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Admixture and racial classification : the use of discriminant analysis in classifying individuals of mixed ancestry

Darcy D. Olson
The University of Montana

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Admixture and Racial Classification:

The Use of Discriminant Analysis in Classifying Individuals of Mixed Ancestry

By

Darcy D. Olson

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Approved by:

Randall R. Skelton

Chairperson

[signature]

Dean, Graduate School

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Admixture and Racial Classification: The Use of Discriminant Analysis in Classifying Individuals of Mixed Ancestry.

Director: Randall Skelton R. S.

The typological approach to racial classification of humans, taken by western European scientists, has proven to be problematic. Today, anthropologists generally agree that there are not now and likely never have been discrete races (AAPA, 1996; Marks, 1994; Marks, 1995). While there has been a trend toward rejecting *race* as a means of describing or explaining human variation (AAPA, 1996, Montagu, 1952, UNESCO, 1965), forensic anthropologists continue to use racial categories to assist law enforcement agencies in identifying skeletal remains (Bass, 1987; Rhine, 1990; Stewart, 1979).

My objective in this project was to explore the effect of admixture on racial classification using discriminant analysis. Using 2 sets of anthropometric data, I compared classification results of individuals with 100% Sioux and 100% European ancestry, to classification results of individuals with varying proportions of Sioux and European ancestry. I addressed 2 hypotheses: (a) that people of mixed ancestry will most often be classified as members of the group that comprises the greater percentage of their ancestry; and (b) the admixture proportion will be roughly equivalent to the probability that an individual with mixed ancestry will be classified as a member of the group that comprises the larger percentage of their ancestry.

I found that classification results for the individuals of mixed ancestry were not better than would be expected from chance.

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INTRODUCTION

The desire to classify the natural world into categories can be traced back to Plato. Essentialism, Plato's idea that the natural world is made up of fixed and ideal types (Wolpoff and Caspari, 1997), is an inherent part of western civilization. This inclination toward classification has long been applied to human beings.

Physical and social scientists have been interested in human variation for centuries (Blumenbach, 1776; Kant, 1775; Linnaeus, 1735). Initially, European expansion into the New World and the resulting exposure to a new variety of human forms was a catalyst for the growing interest in explaining human variation (Hallery, 1971;Wolpoff et. al, 1997). Since that time, the study of race has been complicated and controversial.

The controversy associated with the topic of race stems primarily from the motivation for wanting to explain human variation. Historically, racial classification has been used as a way of justifying the power of whites over other groups (Kleg, 1993; Marks, 1995; Montagu, 1952; Trigger, 1989). If the social and political power of the whites could be scientifically explained, a result of their natural moral and intellectual superiority, it would justify the existing social hierarchy.

The debate over the whether or not racial classification of human beings is worth while endeavor has grown increasingly heated in the last one hundred years. Further, for those individuals that do find value in the study, there is additional debate on both the traits used as the basis for racial divisions as well as the definition of the term. Brues (1990:1) defines race as "a division of a species, which differs from others by the frequency with which certain hereditary traits appear among its members." Others define race as breeding population (Garn, 1957).

In any study of human variation, the definition of the term 'race' directly affects the categories that are used. For example, Garn and Coon (1955) suggested the use of both large geographic races and smaller local races. The geographic races are general and include both a large number of individuals as well as a large variety of traits. The local races are smaller subsets of the geographic races representing breeding populations (Garn and Coon, 1955). This suggestion typifies the problem with any proposed racial boundaries. They are arbitrary (Marks, 1994a; Marks, 1994b; Grant, 1916).

Furthermore, the basis for racial classification is not always based on genetic lineage. In many cases, racial classification is confused with social or cultural affiliation. The history of many Native American tribal membership requirements is an example of the complicated nature of cultural definitions of race. Not only do membership requirements vary from tribe to tribe, but they also vary over time within a given tribe. The Lakota Sioux is an example. In the mid-1800s, with membership down due to war and disease, marriage to a Lakota female entitled a non-Lakota male to full tribal membership status (Clow, 1998). Now, not only must members be at least half Lakota biologically, but they also must live the life of a Lakota (Clow, 1998). The politics of the day have dictated membership requirements. With such flexible definitions of racial classification criteria, the complicated nature of attempting to classify people by race becomes evident. As a result, many in the field of anthropology would like to eliminate the concept of race altogether (Montagu, 1952; UNESCO, 1965).

