral bases of esthetic experiences, this article presents a quantitative analytic review of the motives and methods of providers and consumers of orthodontic treatment.

Method: A primary focus is determining the anthropometric bases of self and others' perceived preference and satisfaction with changes in facial appearance. These quantitative analyses have been based on determining the frequency and magnitude of reliability and validity measures of diagnosis, treatment, and satisfaction outcome. Socioeconomic considerations are also quantitated regarding the discrepancy between objective need for treatment as determined for example by the Index of Orthodontic Treatment Need and the subjective demand for treatment.

Results: The major contribution of this article is the quantitation of the components of esthetic experience from sensation of perception using psycho physical methods, such as Perceptometrics, for determining the morphological basis of perceived facial attractiveness adjusted for ethnocultural differences updated by 3-dimensional and artificial intelligence technology. Recent quantitation of smile components has also added to the measures of esthetically successful treatment. Further contribution of orthodontists to mental and physical health is demonstrated by the differences between perceived personality attributes in profile and full-frontal views of symmetric and asymmetric faces. Such information can facilitate the clinician's ability to determine the ideational representation of the patients' perceived pre- and post-treatment outcome.

Conclusion: The quantitative analysis of the motives and methods involved in the orthodontic treatment process has been combined with the neurophysiological correlates of producing and observing/evaluation of the esthetic experiences of both patients and orthodontists/dentists.

1. Introduction

1.2. The esthetic experience

An esthetic experience can be defined and evaluated by the extent to which it evokes perceived pleasure and associated psychophysiological responses. Quantitating the art and science of this experience requires the development of appropriate metrics relating the objective measured physical world and the frequency of reported specific subjective perceptions of it. Given that a successful outcome of orthodontic treatment is an esthetic experience for both patient and clinician, similar to any visual art form, it may now be included in the emerging subspecialty, cosmetic medicine [1].

1.3. Contributions of the form and function of the orofacial area

Consistent with the evolutionary axiom that form follows function, the role of facial attractiveness in survival and beyond is the key to orthodontists' and others' contribution to serving society.

Underlying these observations is the importance of the orofacial area to survival, socialization, and physical and mental health. Moreover, the orofacial area provides cues to age, gender, personal identity, health, ethnocultural background, emotions, and perceived

Competing interest: Authors have completed and submitted the ICMJE Form for Disclosure of potential conflicts of interest. None declared.

Funding: The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Provenance and peer review: Not commissioned; Internally peer reviewed.

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https://doi.org/10.1016/j.ejwf.2021.03.004

attractiveness of facial and body morphology. In addition to contributing to the quality of life by enhancing occlusal function and gustation, the orthodontists, who see their patients once a month for 2 years during their most formative years, have the opportunity, even obligation to recognize developmental, eating, and behavioral disorders, attention-deficit hyperactivity disorder, and substance and physical abuse.

1.4. Sensation: origin of an esthetic experience

Esthetic experiences originate from a spectrum of energy sources acting on the sensory receptors for vision, audition, olfaction, gustation, and tactility; and together with the somatosensory system, receptors for position (proprioception) and movement (kinesthesia) are also involved in creation and performance. Compared with recognition of sensory inputs contributing to an esthetic experience, their recall from memory is limited to the visual and auditory systems for most people [2].

1.5. Perception

Perception is simply defined as giving organized meaning to sensory input [3]. Consequently, except for reflex physiological responses to disaster, there is no one-to-one relationship between the external world and subjective perception of the external world. This lack of an exact relationship gives the mediating central nervous system the opportunity to distort, hence deceive the observer with illusory visual and auditory experiences. For example:

Practical applications of illusions like camouflage, knowingly or unknowingly, are found in the fashion and cosmetic industries, and with dermatologists, orthodontists, and orthognathic and plastic surgeons. For example, see Fig. 1A and 1B; Fig. 1B with some variation might be used to alter perception of lip line width.

2. Psychophysics

Simply stated, psychophysics is the quantitation of the relationship between the objective environment and subjective awareness and feelings [3], which then allows us to determine what is in the patients' and clinicians' minds about their perceived preferences and proposed changes in facial appearance. Basic to this method are two psychophysical measurements: the "absolute threshold," defined as the smallest detectable magnitude of visual or auditory characteristics, or chemical concentration detectable by the gustatory and olfactory systems [4]. The "difference threshold," for example, is the shortest distance between two adjacent points perceived as one, similar to the Weber Fechner Fraction of the original stimulus based on the magnitude of change recognized (e.g., 1/50th for weight; 1/60 for brightness; 1/333 for audition (pitch); or loudness 1/20; tactile 1/7).

2.1. Orthodontic applications of psychophysical methods for quantitating perception of thresholds or differences between respondent groups

Thresholds in general may differ among observers (e.g., orthodontists and lay people in cant, diastema, lip line and selected smile characteristics) [5,6].

2.2. Other dental applications of psychophysical methods

Note in Fig. 2 that local anesthesia of the periodontal ligament resulted in significantly decreased ability to detect differences in thickness of interdental disks [7].

2.3. Quantitating the morphological basis of facial perception

Early methods of assessing perception of one's own face by self and others included line drawings, silhouettes, moveable wooden pieces that are unfortunately dependent on the subject's psychomotor ability, and systematically touched up photographs [8]. As indicated by Alley and Hildebrandt [9], these methods often result in considerable distortion, significantly different from those obtained with holograms or using more realistic photographs and other computer-aided methods.

