H24 Assumptions and Bias in Recalibrating Age Standards Across Populations

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The goals of this presentation are to explore the application of Bayesian analyses in age estimation for human identification and to demonstrate possible evidentiary biases that result from incorrect assumptions about the data. This is particularly critical for research into population variation where investigators attempt to recalibrate age parameters based on ethnic variation.

This presentation will impact the forensic science community by re- analyzing published data on age estimation for dental methods. The correct application of Bayesian statistics and assumptions about population data are critically important when these methods are applied to estimate age among living subjects, for human identification among decedents, and for the courtroom admissibility of anthropological methods.

In recent years, there have been a number of published articles that argue for population specific standards, in other words, researchers suggest that aging methods should be recalibrated when applied across populations. While Bayesian analyses in forensic anthropology can be very useful in some contexts, it is generally agreed that if informative priors are used they need to be clearly delineated. Without making priors explicit, forensic anthropologists run the risk of introducing biases into evidentiary processes based on assumptions that may not fit well with what is known about a particular case. The use of dental age estimation methods often fail to account for implicit priors. The following study reexamines data from published studies to demonstrate how

interpretations vary based on prior assumptions about the data and how results change based on explicit prior information.

For example, summary data from Kasper et al. (2009 Journal of Forensic Sciences 54(3):651-57) is re-analyzed. Kasper et al. present data on third molar development for 950 individuals ranging in age (at the last birthday) from 12 to 22 years including the mean and standard deviation for age within seven stages of third molar formation ("B" through "H" from Demirjian et al.'s 1973 scoring system). As Konigsberg et al. (2008:542) noted "a final problem with any method that conditions on stage to estimate age is that all of these methods contain an implicit prior distribution for age." This is seen in the present study, particularly for teeth where the root apex is complete (stage "H"). Kasper et al. assume that age within stage is normally distributed, but because their sample's age distribution is truncated at 12 and 22 years, the mean age within stage "H" must be less than 22 years.

With age data, it is difficult to justify the assumption that the age distributions within stages are normal, as these distributions depend on:
(1) the age distributions for when individuals move to the next higher stage; and (2) the overall age distribution of the sample. By Bayes' Theorem:

$$f(a|i) = \frac{p(i|a) f(a)}{\int_{a=0}^{\omega} p(i|a) f(a)}, \quad (1)$$

where p(i|a) is the probability that someone at exact age "a" is in stage "i," f(a) is the probability density function for age, and f(a|i) is the probability density function that someone is exact age "a" given that they are in stage "i," and ω is the upper limit of integration (i.e., the maximum possible age). If a researcher does not wish to include an informative prior then a uniform prior can be substituted, giving:

$$f(a|i) = \frac{p(i|a)}{\int_{a=0}^{\omega} p(i|a)}. \quad (2)$$

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A critical issue for the presentation of aging methods in court when identifying the age of living suspects is the probability of being a certain age. Examples of court cases in which age methods have been disputed are discussed in this presentation. Additionally, other methods of determining the probability of a given age include the use of a parametric model for p(i|a). More specifically a cumulative probit model on the log scale ages can be used to model p(i|a). This is precisely the model that was used by Moorrees, Fanning, and Hunt in their classic studies of dental development.

This paper demonstrates that in using estimated "transition parameters" in log cumulative probit models, the probability that someone is over the age of 18 years is substantially different than the reported accuracy in published studies and demonstrates the need for discussion about the biases implicit in demographic data as well as the possible evidentiary biases that result from such assumptions about the data.

Age Estimation, Population Variation, Bayes' Theorem

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