An examination of the history of attempts to categorize human variation sheds light on the reason for the disdain many people feel for the continued use of these categories.

History of Racial Classification

From the beginning, attempts to classify humans into racial categories have been motivated largely by a desire to perpetuate and justify the existing social power structure (Kleg, 1993; Marks, 1995; Trigger, 1989). Racial categories have historically been based on social perceptions rather than biological variation. In people of mixed ancestry, racial classification is not usually reflective of the greater proportion of ancestry. Instead, it is based upon non-Caucasian ancestry. As Madison Grant the early 20th century theorist stated:

> The cross between a white man and an Indian is an Indian; the cross between a white man and a Negro is a Negro; the cross between a white man and a Hindu is a Hindu; the cross between any of the three European races and a Jew is a Jew (Grant, 1916: 16).

The first attempt to scientifically classify the races of Homo Sapien was undertaken by, Carolus Linnaeus (1735. He proposed a four family classification system based primarily on skin color, but which had corresponding behavioral traits for each category. The most favorable behavioral traits were associated with lighter skin and the least favorable were associated with darker skin (Hallery, 1971).

Johann Blumenbach (1776) refined the classification system proposed by Linnaeus. He used a greater combination of physical traits and was the first to name the races (Wolpoff and Caspari, 1997). Like Linnaeus, his racial categories included both physical and behavioral traits. Again, the White/Caucasian race was associated with the behavioral traits that were most favorable (Hallery, 1971).

In the late 18th and early 19th centuries there were two prevailing schools of thought on human variation. Though the theories differed in the explanation for human variation, both believed in the Universal Chain of Being, and that races were fixed or permanent (Brace, 1982). The Universal Chain of Being was the contention that all living things fit into a fixed hierarchy from simple to complex (Nelson et al., 1992).

The first school of thought, the Monogenists (Blumenbach, 1776), believed that all humans shared a single ancestral pair (Hallery, 1971; Wolpoff and Caspari, 1997). The second school of thought, the Polygenists (Agassiz, 1850; Nott, 1866), believed in multiple origins (Nelson et al., 1992), and ordered each race, not simply humans, into the

Universal Chain of Being (Hallery, 1971). The Polygenists believed races to be fixed and arranged in a hierarchy that not only was created by God, but could not be altered (Hallery, 1971). Almost without exception, the scientific community accepted racial stratification, regardless of whether they believed the races sprang from a single original pair or were created separately (Hallery, 1971).

In 1859, Charles Darwin published The Origin of Species. This work forced the both the Monogenists and Polygenists to reevaluate their theories. With the publication of Darwin's work, decades of debate about the permanence of human variation were interrupted. Darwin's theory, while expressing the common ancestral path of all humans, explained variation in terms of natural selection acting on individuals and evolution acting on populations (Hallery, 1971). These discoveries disputed earlier beliefs in the permanence of human variation. By explaining the mechanism for physical and anatomical change, Darwin's theory should have ended the argument that there is an inherent relationship between physical and behavioral traits. However, it did not. Many scholars continued to discuss human variation in terms of a hierarchical arrangement.

Josiah C. Nott, a firm believer in the permanence of the races, attempted to incorporate Darwin's ideas into his theories without revising them significantly. In 1866, he published Instincts of Race, in which he explained that Darwin's theory had not seriously harmed his theory:

> The question then, as to the existence and permanence of races, types, species, or permanent varieties, call them what you please, is no longer an open one. Forms that have been permanent for several thousands of years, must remain so, at least during the lifetime of a nation. It is true, there is a school of Naturalists among whom are numbered the great names of Lamark, Geoffroy Saint-Hilaire, Darwin, and others, which advocate the development theory, and contend not only that one type may be transformed into another, but that man himself is nothing more than a developed worm; but this school requires millions of years to carry out the changes by infinitesimal steps of progress. (Nott, 1866; 4-5)

No longer able to argue that races are permanent, Nott now claimed that change was so slow as to be irrelevant.

Around the same time, anthropometry, the study and comparison of body measurements, was used to support the view that certain races were superior to others (Broca, 1864). Paul Broca (1824-1880) used variation in cranial capacities to explain the difference between the more successful white males and the less successful women, blacks and poor people (Gould, 1981).