Beginning with children who become more astute with age, except for those with dysmorphia possibly seen in body dysmorphic disorder, most people cannot accurately recognize or reproduce their own profile [8,10]. The obvious paradox is that clinicians until recently based their diagnosis and treatment on profile views, whereas patients' subjective preferences were based on the full face. However, the advent of 3-dimensional (3D) technology in recent years has resolved this apparent paradox.

The observations from the Perceptometrics method described as follows, which provided a range rather than static display of likely treatment outcome, give the clinician more flexibility with treatment planning.

2.4. Perceptometrics

Among the first to use the psychophysics methods to quantitate clinical judgment of facial attractiveness, Giddon et al. developed a computer-animated method for determining the anthropometric bases of preferred and proposed changes in facial morphology, as summarized by Will [11]. This method used dichotomous endpoints to separate "acceptable" from "unacceptable" changes; for example, pretty, beautiful, gorgeous, sexy, and so forth were classified as acceptable compared with ugly, plain, beastly, gross, and so forth being judged as unacceptable.

The most important contribution of the Perceptometrics method was to provide orthodontists and surgeons the frequency and range of acceptable treatment options, rather than traditional static images of before and likely after treatment [11–14].

Basically, the Perceptometrics morphing method provides the ability to compare the midpoint and range or zone of acceptability (ZA) for patients, parents, and clinicians of preferred changes in the soft tissue profile [14].

As shown in Fig. 3, patients also perceived themselves to have a more protrusive mandible than their actual cephalometric profile measurement in agreement in this study with their mothers, who also preferred children to have more bimaxillary protrusion with full lips and strong chin [14].

Children in this study were regularly inaccurate in perceiving their own profiles. In general, young patients, mothers, and clinicians had similar quantitative bases for their perceived profiles. Mothers, however, had smaller ZAs than patients or clinicians, consistent with female individuals having less tolerance for variation from expected outcomes than male individuals [15]. The quantitative lesson for orthodontists is the importance of including parents in treatment planning.

2.5. Quantitating ethnocultural differences in facial perception

Most important for both clinicians and patients is finding ethnocultural differences in preferred profile changes. Using the Perceptometrics method, both clinicians and patients determined such differences. For example, Mexican American individuals preferred greater bimaxillary protrusion than Caucasian orthodontic non-Hispanic white patients and orthodontists [16]. Korean American

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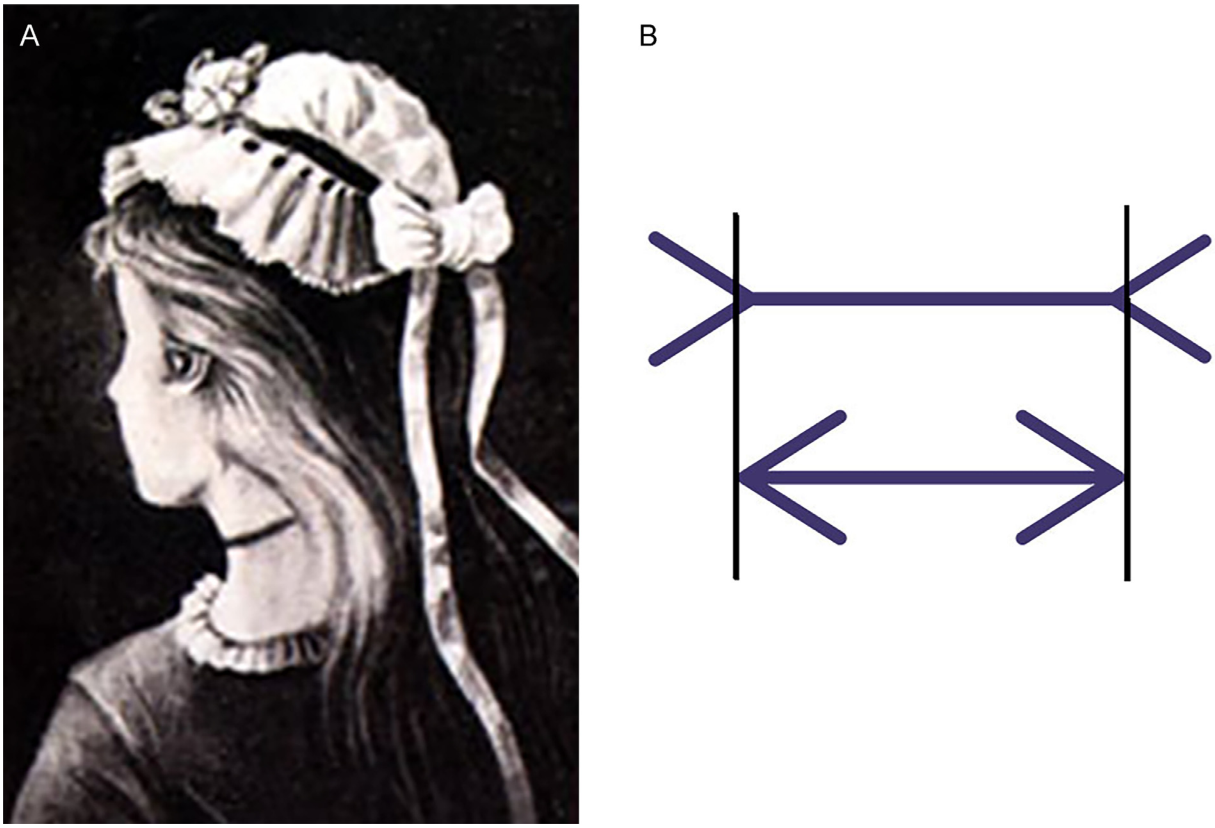

