A17 Craniofacial Modularity and Integration: Implications for Ancestry Assessment

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Learning Overview: The goal of this presentation is to evaluate the covariance of select craniofacial features to assess integration and modularity of the facial skeleton. After attending this presentation, attendees will better understand the morphological relationships between select facial features commonly used in ancestry assessment.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by providing an understanding of the degree of craniofacial morphological covariance, identifying boundaries of correlated traits, and recognizing the implications integration and modularity may have for interpreting skeletal ancestry.

Integration and modularity describe covariation of traits and are conceptually linked. Integration refers to the coordinated joint variation of traits. When such covariation of traits is tightly correlated and internally concentrated within a region, but remains distinct and relatively independent from other traits, this is recognized as modularity. While integration and modularity of the human cranium are well acknowledged in evolutionary and morphometric studies, researching these patterns of trait interactions remains valuable as they directly affect phenotypic trait expression. Quantification of these interactions is relevant to forensic anthropologists because the form and spatial relationships of craniofacial features are commonly analyzed to estimate an unknown individual's ancestral affiliation.

Three-Dimensional (3D) coordinate data were collected from 27 identified individuals analyzed at the University of Florida C.A. Pound Human Identification Laboratory. Selection of individuals included the following criteria: (1) 3D surface scans collected using a NextEngine™ 3D Laser Scanner were available; (2) the individual's age-at-death was ≥18 years; and (3) select craniofacial landmarks were not affected/obscured by pathological conditions, trauma, or taphonomic modification. Coordinate data of 16 standard craniofacial landmarks were collected for each individual and partitioned into "upper," "middle," and "lower" non-overlapping compartments (modules) of the face. Four possible scenarios of these subdivisions were organized, each demonstrating different boundaries defining facial compartments and thus including different combinations of landmarks within compartments.

The data were analyzed in R™ using a simultaneous-fit approach, in which a generalized Procrustes fit was performed on all coordinates, followed by a series of covariance tests to assess integration and modularity (α=0.05). Two-block Partial Least Squares (PLS) analyses of the Procrustes coordinates indicated that of the four compartment scenarios, modules of the face are best compartmentalized by visceral function rather than by the mere proximity of neighboring landmarks (i.e., this scenario showed the highest degree of independence between compartments). Accordingly, skeletal landmarks on the boundaries of the orbital, nasal, and oral cavities correspond to the upper, middle, and lower compartments, respectively. Of this visceral compartmentalization scenario, pairwise PLS analyses of Procrustes coordinates between each module yielded significant results for comparisons of the orbital:nasal (r_{PLS}=0.78) and nasal:oral (r_{PLS}=0.89) compartments; the comparison of the orbital:oral compartments approached significance (r_{PLS}=0.71;p=0.06). The average degree of integration between the three visceral modules was not significant (r_{PLS}=0.80;p=0.77), suggesting that integration among these modules occurs in a chain-link pattern, with those compartments that are more closely linked spatially and developmentally showing greater magnitudes of integration. Pairwise covariance ratio tests were conducted to quantify the degree of modularity of the facial compartments and yielded insignificant results in all comparisons. These results demonstrate that despite regions of trait correlations defined by visceral functions, covariation in facial traits crosses the borders delimiting the distinct organs of special sense.

The points selected for this study, while considered standard craniofacial landmarks, correspond directly to facial features that are regularly used in assessments of skeletal ancestry. Investigating the covariation between these traits can elucidate underlying processes that produce phenotypic variation, and in this context, aid the understanding of craniofacial traits and which are biologically meaningful for ancestry assessments. In summary, this study shows that the facial skeleton can be partitioned into three modules based on visceral function that show large magnitudes of integration with one another. Importantly, this integration is not uniform throughout the face, meaning that some traits are more highly correlated with each other to the exclusion of other traits. These findings have implications for ancestry assessment, wherein methods rely on relative relationships between traits, or assessing multiple traits that this study shows to be highly integrated and are consequently not independent of one another. Therefore, this research can serve as a foundation to advance approaches to ancestry assessment.

Trait Covariation, Geometric Morphometrics, Morphological Variation