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Review Article

Conceptual transitions in methods of skull-photo superimposition that impact the reliability of identification: A review

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ABSTRACT

Establishing identification during skull-photo superimposition relies on correlating the salient morphological features of an unidentified skull with those of a face-image of a suspected dead individual using image overlay processes. Technical progression in the process of overlay has included the incorporation of video cameras, image-mixing devices and software that enables real-time vision-mixing. Conceptual transitions occur in the superimposition methods that involve 'life-size' images, that achieve orientation of the skull to the posture of the face in the photograph and that assess the extent of match. A recent report on the reliability of identification using the superimposition method adopted the currently prevalent methods and suggested an increased rate of failures when skulls were compared with related and unrelated face images. The reported reduction in the reliability of the superimposition method prompted a review of the transition in the concepts that are involved in skull-photo superimposition. The prevalent popular methods for visualizing the superimposed images at less than 'life-size', overlaying skull-face images by relying on the cranial and facial landmarks in the frontal plane when orienting the skull for matching and evaluating the match on a morphological basis by relying on mix-mode alone are the major departures in the methodology that may have reduced the identification reliability. The need to reassess the reliability of the method that incorporates the concepts which have been considered appropriate by the practitioners is stressed.

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1. Introduction

Since the innovation of the skull-photo superimposition method reported by Professors Glaister and Brash in 1935 [1], the photographic process of image overlay has undergone significant technical progression [2–10] (Table 1). It has evolved into a real-time video process [11–30] (Table 2) that has evoked considerable research aimed at automating the procedure using computers and software [31–42] (Table 3). A much-cited report on the reliability of the video superimposition method by Austin-Smith and Maples [22] indicated a failure to exclude identifications of approximately 9% when comparing three skulls with 100 front-view photographs of living individuals. Recently, Gordon and Steyn [42] superimposed 40 digitized facial photographs with 3D digital images of 10 skulls each (a total of 400 superimpositions were done for each of the morphological and landmark methods) and observed that the failure to exclude (false positives) was 17.3% and 32% for the morphological and landmark methods, respectively. In addition, these authors [42] reported that the failure to include (false negatives) was 15% for the morphological method and 20% for the landmark method. The fact that skulls failed to match their related faces during superimposition in 15–20% instances appears counterintuitive. This finding raises troublesome questions because it has been relatively well accepted that *the skull is the matrix of the living head . . . and face in life* [43] and *creates the architectural form of the head and provides the basic structure for the face* [44], which is a concept shared by many other authors [20,45,46]. Furthermore, in view of the number of real-world cases in which the superimposition method has provided reliable results, the rate of failures reported by researchers [22,42] appears inflated and has prompted a review of the concepts underlying the methodologies recommended by practitioners and those used by researchers to identify divergences, if any.

2. Practitioners' and researchers' methods: specific conceptual variances

The reported instances of applications of the superimposition method for identification purposes in routine case work include 25 in the CA Pound Laboratory, Florida [25], 52 in Japan [23], 108 in China [47], 71 in Hungary [48] and 251 in India during 1970–1989 [18], which increased to 1800 during 1990–2010 [49], together totaling 2307. A recent national level survey in India revealed that the number of superimposition-based court testimonies in the Tamil Nadu state during 2005–2009 was 200 [50]. Additional authors have indicated the consistency of this method albeit without statistical details [28,29,51,52]. Thus far, in real-life scenarios, a lone misidentification has been reported by Dorion [8]. It does not appear reasonable to assume that all of the identifications that were reached circumstantially during the investigations would always be accurate when rendered using the superimposition method. Rejection of the identities achieved during investigations has been reported by practitioners using the superimposition method [53]. Similarly, in Tamil Nadu, India, 5 of the excluded individuals were found to be alive, subsequent to 25 exclusions when using superimposition [54]. In practice, the reliability of the superimposition method appears to exceed the rates calculated by researchers [24,44].

Practitioners reporting on the use of photographic and video superimposition methods have described the methodology they adopted elaborately [4,5,8,10,13,14,16,18–21,23,26,27,30,47,55]. The methods employed by researchers using computers and software [31–42,56] and the authors who studied the reliability of identifications by superimposing skulls with photographs of known faces using video cameras [22] or computer devices [42] are also available. Conceptually, the methods reported by the practitioners and those reported by the researchers do not appear to be similar with respect to the use of 'life-size' enlargements, the methods used to orient the skull and the methods employed to assess the goodness of fit, particularly using the mix or wipe-mode to evaluate the match (Tables 2 and 3). Clearly, the overlap in the contributions provided by many research papers and practitioners render it difficult to identify a method that is used specifically by practitioners or researchers in absolute terms; the distinction made here relies on the more popular use of a particular method by a group. Practitioners have typically relied on the use of 'life-size' skull-face images [11–19,21,24,27,30,53], the application of anatomical points in the front (eye) and the rear (ear) planes of the face for orientating the real skull *prior to* obtaining the match [15,18,19,27,30], the assessment of morphological congruence using the wipe-mode in addition to the mix-mode [15,18,19,27,30,53] and the assessment of asymmetries when evaluating the goodness of fit [3,7,27]. In contrast, researchers have typically relied on using images of less than 'life-size' [31,32,34–42,57], the application of anatomical points in the front (eye) plane of the face alone when orienting the skull and obtaining the match by overlay [31,32,34–42] and the relationship between cranial and facial landmarks observed in mix-mode when evaluating the match during superimposition [31,34–42,57] without specifying the assessment of asymmetries when evaluating the goodness of fit [31,32,34–40,42,57].

3. 'Life-size' face-image and skull orientation: the two critical requirements

Fundamentally, skull-photo superimposition is an image-mixing process that helps examine the appropriateness of the salient features in the image of the skull in question (that has been anatomically oriented to correspond to the posture in the face-image) for the missing individual's face-image that has been magnified appropriately; the classical example is that described by Glaister and Brash [1]. Subsequent authors describing the photographic process of overlaying transparencies [2,4,6,8,9] (Table 1) and those developing the now popular real-time video superimposition method [11–19,21,24,27,30,53] (Table 2) have adhered to the use of 'life-size' images and methods for anatomically orienting the skull to correspond to the face-angle observed in the photograph. The cardinal principle in skull-photograph superimposition is that during conditional registration of the skull- and face-images, the outlines of the bones in the skull-image and the outlines of the tissue in the face-image correspond with each other and that the organs of the face exhibit appropriate positional relationships with the corresponding skeletal components in the skull [11,18,19,27,53,55]. Recent research has not mentioned the use of 'life-size' images or the reliance on anatomically related points for orienting the skull (Table 3). A conceptual basis for using 'life-size' enlargements and for orienting the skull based on anatomy would justify the practitioners' adherence to these important criteria during superimposition.

4. On the concepts and methods relating to the use of 'life-size' enlargements

When discussing the conceptual basis for using 'life-size' images, Glaister and Brash [1] concluded that it was a "safer plan to make the enlargements of both the skull and portrait natural size, the former exactly so, the latter as near as might be feasible" because it would form "a more crucial experiment" than to fit the skull and face images without regard to their actual sizes. The concept underlying the use of 'life-size' images is that a comparison achieved by overlaying two physically separate images necessarily requires each image to be of the same relative