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Research paper

# Feature proportion accuracy of hand-drawn facial approximation

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ABSTRACT

Several studies have investigated the predictive accuracy of facial approximation methods for individual facial features, but few have investigated the ability of these methods to accurately predict the relative dimensions of these features. Photographs of 10 skulls from the William M. Bass Donated Skeletal Collection were used to create hand-drawn facial approximations following the guidelines presented in Taylor (2001). Measurements of the eyes, nose, and mouth were made and converted to ratios for comparison to their corresponding antemortem photographs. Potential error introduced by angulation in the antemortem photographs was assessed by finding similar ratio values for volunteers who were photographed at a series of angles. Eye measurements were distorted when individuals were turned 30 to 70° away from the camera. However, all antemortem photographs displayed individuals turned 30° or less from the camera. Wilcoxon signed rank tests revealed no significant differences between the hand-drawn approximations and the antemortem photograph measurements values for all feature relationships except for the eye width to iris diameter ratio, likely because the Taylor (2001) method does not reference the underlying bone when approximating the size and appearance of the eye.



## 1. Introduction

When human remains are discovered, every attempt is made to identify the individual. DNA analysis, fingerprint analysis, dental radiograph comparison, or X-ray comparison may supplement circumstantial evidence and establish identification [15]. Sometimes identification using these methods is not possible, as when antemortem records are unavailable for comparison. If the soft tissues have decomposed or been damaged beyond the point useful for identification, an osteological examination may be performed to establish a biological profile for comparison to missing person records. In the absence of a match, craniofacial approximations [32] may be generated and circulated by law enforcement as a last resort [4,33] in an effort to generate leads from the community. Facial approximations are also used in archaeological contexts to provide artistic representations of past populations and individuals (e.g. [10]). Over the years, several methods for estimating facial soft tissue features from visible bony landmarks have been developed. These methods include both two-dimensional and three-dimensional techniques. The present study compares hand-drawn approximations based on a widely-circulated method with associated antemortem photographs.

Computer-generated three-dimensional facial approximations from human skulls are becoming more commonplace in forensic investigations. For a given sex, age, and ancestry, these programs use an "average" face as a contour surface map that can be deformed to correspond to the unique topography of the underlying bone [25,33,47]. This method is therefore similar to three-dimensional clay modeling techniques in that representation of the soft tissues can be manipulated according to the unique features of an individual skull. This method is relatively easy to use and has the additional benefit of producing an image that can be easily manipulated and viewed from different angles. Traditionally, the role of facial approximation has fallen to forensic artists, who may produce either two- or three-dimensional reconstructions depending on the condition of the skull and the method preferred by the artist [46]. While computer-generated approximation methods are presumed to produce easily repeatable results, they are generally based only on the gross skull morphology captured by a surface scanner or CT scan, and do not communicate some of the more subtle features that may be gleaned from thorough inspection and interpretation by the forensic artist [49,51].

Furthermore, the forensic art community does not appear to be unified in its choice of software or reference materials for computer-generated approximations. The 2010 Standards and Guidelines for Forensic Art and Facial Identification by the Forensic Art Subcommittee of the International Association for Identification [13] provides only the most general recommendations for digital approximations, stating they may be generated "by either automated or modeling systems". The NIST [21] Organization of Scientific Area Committees includes a subcommittee on Facial Identification and Video/Imaging Technology & Analysis, but neither of these address facial approximation. The Scientific Working Group for Forensic Anthropology (SWGANTH) [29] briefly

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addressed facial approximation in its 2011 document, but stopped short of recommending “specific techniques”, citing the continuing evolution of current methods.

While digital facial approximations have recently been tested for their quantitative accuracy [2,17], the qualitative resemblance or recognizability of such approximations is often not addressed as relevant technologies have evolved (notable exceptions include [6,50]). As mentioned above, the inclusion of finer details such as subtle asymmetries and age-specific features in an approximation require thorough examination of skeletal material by the artist, and artistic skill to interpret those details. The ability to examine skeletal material and render detail in digital approximations is often hampered by the nature of current techniques, ensuring the continued production of manually generated facial approximations.

It is for the above reasons that the current study utilized a hand-drawn facial approximation technique. Taylor's [46] guidelines were chosen in particular because they are commonly used by approximation specialists [4,33], are detailed, and are easily accessible to the competent reader. As other authors have noted, (e.g. [4,33,48]), this popular method rests on several assumptions that have not been tested until recently. For example, facial approximations have traditionally relied on tissue depth measurements provided by Rhine and Moore's [26] cadaver study, which controlled for sex, ancestry, and body weight. With the advent of portable ultrasound technology, DeGreef et al. [4] were able to demonstrate that tissue depth data collected from cadavers is significantly different from tissue depth data collected in-vivo at most facial landmarks. Approximations created using data from Rhine and Moore [26] are therefore apparently more likely to appear thinner than faces created using in-vivo data. Recent research has also expanded to include populations outside those used to compile the original tissue depth data sets. For example, Panenková et al. [24] found tissue depths for the midface in a Slovak population. However, it is unclear to what extent differences between these new samples and the original cadaver data are biologically significant rather than a statistical inevitability [41].

