Technical Note

Automated Facial Recognition and Candidate List Rank Change of ReFace Facial Approximations Generated with Multiple Eye Orb Positions

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Abstract

Expanding on research previously reported by the authors^{1,2,3}, this study further examines the recognizability of ReFace facial approximations generated with the following eye orb positions: (i) centrally within the bony eye socket, (ii) 1.0 mm superior and 2.0 mm lateral relative to center, and (iii) 1.0 mm superior and 2.5 mm lateral relative to center. Overall, 81% of the test subjects' approximation ranks improved with the use of either of the two supero-lateral eye orbs. Highly significant performance differences ($p < 0.01$) were observed between the approximations with centrally positioned eye orbs (i) and approximations with the eye orbs placed in the supero-laterally positions (ii and iii). Noteworthy was the observation that in all cases when the best rank for an approximation was obtained with the eye orbs in position (iii), the second best rank was achieved with the eye orbs in position (ii). A similar pattern was also observed when the best rank was obtained with the eye orbs in position (ii), with 60% of the second best ranks observed in position (iii). It is argued, therefore, that an approximation constructed with the eye orbs placed in either of the two supero-lateral positions may be more effective and operationally informative than centrally positioned orbs.

KEYWORDS: forensic anthropology, facial approximation, facial recognition, unidentified decedents, missing persons, biometrics.

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Introduction

Facial approximations of unidentified individuals, be they manual or computer assisted, inherently contain a degree of artistic subjectivity (1-3). Nevertheless, it has been posited [4] that the majority ($\approx 67\%$) of a facial approximation can be estimated objectively by the underlying morphology of the skull. Subject to a degree of artistic privilege, however, is the construction and positioning of the highly variable facial features (e.g., eyes, nose, and lips) (1-7). A recent development in the field of facial approximation is debate regarding appropriate placement of the eye orbs within the bony eye orbits of the skull [4-8].

Two primary factions exist regarding appropriate eye orb positioning. The first contends that eye orbs should be positioned centrally within the bony eye orbit [4, 9-12], while the second faction argues that a supero-lateral position (from center) more appropriately reflects anatomical ground truth [5-7, 13-16]. Although empirical evidence exists supporting both positions, cognitive and neuroscience researchers assert that humans perceive the face as a holistic structure and, consequently, exhibit discrimination insensitivity to subtle spatial shifts of single facial features [17-23]. It has been argued, therefore, that from a practical perspective minor variation in eye orb position (e.g., 1-2 mm) is not alone likely to significantly alter facial geometry nor to negatively impact perception and potential response from a publically displayed facial approximation [17-22, 24]. Conversely, where such a seemingly minor difference may be operationally relevant and produce a significant impact is in contexts where a facial approximation is intended for an objective evaluation in which the eye locations play a critical role in multiple functions performed during the objective examination, as is the case in automated facial recognition systems.

Locating the position of the eye regions in a facial image, referred to as eye localization, is necessarily one of the first essential steps in automated facial recognition. Facial recognition systems

use a suite of complex algorithms to assess ocular and peri-ocular features to locate, define, and mark the centers of the eye regions [25,26]. The landmarks placed at the estimated centers of the eye regions are used as anchoring points for critical algorithmic functions such as image normalization, feature extraction, and for measuring the relative positions of facial features [25,27]. Based on the information obtained from these algorithmic functions, facial recognition systems attempt to match an image of interest (e.g., a photograph or facial approximation) to one or more records within a database of images, subsequently producing a candidate list of the most likely matches. Given the significance of the eye regions in automated facial recognition algorithms, it is posited that candidate list constituency and corresponding ranks will vary when the eye positions of a facial approximation probe are manipulated. Advances in facial recognition technologies now afford researchers a unique opportunity to objectively examine this hypothesis.

Expanding on research previously reported by the authors [28-30], this study employs an automated facial recognition system as a means of objectively evaluating the change in match ranks of facial approximations generated with multiple eye orb positions (e.g., a central position versus more supero-lateral positions). The results of this study will contribute to the existing literature examining current forensic facial approximation eye placement techniques, address the first and second objectives of facial approximations as defined by SWGANTH [31], and further evaluate the utility of facial approximations in operational contexts.

1. Materials and Methods

The research model employed in this study has been reported [28] and is, therefore, only briefly discussed here for the purpose of pointing out certain methodological differences. Given that the baseline performance for the facial recognition system (NeoFace® Reveal, NEC Corporation of America, Irving) employed in this study has been established by the authors in two prior research studies [28,29],

no internal control was conducted. In contrast to the methodology detailed in [28]: (i) only a blind search against the entirety of the gallery (g) was conducted for each test (t) subject, (ii) the probe (p) set consisted of only average weighted approximations with visible eyes, and (iii) three approximations with varying eye positions (described below) were generated for each test subject (gallery and approximation types defined in [28]). The reader is referred to the aforementioned study for a detailed explanation of the materials and methods not expressly discussed.

