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# Is sex estimation from handprints in prehistoric cave art reliable? A view from biological and forensic anthropology





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#### ABSTRACT

Estimation the sex of the creators of rock art scenes from handprints left in prehistoric caves has been of growing interest in archaeology in recent years. It has been suggested that both males and females were involved in symbolic activities, which has shaped the view of gender roles in prehistory. The experience from biological and forensic anthropology suggests, however, that using recent standards for the sex estimation of prehistoric handprints may be prone to errors. The aim of this study is to document the accuracy and reliability of sex estimation from handprints in a recent European sample and to assess the applicability of recent standards to the sex prediction of prehistoric artists. Our sample consists from 100 handprints of recent males and females from southern France. The sex of handprints is estimated by two discriminant functions using five direct measurements (DF<sub>direct</sub>) and two indices (DF<sub>index</sub>). The results showed that DF<sub>direct</sub> correctly predicts sex in 92% of recent handprints but only about half the handprints can be classified with a certainty higher than 95%. The accuracy of  $DF_{index}$  is only 63% and cannot be successfully applied to sex estimation. We further suggest that the accuracy of both functions is overestimated due to the correct classification of handprints by chance and that especially DF<sub>index</sub> is able to predict sex even in randomised datasets with no sexual differences. Finally, we demonstrate that both DF<sub>direct</sub> and DF<sub>index</sub> perform poorly when they are applied to population with hand size different from that used to derive them, i.e. that functions do not generalise across different populations and time periods. We argue that, given the lack of information about hand size in the population of prehistoric artists, recent attempts to estimate sex from handprints depicted in Palaeolithic cave art using morphometric data from recent populations is inevitably associated with unpredictable bias.

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#### 1. Introduction

In the recent decade increasing interest has been paid to the reconstruction of the biological identity of individuals who left handprints on the prehistoric caves and rock shelters around the world. Based on the size and shape of prehistoric handprints, attempts have been made to estimate age (Bednarik, 2008; Gunn, 2006; Guthrie, 2005; Manhire, 1998), body height (Manhire, 1998), or laterality (Cashmore et al., 2008; Faurie and Raymond, 2004; Gunn, 2007; Uomini, 2009) of their makers.

Considerable attention has also been given to the estimation of sex of prehistoric artists. For example, Henneberg and Mathers (1994) planned to estimate sex from hand stencils in the rock

\* Corresponding author. Tel.: +420 533 435 223. *E-mail address:* galeta@sci.muni.cz (P. Galeta). shelters in southern Africa. They measured handprints of recent descendants from the Khoisan population that are believed to physically resemble the makers of handprints in prehistoric South African shelters. They found, however, a considerable overlap in the hand size between recent males and females and concluded that sex estimation from handprints has to be undertaken with caution. McDonald (1995) and Gunn (2006) who studied hand stencils in the rock shelters in the Sydney basin and central Australia respectively, achieved similarly unambiguous results.

The majority of recent studies on sex estimation from prehistoric handprints, however, have yielded more conclusive evidence. Guthrie (2005) identified the sex of 201 Palaeolithic handprints from Spanish and French caves. He used nine hand dimensions measured in the sample of about 700 individuals of Euro-American origin from Fairbanks, Alaska as a baseline for univariate comparison. Guthrie was able to classify 19% of handprints (39 out of 201) as belonging to female (or young boys) and remaining 81% of handprints as those of males. Snow (2006) estimated the sex of six hand stencils from Upper Palaeolithic caves in France based on two discriminant functions derived from a reference sample of 111 students from Pennsylvania, USA. He showed that 67% (four out of six) of Upper Palaeolithic stencils can be attributed to females. Later, Snow (2013) analysed a larger sample of 32 European Upper Palaeolithic stencils using the same discriminant functions as in 2006 and showed that 75% (24 out of 32) of prehistoric stencils belonged to females and 25% handprints were made by males. Wang et al. (2010) re-analysed the stencils originally studied by Snow (2006) using a new computer-automated technique (Support Vector Machine model). They argued that their method benefited from the fact that it uses normalised relative measures, which allows handprints to be classified without scale information and requires only a high-resolution digital image as an input. Within a sample of six of Snow's Palaeolithic stencils, they distinguished those belonging to both males and females although they found two stencils with sex estimations that are different from those in the Snow (2006) study. Chazine and Noury (2006) estimated the sex of 34 hand stencils from Gua Masri II Cave in Borneo and they, using automated software (Kalimain<sup>©</sup>), were able to recognise 44% (15 out of 34) of stencils belonging to females.

The studies on sex estimation from prehistoric handprints revealed, that contrary to general view (cf. Guthrie, 2005), both males and females were likely to be involved in prehistoric painting. These results have had a direct impact to our understanding of ritualistic behaviour and sexual division of labour in prehistory (Bolger, 2012; Hays-Gilpin, 2004). The fact that prehistoric artists were females as well as males, was further incorporated into popular media (e.g. Foucher et al., 2007; Chazine, 2009) and has become generally accepted within archaeological community.