The acceptance of both the concept of definable races, and the moral and intellectual superiority of certain races over others led to the science of eugenics. Eugenics, proposed by Francis Galton (1822-1911), was an attempt to achieve racial purification. Believing that the races were decaying due to interbreeding, Galton proposed laws restricting marriage between certain races as well as sterilization of members of certain groups (Galton, 1883). The movement found support in the upper class in both Europe and the United States. It was seen as a way to eliminate criminals, the sickly, and the mentally retarded (Nelson et al., 1992). The movement gave scientific justification for genocide (Montague, 1952).

In the United States at the turn of the century, professors at Columbia University and Harvard University differed ideologically on the subject of human races. Franz Boas, at Columbia University, questioned the value of racial classification. His argument was two-fold. First he disputed the link between biological traits and cultural characteristics (Boas, 1894). Correlating biological variation with behavior had been the justification for the hierarchical ordering of the races (Blumenbach, 1776; Nott, 1866). Boas introduced the idea of cultural relativism which states that each culture is a product of its own history and can not be ranked in comparison to other cultures (Boas, 1894). In addition, he argued that cultures change at a much greater rate than the rate at which biological changes occur. Therefore, he saw no justification for connecting behavioral characteristics to physical characteristics (Boas, 1894).

Franz Boas also questioned the validity of evaluating biological affinity through phenotypic traits. To test the relationship between ancestry and physical traits, Boas collected anthropometric data from immigrants and their offspring. The results of that study supported his contention that races do not reflect permanent categories of human variation (Boas, 1911). He observed variation in form between parents and their offspring. He argued that if continuity in bodily form could not be found from one generation to the next in a family, the value of racial classifications needed to be reexamined (Boas, 1911).

At Harvard University Earnest A. Hooton, the father of American Physical Anthropology, felt that 'race' was a fundamental question to be addressed by physical anthropologists (Nelson et al., 1992). Because he was responsible for training virtually all the physical anthropologists in the United States prior to World War II, his views continue to have notable impact on the discipline today (Wolpoff and Caspari, 1997).

Hooton represented a transitional period in the study of human variation. Hooton differed from his contemporaries in the dichotomy of his views. He certainly believed races existed, in fact, he believed they were definable and statistically distinguishable (Wolpoff and Caspari, 1997). In fact Hooton suggested that there were five subspecies of Homo Sapiens. However, he did not believe that races were immutable categories. Furthermore, Hooton was the first to stress the importance of polymorphism in human population (Marks, 1995). His emphasis on individual variation led Hooton to describe race as a "vague physical background, usually more or less obscured or overlaid by the individual variations in single subjects, and realized best as a composite picture" (Hooton, 1926:79).

After World War II, the effects of racism and the eugenics movements were impossible to ignore. Within recent history, the slavery of the Africans as well as the Holocaust in Germany were glaring examples of the negative effect of attempts to classify humans into racial categories. Consequently, there was a movement, particularly in American anthropology, to reject the concept of race all together.

In 1950, UNESCO published a statement on human rights. The statement was revised several times in 1952, 1965 and 1975. The statement cited the harm that had resulted from racist views. Though the statement accepted the validity of race as a biological concept, it pointed out that the term *race* had been misused in referring to nationalities, religions, and cultural groups (UNESCO, 1965). Because the "popular parlance" of the term had resulted in serious errors UNESCO made the recommendation to replace *race* with *ethnic group* (UNESCO, 1965). Variation was the foundation of the new synthesis. The focus in studies of human variation became "the importance of understanding the *patterns of variation* within as well as between populations" (Wolpoff and Caspari, 1997:155).

Ashley Montagu, professor at Columbia University, supported the replacement of the term *race* with *ethnic group*. Defining *race* as "a group of individuals marked off from all others by a distinctive heredity and the possession of particular physical and mental characteristics" (Montagu, 1952:158), he argued that there is only one race. Citing the effects of the eugenics movement, Montagu pointed out the danger of the continued use of the term *race*. He recognized that race is only a word and, if used correctly in the biological sense, it is not harmful. However, he argued that the answer was not simply to educate people on the definition; perpetuating the concept that there are distinct races was very dangerous, as history had shown (Montagu, 1952).