The complete, unaltered image gallery ($g = 6159$) previously constructed by the authors [28] was used in this study. The test subjects examined ($t = 27$) in this research were members of the two original samples compiled and reported in [28,29]. The test subjects were Americans ranging in age from 17 to 73 years (average: 41, median: 40) with representation of both sexes ($M = 16$, $F = 11$) and four self-identified ancestral descent groups (African ($t = 1$), American-Indian ($t = 2$), Caucasian ($t = 21$), and Hispanic ($t = 3$)). Inclusion as test subjects was based on the final ranks recorded in the aforementioned studies [28,29]. All test subjects who originally ranked at or above candidate position 100 ($\geq R_{100}$) were included as members of the subset examined in this study. Higher ranking subjects (i.e., those exhibiting poorer match performances) were chosen in order to more fully examine rank change. For example, although a test subject whose final rank in [28,29] was R_{10} or less may exhibit improved rank with adjusted eye positions, the absolute numerical change would likely be small and potentially minimally informative. Because the primary aim of this study was to assess potential rank improvement based on eye position, the authors chose to evaluate approximations with higher ($\geq R_{100}$) final ranks in order to more fully visualize the magnitude of change. The probe set ($p = 81$) consisted of three facial approximations per test subject, one each generated using the following eye orb placements: (i) centrally positioned within the bony eye orbit (see [28] for definition of central position), (ii) eye orbs positioned 2.0 mm lateral and 1.0 mm superior relative to center (Position A), and (iii) eye orbs

positioned 2.5 mm lateral and 1.0 mm superior relative to center (Position B). Proponents of the non-central eye orb position indicate that an eye orb placed 2.3 mm lateral and 1.4 mm superior relative to center is most appropriate for contemporary approximations [5-7]. Currently, the ReFace application allows only 0.5 mm medial-lateral and 1.0 mm superior-inferior eye orb adjustment increments. Given this application constraint, the recommended precise 1.4 mm and 2.3 mm supero-lateral placement was unobtainable. Therefore, this study evaluated eye orb positions located at both 2.0 mm and 2.5 mm lateral to a central position. A superior adjustment of 1.0 from center was considered the most appropriate for the recommended 1.4 mm superior placement given that the next available adjustment increment possible within the ReFace application was 2.0 mm superior. Images were approved for use by the Institutional Review Board of the Federal Bureau of Investigation. Protection of the anonymity of the living test subjects precludes publication of their images. The facial approximation images presented in this study are computer generated statistical models and do not reflect the actual visages of the test subjects.

2. Results and Discussion

The Cochran's Q test of equality [32] for comparison of repeated, binary response data from >2 dependent groups was employed to assess rank change across the eye placement treatments ($n = 3$) examined in this study. Pairwise Cochran's Q tests were also employed to further identify differences between eye placement treatments. Fisher's exact tests (for non-matched groups) [33] were employed to analyze demographic cohort relationships (e.g., males versus females). A sequential Holm-Sidak procedure [34] was employed to control for the possible effect of simultaneous comparisons (>2 groups). Data were analyzed using SPSS 16.0 (Chicago, IL) and Microsoft Excel 2007 (Redmond, WA).

Overall, 81% of the test subjects' approximation ranks improved with the use of either eye orb Position A (37%) or Position B (44%), with no improvement observed in the remaining 19% (i.e.,

approximations with centrally positioned eye orbs). For the male cohort, 88% of the cohort's approximations exhibited improved rank with eye orbs in either Position A (38%) or Position B (50%). Although comparable, the female cohort exhibited a lower percentage (72%) of approximations exhibiting rank improvement with supero-lateral eye orb placements (Position A=36% and Position B=36%). While similar, and non-significantly different ($p = 0.37$), performance measures were observed between males and females, it could be cautiously posited that approximations with supero-lateral eye positions were more effective for the male cohort given that a larger percentage of improved ranks was observed for the male approximations with eye orbs in Positions A and B.

For significance analyses, two approaches were employed to evaluate the results: (i) examination of the three placement positions as separate, dependent entities and (ii) examination of the results for Positions A and B collapsed into a single performance metric. Significance analyses were conducted for the following comparisons using the three eye positions as separate entities: (i) overall (i.e., across the three eye positions), (ii) central position versus position A, (iii) central position versus position B, and (iv) positions A versus B. Significance analyses were also conducted for the following comparisons between the central and collapsed non-central eye orb result groups described above: (v) overall (i.e., between the two groups) (vi) male cohort, and (vii) female cohort. Highly significant performance differences (all $p < 0.01$) were observed for comparisons (i), (ii), (iii), (v), and (vi). Conversely, no significant performance differences ($p = 0.05$ and $p = 0.23$, respectively) were observed for comparisons (iv) and (vii). The results of comparisons (vi) ($p < 0.01$) and (vii) ($p = 0.23$) further support the aforementioned hypothesis that non-centrally positioned eye orbs may be even more effective for the male cohort (i.e., comparison vi).

Noteworthy was the observation that in 100% of the cases when the best rank (of the three eye orb positions) for an approximation was achieved with the eye orbs in Position B, the second best rank

was achieved with the eye orbs in Position A. A similar, and non-significantly different ($p = 0.73$), performance pattern was also observed when considering the ranks observed for eye orb Position A, with 60% of the second best ranks observed in Position B. It is argued, therefore, that an approximation constructed with the eye orbs placed in either of the two supero-lateral positions would yield results more informative than centrally positioned eye orbs when used as probes in facial recognition systems. It must be noted, however, that given the disparate sample sizes across the ancestral groups in this study (e.g., 78% Caucasian), it is possible that a supero-lateral eye position may not be similarly effective for all ancestral groups.

3. Conclusion

Using a commercial facial recognition system, this research objectively examined the change in match ranks of ReFace facial approximations generated with multiple eye orb positions. Although the sample employed in this study was small ($t = 27$), the preliminary results suggest that positioning the eye orbs in a more supero-lateral position within the bony eye orbit of a facial approximation may improve match ranks when approximations are used in an automated facial recognition context. Facial perception research has demonstrated that minor adjustments in eye positions do not adversely affect human recognition [17-22,24]. Given this assertion, and the results of this study, it is argued that the most operationally effective facial approximation will contain supero-laterally placed eye orbs, particularly if only a single approximation is developed and employed in both human and objective facial recognition scenarios. Larger studies with more diverse demographics are, however, needed in order to more fully evaluate the utility of facial approximations developed with supero-lateral eye orb positions.

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