Fig. 1. (A) Bi-stable ambiguity: Image is seen either as a profile of an old women or a three-quarter left rear facial view of a young woman (from an anonymous German postcard from 1888). (B) Linear illusion: The line between the opening inward carets indicating a lesser magnitude is perceived as longer than the line between carets directed outward. (Donaldson D, Macpherson F. July 2017. "Müller-Lyer Illusion" in F. Macpherson, ed., The Illusions Index. Retrieved from https://www.illusionsindex.org/ir/mueller-lyer.)

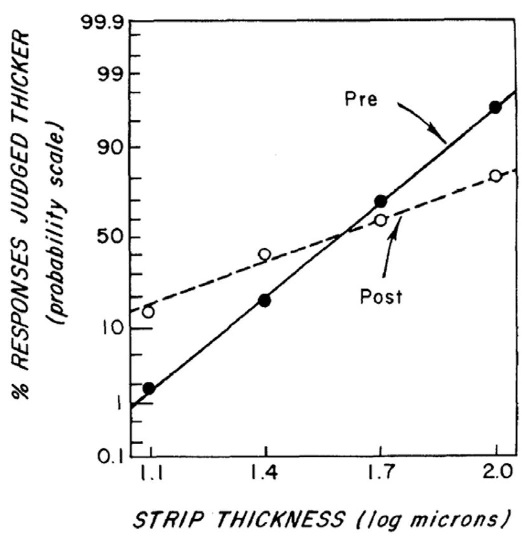

Fig. 2. An example of psychophysics used in dental research. Note that topical anesthesia of the periodontal ligament resulted in significantly decreased ability to detect differences in thickness of interdental disks. [7].

female patients prefer a more protrusive nose, whereas male patients prefer a more retrusive chin than their Caucasian orthodontist [17].

Simpler psychophysical methods were also used to determine the anthropometric differences through separating faces perceived as Most Likely and Least Likely Chinese, Japanese, or Korean. As expected, Asian observers perceived their own ethnic group as the most attractive. Demographically, the proportion of faces judged as Chinese, Japanese, or Korean was similar to the local census [18]. Moreover, as expected, each of the three Asian judge groups perceived its own ethnic group as most attractive.

2.6. Quantitating the objective and subjective determinants of facial function and form

The need for orthodontic treatment is determined by the orthodontist based on assessment of occlusal dysfunction, using for example the Index of Orthodontic Treatment Need [19] validated by the correlation of intra-oral photographs. In comparison, demand for and subsequently obtaining treatment are based primarily on self and other perception of facial attractiveness. Some ways to measure this perception include morphed photographs [20]; methods of constant stimuli, signal detection theory, and adaptive probit estimation [21]; and questionnaires such as the Oral Aesthetic Subjective Impact Scale [22].

The FACE-Q is a widely used, valid and reliable, culturally sensitive, self-report measure of the physical components of facial attractiveness before and after treatment [23]. This procedure shows the relative importance of specific features to facial attractiveness; for example, the chin, nose, forehead lines, eyebrows, nasolabial folds, lips, and so forth, and their relation to quality of life. It provides clinically useful information of the patient's self-reported sat-

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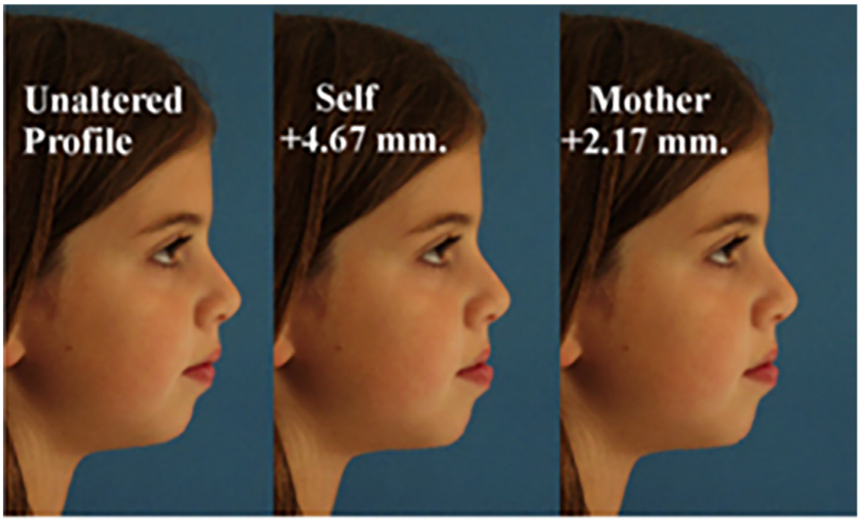

Fig. 3. Translucent overlays can be used to demonstrate discrepancies between patient/child and the mother in preferred outcome of changes from unaltered facial profile [14]. (Responses of clinicians are available from authors.) (General permission granted: Miner RM, Anderson NK, Evans CA, Giddon DB. The perception of children's computer-imaged facial profiles by patients, mothers and clinicians. Angle Orthod 2007;77:1034–1039.

isfaction with changes in response to treatment outcomes of selected body parts. Also note that it should not be assumed that the face is the most important factor in self-esteem/concept, which may vary for geographic and financial reasons. For example, there are many cross-cultural and self-reported studies comparing face and body satisfaction, such as the Body Esteem Scale and the Body Appreciation Scale [24,25].