In contrast to the popularity of sex estimation from handprints in prehistoric literature, until recently, few attempts have been made to estimate sex from hand and/or handprints in forensic and biological anthropology. Standards for sex estimation based on the direct dimensions of hand have been established in adult population of India (Kanchan and Rastogi, 2009; Krishan et al., 2011), in Indo-Mauritian adult population (Jowaheer and Agnihotri, 2011), in adult Upper Egyptians (Aboul-Hagag et al., 2011), and in Western Australian population (Ishak et al., 2012). Other authors have proposed sex classification models based on the ratio between the index and ring finger length, for example in South Indian adults and adolescents (Kanchan et al., 2008; Kanchan et al., 2010) and in adult Upper Egyptians (Aboul-Hagag et al., 2011). The accuracy of the sex classification methods described above oscillates mostly between 80 and 90%. To our knowledge, no forensic standards for sex estimation based on hand dimension have been reported for groups of European origin, although male-female differences in hand dimensions have been demonstrated in many studies (Hönekopp and Watson, 2010; for review, see, Voracek and Loibl, 2009).

The scarcity of forensic studies on sex estimation based on hand and handprints may be, in our opinion, explained by two main factors: (1) low accuracy (i.e. small differences between sexes) and (2) low generalisability (i.e. large differences between populations) (Nelson et al., 2006; Voracek, 2009).

Although the 80–90% accuracy of hand-based sex classification methods (for references, see above) may be considered sufficiently high, it corresponds to an overlap between the distributions of handprint dimensions in males and females (Voracek, 2009) (see, for example Fig. 1 in Results, where distributions of males and females are highly superimposed). Within the overlapping area between the distributions sex is often misclassified because the handprints of males have similar dimensions to those of females. The probability of being male for handprints in the overlapping area is almost as high as the probability of being female (i.e. close to 0.50). To avoid errors in classification, such handprints should be treated as of unknown sex. By contrast, handprints located in the non-overlapping area are well distinguishable between males and females and their sex can be estimated with a high probability of correct classification (as high as 0.95 or more) (cf. Murail et al., 2005). Although the large overlapping area may prevent the effective application of this sex classification method in forensic practice, its size has not been reported in the handprints literature. Only Voracek (2009) pointed out that in the sex classification based on the digit ratio (2DP/4DP), the overlapping area is about 67% of the total distribution, i.e. about two-thirds of the handprints may not be accurately assigned to either the male or female group.

Another problem with interpreting the accuracy of the sex classification model is that it overestimates the true accuracy rate when it is computed from the same data as is used in generating the model. The true accuracy rate, i.e. the accuracy over the entire population of handprints that the sample is designed to reflect, is likely lower than the accuracy estimated from the sample data (DeGusta and Vrba, 2003). Kovarovic et al. (2011) showed that their discriminant analysis applied to faunal datasets overestimated the true accuracy rate by approximately 5-15%. They argued addressing the overestimation by a cross-validation procedure (e.g. jackknife) and by the use of statistics that take into account the probability of correctly classifying individuals by chance (e.g. TAU statistic, for details, see Methods). The actual level of accuracy overestimation in the sex classification of handprints is unexplored as such techniques have not been implemented in the handprints data vet (with the exception of Ishak et al., 2012).

The low generalisability of sex classification methods causes further limitations to reliable sex estimation based on handprints. Many authors (Bidmos and Dayal, 2004; Bruzek and Murail, 2006; Calcagno, 1981; Dirkmaat et al., 2008; Pereira et al., 2010) have shown using the example of various human bones that the rate of correct sex prediction decreases if the classification models are applied to samples other than those from which they are derived. In the absence of appropriate reference standards, the sex of prehistoric handprints inevitably has to be estimated using recent reference data. The extent of the decrease in correct predictions in the handprints data, however, is still to be examined.

The aim of this study is (1) to assess the accuracy of sex classification based on handprints of European origin; (2) to quantify the extent of the overestimation of the accuracy in handprint data using a cross-validation procedure and chance corrected statistics; (3) to determine the reliability (generalisability) of sex classification based on handprints, i.e. to calculate the rate of correct prediction in a sample that is different from the original reference sample; and (4) to interpret the results in terms of their applicability to the sex estimation of the creators of the rock art scenes. Our approach directly addresses the current debate within the parietal art community. We consider only biological aspects here, i.e. we do not discuss secondary factors that may affect the accuracy of sex estimation in prehistory using handprints, e.g. the relief and the texture of cave wall, the printing technique used in prehistory or taphonomic bias (for details, see, Guthrie, 2005).

#### 2. Material and methods

#### 2.1. Sample

The total sample consisted from 100 right handprints of 50 males and 50 females from Bordeaux University in southern France (the French sample) (Maestracci, 2007). The handprints were acquired using a photocopier machine following a standardised procedure. Hands were placed lightly on the centre of the glass plate (parallel to the shorter side of the machine) with the fingers

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