Not everyone accepted Montagu's position on the existence of a single human race. C. S. Coon, the second student to graduate under the tutelage of Earnest Hooton at Harvard, incorporated Hooton's view of evolution and race into his work; he went several steps beyond. Coon traced Hooton's five subspecies of humans through the fossil record to pre-Homo sapiens (Coon, 1962). He linked "the length of time a subspecies had been in the sapiens state" (Wolpoff and Caspari, 1997:164) to cultural achievement. He cited the cultural achievements of Europeans as evidence that they were superior. In almost every way, Coon's writings harkened back to the early typological thinking of the late eighteenth century. He even correlated brain size to both intelligence and behavior using the large cranial capacity of Europeans as further evidence of their superiority (Wolpoff and Caspari, 1997).

Today, the study of race is divided into two prevailing schools of thought. One school is interested in the process of biological change, while the other is interested in identification and classification (Marks, 1994b). For the first group, understanding the mechanisms of change means not only being able to understand where we came from evolutionarily but, using that insight to understand the process and how that might affect the future. As Jonathan Marks, professor of Anthropology at Yale University explains:

> There **are** races, and they are very important to us, but (1) they are defined by arbitrary and often discordant biological criteria; (2) the categories are bio-cultural; (3) they reflect the imposition of discrete boundaries on continuous biological variation; (4) race is historical and non-explanatory; (5) race is transmitted by a mechanism of folk heredity that runs parallel to biology, but is not itself biological. (Marks, 1994b:1-2).

Unlike Marks, Stephen Nawrocki, a biologist from the University of Indianapolis believes that race is a valid biological concept. Though Nawrocki does not believe that there are pure races exist, he does not believe that race is primarily a cultural construct (Nawrocki, 1993). Like all living organisms Nawrocki argues that organizing humans into sub-categories lends helps researchers understand the nonrandom clustering on heritable traits. In this way, Nawrocki argues that race is not is a valid biological concept.

In 1996, the American Association of Physical Anthropologists published a statement on their position on the biological aspects of race. The statement reads as advice to researchers on appropriate uses for studies of human variation. The article warns against the use of research that may perpetuate social stereotypes and biases.

The following is an outline of the major points:

- All humans living today belong to a single species and share a common descent.
- There are no pure races today and there is no evidence that there ever were.
- There are no discrete races of Homo Sapiens.

- The genetic composition of each population is influenced by a variety of factors. Features that have universal value for survival are not known to occur more often in one population over another. Therefore, it is useless to attribute any general inferiority or superiority to any population.
- There is no biological obstacle to breeding between two populations.
- Behavioral differences are a result of physical, cultural, and social environmental influences (AAPA, 1996).

This statement reflects the general attitude of most anthropologists today. Discrete categories for human variation do not exist. Furthermore, many factors influenced variation including admixture, gene flow, and mutation. Therefore, categories of human variation serve no purpose and can have very detrimental effects.

Interestingly, however, forensic anthropologists continue to use racial categories successfully in analyzing human skeletal remains for law enforcement agencies (Bass, 1987; Sauer, 1992; Steele et al., 1988). As Sauer states it in the title of his 1992 article, "If races don't exist, why are forensic anthropologists so good at identifying them?" (Sauer).

Forensic Anthropology and Race

Forensic Anthropology is a specific application of physical anthropology. It is the "application of the methods and expertise of physical anthropology to the legal process" (Skelton, 1994:1). Forensic anthropologists analyze human skeletal remains to help the police identify the deceased. Over the years, techniques have been developed and refined for estimating age, sex, and stature. These techniques have been relatively free of controversy. However, attempts to estimate race are significantly more controversial (Bass, 1987; Steward, 1979).

In forensic anthropology, a three-race classification scheme is most commonly used: Caucasoid (white or of European descent), Negroid (black or of African descent), and Mongoloid (Asian and Native American descent) (Bass, 1987; Giles and Elliot, 1962; Steele and Bramblet, 1988; Stewart, 1979). Whether or not this scheme is adequate to address the cultural question of ethnicity is questionable. Some have proposed the use of a classification scheme that defines large geographic races that are comprised of smaller local races (Garn and Coon, 1957). The problem is that, regardless of size, the races are defined by the typical combination of traits. Further, variance between members of the same group is often greater than the variance between members of different groups (Wolpoff and Caspari, 1997). Therefore, defining more races only increases the problem.

