A126 Conditional Independence and Appropriate Number of Stages in Juvenile Dental Age Estimation

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Learning Overview: After attending this presentation, attendees will better understand the importance of testing for conditional independence, as well as how to determine the most appropriate number of stages in age estimation methods.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by challenging an assumption that impacts the correct precision of estimated age intervals.

Juvenile age estimation escapes many of the problems that plague adult age estimation by virtue of the fact that developmental characteristics are more highly correlated to chronological age than are degenerative characteristics. While juvenile age estimation is less prone to issues such as wide age intervals and age mimicry of reference samples, other important challenges are shared. The viability of the conditional independence assumption must be questioned in both juvenile and adult age estimation. This issue is even more pressing in juvenile age estimation where a much larger number of traits are often included in a single estimate.

Conditional independence means that two traits are independent of one another once the effect of chronological age on each trait is accounted for. This assumption allows for the straightforward construction of age intervals when multiple indicators are used. Unfortunately, further testing has revealed that the assumption does not hold for either adult or juvenile age indicators.[1] Assuming independence of related indicators will produce intervals that are too narrow. Furthermore, this raises the possibility of bias, since the number of indicators used may not be large enough to support the central limit theorem, especially when indicators are not independent. This project tests the hypothesis that the permanent dentition within a single quadrant are conditionally independent from one another in development given age.

The data consist of Moorrees, Fanning, and Hunt scores of the lower left quadrant of permanent dentition from panoramic radiographs of 738 female British children between 2 and 25 years of age.[2] Data were generously donated by Helen Liversidge. Ten percent of the sample (n=74) was withheld from analysis for cross-validation. Every stage for each tooth was tested for outlying ages using a first derivative test. Lagrange multiplier goodness-of-fit tests were used to determine whether the data fit a cumulative probit model on a straight or log scale. For teeth that did not fit the model with fewer than 1% of the training sample removed as outliers, stages were systematically collapsed until a fit was found. Both staging systems were then tested for conditional independence using the mvord package in R.[3] The collapsed stage system was compared to the original staging system by estimating ages for the withheld portion of the sample via the corresponding cumulative probit models.

All but the third molar fit a log-scale cumulative probit model with outliers removed. For the third molar, stages 0-2 were collapsed, producing a 14-stage model. Variance-covariance matricies of the original and collapsed staging systems produced chi-square values of 763 and 1,296, respectively, when compared to the identity matrix using Bartlett's test. The r^2 between known ages and estimated ages of the withheld sample was 0.9255 for the original staging system and 0.9267 for the collapsed staging system. Slopes were 0.9611 and 0.9595 respectively. When 95% probability regions were constructed for the withheld samples, the actual success rate of true ages falling within the estimated interval was 72.9% for both systems.

In conclusion, the collapsed staging system performed similarly to the original system in accuracy and precision of estimates as well as conditional independence of teeth. This indicates that it is possible to optimize dental staging systems so that only meaningful transitions are recorded. Low success rates indicate that the conditional independence assumption is not supported in either case. Failure of this assumption produces age intervals that are too narrow.

Reference(s):

1. Konigsberg, Lyle W. Multivariate cumulative probit for age estimation using ordinal categorical data. *Annals of Human Biology* 42, no. 4 (2015): 368-378.
2. Moorrees, Coenraad F.A., Elizabeth A. Fanning, and Edward E. Hunt, Jr. Age variation of formation stages for ten permanent teeth. *Journal of Dental Research* 42, no. 6 (1963): 1490-1502.
3. Hirk, Rainer, Kurt Hornik, and Laura Vana. mvord: An R package for fitting multivariate ordinal regression models. *R package vignette*, 2018a. URL https://cran. r-project. org/web/packages/mvord/vignettes/vignette_mvord. pdf (2017).

Juvenile Age Estimation, Dental Development, Conditional Independence

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