Estimation of individual features has undergone scrutiny as well. Stephan [33] called the mouth width determination recommended in Taylor [46] “highly inaccurate”, in that it consistently underestimated mouth width. Similarly, Stephan et al. [34] found that Krogman's ([14], also cited in [46]) method of nose projection estimation “performed poorly” compared to other methods, and presented improved means of prediction based on living subjects. Similarly, Rynn et al. [28] tested several methods of nose prediction by comparing approximated noses to antemortem CT scans and photographs. They also found Krogman's method to be inaccurate, but found Gerasimov's “two-tangent” method in combination with several regression equations obtained from cephalograms produced relatively accurate results. Stephan and Devine [38] also describe how the facial outline is not a simple function of the temporalis muscle alone as it is commonly assumed to be by forensic artists. Ear shape remains a problematic feature in facial approximation, although Guyomarc'h and Stephan [7] provided regression equations for the estimation of ear size.

Wilkinson and Mautner [48] compared the method of eye projection estimation for lateral views recommended in Taylor [46] to data gathered via MRI cranial images, and found that in-vivo eye projection was significantly greater than assumed by current approximation guidelines. Regarding frontal views, Stephan and Davidson [37] found that the eyes are not placed centrally within the orbit as supposed by Taylor [46], but are more superiorly placed. However, Stephan and Davidson [37] found general agreement between recommended and actual canthi placement. While Stephan and Davidson [37] and Stephan et al. [39] have addressed the anatomical placement of the eyeball relative to the bony orbit, they have not addressed eye size or internal proportions. Guyomarc'h et al. [8] established mean eyeball volumes in addition to measures of eyeball position, but did not discuss how these measures compared to iris diameters or other soft tissue features of the face.

The above studies analyze individual features within the face, but none have examined the proportional relationships between or within individual features. The current study is therefore an attempt to assess the accuracy of the commonly practiced method outlined in Taylor [46] on a more holistic scale than has previously been attempted. The present study tested the null hypothesis that there are no significant differences in facial feature proportions between manually constructed facial approximations and photographs of corresponding living individuals (for all comparisons, $H_0$: hand-drawn feature ratio = antemortem photograph feature ratio). Paired *t*-tests compared facial feature proportions between approximations and the associated antemortem photographs. The following terms are used throughout the remainder of this paper, and are defined here. “Canthus” refers to the corner of the eye where the upper and lower lids meet. The “philtrum” is the indented fold of skin between the nose and the upper lip at the midline of the face. The “alar groove” is the groove formed at the attachment site of the lateral nostril of the nose.

## 2. Materials and methods

Ten undamaged skulls from the William M. Bass Forensic Skeletal Collection were photographed to obtain both frontal and lateral images. All skulls represented males of European ancestry between the ages of 46 and 65 years. Constraint was placed on the sex, age, and ancestry of the individuals studied in an effort to minimize within-sample variance. European-derived males between the ages of 46 and 65 were chosen in particular because of their availability within the William M. Bass Forensic Skeletal Collection. Skulls were selected primarily for their association with an available antemortem photograph, as well as for their sex, age, and ancestry. Estimation of facial height is usually aided by the occlusion of the molars, which guides the positioning of the mandible. However, in edentulous individuals, occlusion is not possible, and positioning of the mandible becomes more speculative. For this reason, edentulous skulls were excluded from study.

Photographs were taken using a Nikon D70 digital camera with an AF-S Nikkor 18–70 mm 1:3.5–4.5 ED lens. Taylor [46] recommends a lens with a focal length of 100 to 200 mm; lenses with smaller focal lengths cause perspective distortion that causes objects to look smaller the further away from the lens they are. The lens used in this study was appropriate since 35 mm cameras have a diagonal picture angle approximately one and one half times that of the D70 camera [23]. For example, a 35 mm camera using a lens with a 100 mm focal length would only require a 66.7 mm lens in the D70 camera to produce a similar picture angle. Thus, the lens used in this study produced a focal length roughly equivalent to that recommended by Taylor [46]. While the distance between the camera and the skull remained constant, the value of this distance was unfortunately not recorded. Furthermore, the distance cannot be reliably estimated because the focal length of the lens at the time of photography was not recorded. Future studies must note these values to ensure the prevention of image distortion [42].

Marker placement and photography were carried out following guidelines provided in Taylor [46]. Vinyl machine eraser strip markers were placed over 21 anatomical points (10 midline and 11 bilateral) on each skull according to tissue depth data for European-derived individuals provided by Rhine and Moore [26]. Frankfurt Horizontal was maintained in the photographic image by aligning a small wooden stick glued to the top of the external auditory meatus with the inferior margin of the orbit.

To determine which set of tissue depth markers to use, body mass index (BMI) was calculated from the recorded height and weight of each donor. “Obese” markers were used on individuals determined to be “overweight”, i.e. with a BMI of 25 or more [20]. Before photography, dental wax was placed between the glenoid fossa of the temporal bone and the mandibular condyle, to approximate the spacing provided by the temporomandibular joint's articular disc in life. The skulls were