The obvious discrepancy between the motives and methods of the orthodontic health care provider and patient consumer must be realistically considered with respect to the consistent observation that esthetics is the main motivational reason for seeking orthodontic care rather than function of the orofacial area [26]. Consequently, treatment planning is essentially based on determining what is in the patient's mind, including ideational representation of the dysmorphic and dysfunctional need for treatment options relative to cost and willingness to comply with treatment to obtain the expected outcomes.

2.7. Artificial intelligence

Facial attractiveness, whether observed by self or others, can now be quantitated by artificial intelligence (AI). Specifically, "machines" can be taught to rate facial images on a scale from 1 (very unattractive) to 7 (very attractive), which correlated with human raters ($r = 0.65$, $P < 0.001$) [27], with the obvious potential for determining the optimal contribution of individual features to facial attractiveness. Because the current panel-based methods of determining facial attractiveness are limited by dispersion-related issues and remain practically unavailable for patients, AI could be a helpful tool as a less cumbersome method for quantitatively comparing the relative attractiveness of healthy patients as well as determining the magnitude of dysmorphia independent of dysfunction in patients with cleft lip and palate and other anomalies [28].

Computerized images using AI have reaffirmed the preference for average faces over those judged extremely beautiful by computer AI-directed algorithms, which in previous studies have been shown to correlate significantly with human judgments of similar faces [27]. In general, what is considered beautiful across almost all cultures factors down to those faces closest to being average and symmetrical.

2.7.1. Quantitating compliance with orthodontic treatment

Compliance with the recommendations of health care providers has now been recognized as essential to improved health care at lower cost. For orthodontics specifically, patients must be made aware of the need to maintain and/or improve oral hygiene consistent with dietary restrictions and keep follow-up appointments for removal of appliances like headgear, elastics, or retainers. Bos [29] in fact should be remembered for her classic study in which she quantitated the frequency of various positive and negative reasons for compliance with orthodontic treatment.

2.7.2. Quantitating facial attractiveness

As noted by several authors, beauty is not necessarily in the eyes of the beholder [30,31]. In addition to individually and culturally preferred facial attractiveness, there are common soft tissue preferences for features, such as small noses, large eyes, smooth skin, and high forehead, often associated with a baby face, adjusted for gender differences in cheek bones and chin [32,33], similarly found in using 3D manipulation of facial images and landmarks [34]. Moreover, although hard tissue configurations of beauty can be identified across cultures [35], seeking to obtain the seamingly ideal golden proportion is no longer in vogue [36].

2.7.3. Average faces

The finding of Langlois and Roggman [37] that the average face was more preferred than the most attractive face [37] was initially challenged by Alley and Cunningham [38] as misrepresenting the relative differences between average and most attractive faces. It was later verified by several authors [39] and further reaffirmed with computer and AI technology [40]. In general, these observations are consistent with the tendency to regress toward a mean prototype for a given population, as shown in composite faces in Fig. 4

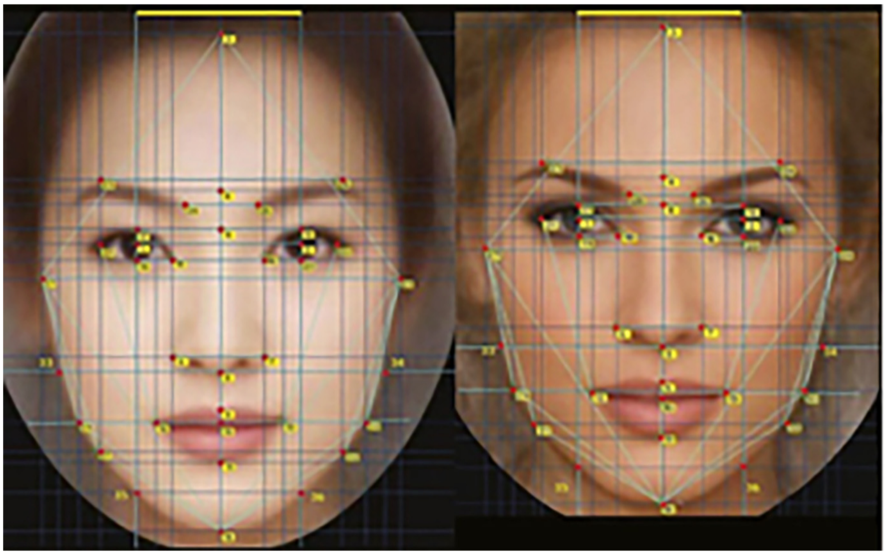

Fig. 4. Attractive Caucasian and Asian composite faces. From an international perspective the faces represent a recent comparison of the most attractive Asian and Caucasian faces. (From Rhee SC. Differences between Caucasian and Asian attractive faces. Skin Res Technol 2018;24:73–9; permission from Wiley).

2.7.4. Quantitating smile esthetics

The magnitude of the orofacial components of an esthetically pleasing smile includes smile arc and size of the buccal corridors in 2 or 3D. As noted by Akyalcin et al. [41], there are various dimensions of an attractive smile, for example, the smile arc and amount of gingival display (Gingival display/Visible dentition display (%) 3.8 ± 3.4; Smile arc discrepancy/Smile frame [%] 17.7 ± 3.6 as attractive) were related to the degree of successful treatment outcomes as determined by the American Board of Orthodontics for certification as an orthodontist [41]. In general, tolerance for anomalies following orthodontic treatment is least for midline diastema and most for gummy smiles, which varies by age and gender [42].

Other quantitative dynamic aspects of the smile include activation of the circumoral muscles of facial expression: four labial muscles (levator labii superioris, zygomas major, minor, and risorius), which rated more favorably than those involving only risorius [43]. Quantitating activation of the eye muscles, orbicularis oculi, is yet another important component of an attractive smile.

2.7.5. Quantitating treatment outcome

The systematic evaluation of treatment outcome and patient satisfaction includes symmetry, balance, and context in relation to prevailing preference for facial and body morphology [44,45].

Evaluation of facial attractiveness certainly augments treatment planning and success of orthodontics and/or surgical treatment. For example, pre to post changes in anthropometric proportions have been used to predict the outcome of orthognathic surgery in terms of postoperative facial morphology [46].

Pretreatment anthropometric/cephalometric proportions have also been used to predict the outcome of orthognathic surgery [47]. For example, in a related study, the rank order of facial attractiveness was highly correlated with similar measures postoperatively [48].

The unreliability of predicting static soft tissue outcomes was in fact the reason for the Giddon group to develop the computer-animated Perceptometrics method to provide a range of acceptable outcomes.

2.8. 3D technology

In recent years, 3D technology has been increasingly used to achieve a more precise relation between objective facial morphology and subjective esthetic perception in diagnosis and treatment planning. Ghoddousi et al. [49] compared the following methods: manual anthropometry, 3D stereophotogrammetry, and 2D photograph, finding that measurements by 2D were more variable than manual, whereas 3D measurements were more comparable with manual measurements. In 3D, the female faces were rated as more attractive than in 2D, establishing the 3D as more clinically and experimentally useful than 2D [50], which seems to resolve the historical paradox of orthodontists basing treatment planning on cephalometric profile, whereas patients base their perceptions and preferences on their frontal face [8]. In any case, these more sophisticated procedures are more likely to be used by orthognathic surgeons than clinical orthodontists.

2.9. Visual Treatment Objective or VTO

The Visual Treatment Objective or VTO was initially developed by Holdaway [51,52] to predict the postoperative outcome of treatment and/or orthognathic surgeons. Following from the Perceptometrics approach of Kitay et al. [53] and Giddon et al. [54], computerized methods such as Dolphin VTO have made visualizing proposed soft tissue changes possible. However, Peterman et al. [55] found that although the A and P outcome of comprehensive orthodontics and two-jaw orthognathic surgery for Class III patients could be predicted by Dolphin VTO within ± 2 mm, the predicted outcome of postsurgical lower lip was inaccurate.

2.10. Duration of treatment and mental health

Often overlooked in this equation is the effect of the duration of treatment and mental health. There is little doubt that intended or unintended changes in physical appearance have a biobehavioral impact on patients, depending on the duration of treatment. In fact, there is a significantly greater biobehavioral adjustment required for sudden physical changes occurring with plastic and orthog-

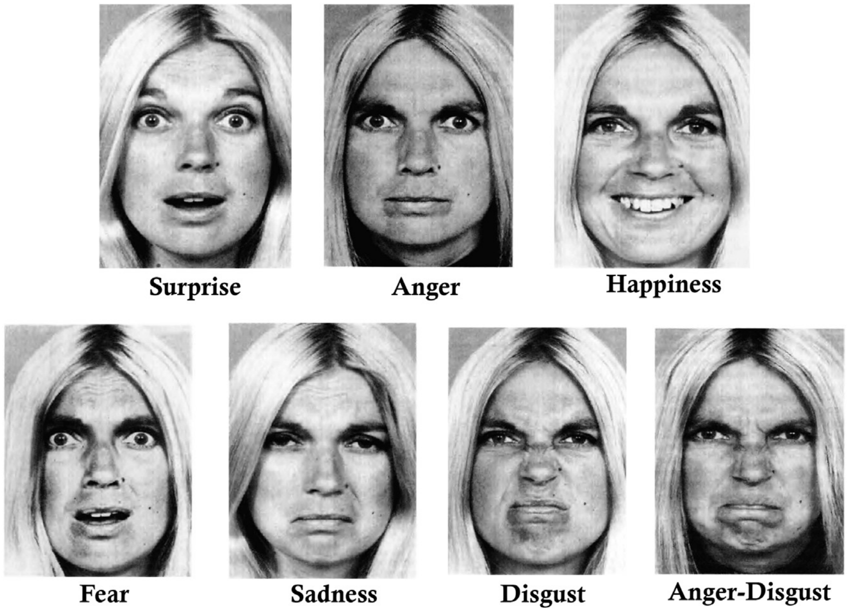

Fig. 5. Seven basic facial expressions of emotional responses [58]. (Permission granted from Paul Ekman Group.)

nathic surgery than experienced with orthodontic treatment associated with transient pain related to tooth movement [56]. Frost and Peterson [57], for example, found that 70% of orthognathic surgical patients experienced postsurgical depression.

3. The Face

This section discusses other quantitative contributions of oral facial function to survival, socialization, and quality of life.

3.1. Facial expression

Together with the speech apparatus for communication of message content essential for socialization, movements of the circumoral muscles of facial expression have been classified metrically by Ekman and Friesen [58] into seven basic emotional responses to a given message, as shown in Fig. 5.

Other ethnocultural differences between Asian and Caucasian health care providers in perception of facial expressions have been both described and quantitated by Giddon and colleagues [59,60].

The role and importance of the smile as it is involved in facial expression, with and without teeth showing, have a fascinating socioeconomic history [61].

Beyond the inability to swallow rice [62] and later psychophysiological methods (Polygraph), advanced AI digital technology now makes it possible to detect subliminal movement of muscles of facial expression by self or others, for clinical and forensic use [63].

3.2. Quantitating facial morphology

Even with the scientifically discredited physiognomy and phrenology for attributing personality and other characteristics to differences in head and face shape, the phenomena still exist today as reliable stereotypes within a given culture. The vestiges of phrenology have returned with the association of head shape variation in autism spectrum disorder and schizophrenia [64].

The Giddon group [65] found differences in the patterns of personality and other attributes between faces displayed frontally and profiles (see Fig. 6A). Compared with full faces, profiles were perceived as significantly less “outgoing,” “successful,” “influential,” “competitive,” “athletic,” “sociable,” “likable,” “bold,” “attractive,” and “distinctive” ($P < 0.05$ to $P < 0.004$). Consistent with previous research on facial configuration, brachyfacial individuals were found to be significantly less “adaptable,” “likable,” and “honest” ($P < 0.05$) and more “proud” and “dominant” ($P < 0.01$) than the mesofacials and dolichofacials (see Fig. 6B). To the extent that orthodontic treatment makes significant changes in the positions of individual teeth, there may be some concern or improvement in smile esthetics in relation to personality perception, as has been demonstrated over many years of prosthodontists’ use of the principles of biometrically based positioning of teeth in artificial dentures.

Facial profiles, when compared with frontal faces, show decreased identification rates for expressions of sadness and disgust and significantly reduced perceived intensity for all the expressions tested [66]. Kerns et al. [67] found that when looking at the patient from the frontal view, teeth compared with lips and chin overwhelmingly influenced facial attractiveness. However, when looking at the patient profile, lips were the most important feature for overall facial esthetics. Furthermore, for the same smile, profile views were rated higher than frontal views.

Although these observations are interesting and may be useful for cosmetic treatment planning and initial judgments, such as triaging of patients, this categorization can lead to prejudice and profiling, with face shape being the basis for stereotypes of likely behavior. Although face stereotypes are often shared by people within a given culture, there is little validity to the assessments of a given individual [68].

3.2.1. Facial asymmetry

In contrast to random asymmetry often seen in body surface areas, there are many directed lateralized organs, such as the heart and descending colon on the left side; the liver, gall bladder, and spleen on the right side. Facial asymmetry is due in part to hemisphere organization. In most right-handed humans, the left side of the face tends to be larger [69], revealing more neg-

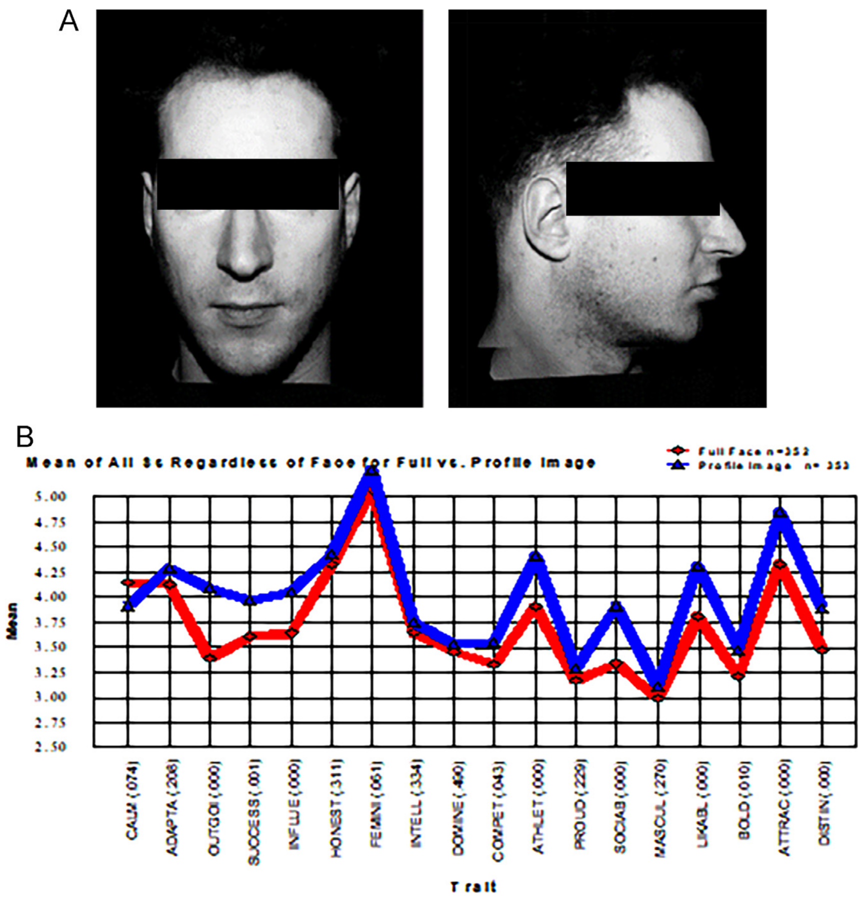

Fig. 6. (A) Example of one of the stimulus faces in frontal and profile view with differences in personality as listed across the abscissa of (B). (Permission from Psychological Image Collection at Sterling: PICS, http://pics.stir.ac.uk). (B) Comparison of attributes of full face and profile. Mean of all Ss regardless of face for full versus profile image. (From Schack K. Personality and craniofacial morphometry [postdoctoral thesis]: Harvard School of Dental Medicine, Boston, MA; 2001. Permission not needed; figure was created by student under supervision of Dr. Giddon.)

ative emotions reflected by the circumoral muscles of facial expression [70,71] and most jaw deviations asymmetric to the left [70,72]. Although the sensory and motor pathways for the upper face are bilateral, the innervation of the lower face is contralateral with decussation of the trigeminal and facial nerves [73], which recently has been questioned by Loder and colleagues [74].

3.3. Lateralization of faces

Less obvious to orthodontists, people/patients prefer showing one side of the face, that is, the left side is more frequently preferred by patients reading from left to right than right to left readers [75]. Displaying more of the left than right face has a long history of being associated with religion and deference to God. The historical interplay of environmental, psychological, and neurophysiological factors has resulted in 90% of religious paintings [76] and 60% of portraits [77] having more of the left face displayed, including many self-portraits by old “masters.”

Consistent with deference associated with religious beliefs, display of the left face in portraits is associated with more respectful or compliant individuals, often of lower socioeconomic status. See example in Fig. 7 of a Norman Rockwell painting. Display of the right face in portraits, coins, stamps, is generally indicative of people with more power and status.

4. The neurophysiological correlates of an esthetic experience

The neuroanatomical pathways involved with an esthetic experience begin with the presentation of the visual stimulus to the retina. The image is then transmitted to the lateral geniculate nucleus in the thalamus, then to the primary visual cortex, through one of two pathways [78]. The first is the inferior ventral visual pathway containing mu opioid receptors that are activated by pleasurable visual stimuli [79], and ultimately ends in the right inferior temporal and occipital cortex for facial recognition [80]. With additional extension to the hippocampus, this first pathway integrates visual stimulus with memories of people, places, and things, associating them with emotions in the amygdala. The second visual pathway identifies the location of the stimulus.

At least two major supervening systems are active in both the creation and observation of art: the default mode network (DMN) and the executive network (EN) [81], both of which are modified by personal motivation.

4.1. Brain activation of the artist

Advanced imaging technology, such as functional magnetic resonance imaging (fMRI) and positron-emission tomography (PET), has enhanced the ability to determine the neurophysiological correlates of an esthetic experience, including the contemplation and creation of a work of visual art by an artist or of a treatment plan by an

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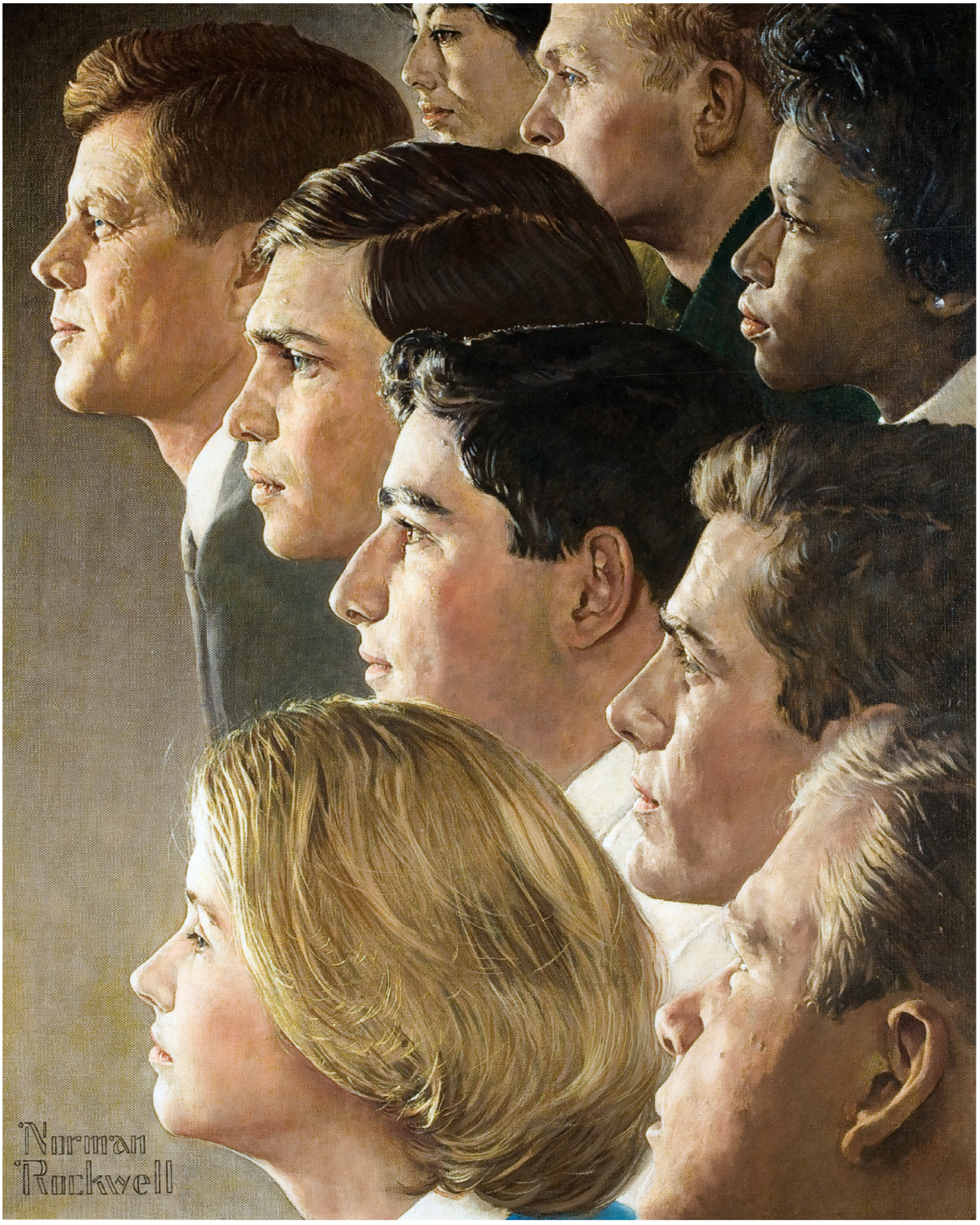

Fig. 7. The Peace Corps. (Artwork Courtesy of the Norman Rockwell Family Agency and Norman Rockwell Museum Collection.)

orthodontist/surgeon. For visual art creation, both DMN and EN activation are enhanced [82]. A recent study of differences in pathways of brain activation among the artist, performer, and observer revealed that art performers show greater functional connectivity than an observing and evaluating group between the DMN to the premotor and prefrontal cortices, superior and inferior parietal lobes, and middle and superior temporal gyri [83]. The major differences among the three groups are depicted visually in Fig. 8.

4.2. Brain activation of the orthodontist/dentist

Similar to the brain activation during the cognitive and affective activities [84] of a sculptor contemplating and creating a new work

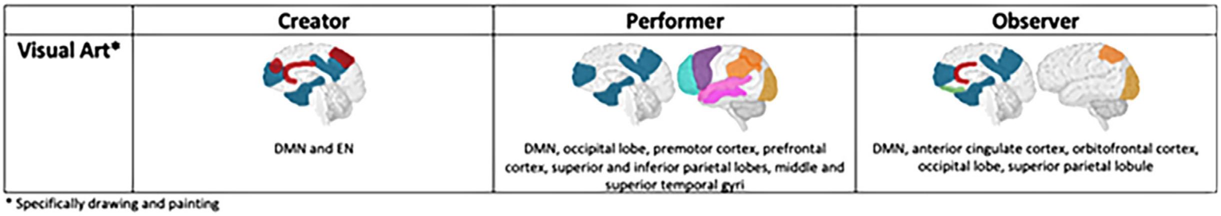

Fig. 8. Different areas of brain activation as a creator versus performer versus observer. (Figure created by co-author of paper.)

for evaluation by self and others, the orthodontist is involved in neurophysiological processing when planning, implementing, and evaluating an esthetic outcome together with the patient.

Therefore, dentists and surgeons, like visual artists, execute physically appealing treatment, which measurably activates the prefrontal cortex of the DMN [85] together with brain activation associated with fine motor movements such as the primary motor and premotor cortices, supplementary and presupplementary cortices, posterior parietal cortex, basal ganglia, and cerebellum [86,87].

With the development of fMRI and PET scanning, it became possible to quantitatively relate ratings or ranking of esthetic satisfaction to magnitude and patterns of brain activation.

Given the known differences in brain activations among creators, performers, and observers, it is not surprising that experienced portrait artists demonstrated less activation of the right posterior parietal area than novice artists [88], who must spend more time with facial details than experienced artists. Similarly, motoric behavior associated with the performance of expert pianists reveals less activation of primary and secondary motor areas than lesser-skilled performers [89]. It is anticipated that experienced dentists similarly expend less energy than a novice clinician [87].

5. Conclusion

Quantitating esthetic clinical success begins with identifying the fraction of the energy spectrum responsible for activating the sensory and subsequent cognitive, affective, and voluntary and involuntary behavioral responses to the mostly subjective perceptions of the environment. Many quantitative methods for assessing all phases of orthodontic diagnosis, treatment, and satisfaction follow from the use of psychophysical methods to determine and evaluate the relationship of the anthropometric or other objective measures of need for orthodontic treatment relative to the subjective demand for care.

These observations should be incorporated into dentistry and medicine to qualify for third-party payment for improving physical and mental health.

Acknowledgments

We are grateful to Caroline Rains for preparation and editing of the manuscript with the help of Greta Johnson, Ariel Eisen, Meryl Phair, and Grace Phair.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejwf.2021.03.004.

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