While the three-race system has been successful (Sauer, 1992), Marks argues that, this does not necessarily mean there is any relevance to the categories (Marks, 1994a; Marks, 1994b). He points out that although most skeletal remains can be allocated to one of the three categories, analysis of a large sample of skeletons would not likely yield the same three categories had they not been previously defined.

So far, the skull is the only area of the skeleton used to estimate racial affinity with degree of any reliability (Bass, 1987; Rhine, 1990; Stewart, 1979). There are two methods used by forensic anthropologists to estimate ancestry: (a) visual assessment and (b) discriminant analysis (Bass, 1987; Steele et al., 1988). To employ either technique, two things must be true: (a). The racial categories must reflect valid population differences and (b). the traits being evaluated must effectively distinguish between the populations (Bass, 1987; Steele et al, 1988; Stewart, 1979).

Visual assessment of racial affinity is a subjective methodology that requires experience and expertise. The researcher examines the skull and evaluates traits. Each of the traits is ranked based on its discriminating power. Researchers have refined techniques for visual assessment, and they often yield excellent results (Krogman, 1962; Rhine, 1990; Shipman, 1985; Stewart, 1969).

The following is an amalgamation compiled by Randy Skelton (1997) of traits associated with the three racial categories taken from Morse et al. (1983), Krogman (1962), El-Najjar and McWilliams (1975), and Shipman, et al. (1985):

Trait	Mongoloid	Caucasoid	Negroid
Skull length	long to short	long to short	mostly long
Skull breadth	broad	narrow to broad	narrow
Skull Height	medium	high	low
Sagittal Contour	arched	round	flat
Transverse Contour	round	long & round	long
Frontal bossing	females only	females only	both sexes
Face Breadth	broad	narrow	narrow
Face Height	high	high to medium	low to medium
Face Projection	not projecting	nose projects	jaw projects
Zygomatics	weak back taper	strong back taper	strong back taper
Interorbital Dist.	medium	narrow	wide
Orbital Shape	rounded	angular to round	rectangular
Nasal Orifice Width	medium	narrow (ht=2wd)	wide (ht=wd)
Nasal Bone Width	medium	narrow	wide
Nasal Sill	sharp edges	smooth edges	sharp edges

Ruggedness	Medium	gracile	rugged
Incisor Shoveling	very common	occasional	rare
Palate Width	medium	narrow to medium	wide

The key to visual assessment is to recognize a pattern. Again, it is the combination of traits, not any particular trait, that determines appropriate classification (Bass, 1987; Brues, 1990; Shipman et al., 1985).

Discriminant analysis is a statistical technique used to predict a non-metric classification using metric independent variables (Hair et al., 1995). Giles and Elliot (1962) developed a set of discriminant functions for estimating race that is currently used in forensic anthropology. These functions use eight standardized anthropometric measurements of the crania. The measurements, as defined in Steele and Bramblett (1988), are as follows:

- Maximum Cranial Length (g-op): distance in mid-sagittal plane from the anterior point on the frontal (glabella) to the most posterior point on the occipital (opisthocranion).
- Maximum Cranial Breadth (eu-eu): greatest width between the parietal eminences (euryon).
- Cranial Height (ba-b): distance from the midpoint of the anterior border of the foramen magnum (basion) to the intersection of the coronal and sagittal sutures (bregma).
- Basion-Nasion (ba-n): distance from the anterior border of the foramen magnum (basion) to the point of intersection of the internasal suture and the nasofrontal suture (nasion).
- Bizygomatic Breadth (zy-zy): maximum width of the lateral surfaces of the zygomatic arches measured perpendicular to the median sagittal plane. Points of reference for measurement are zygion.
- Basion-Alveolar Length (ba-ids): distance from anterior border of the foramen magnum (basion) to the most anterior inferior point on the maxilla in the median sagittal plane (alveolare).
- Upper Facial Height (ids-n): distance from the most anterior inferior point on the maxilla in the median sagittal plane (alveolare) to the point of the intersection of the internasal suture with the nasofrontal suture (nasion).

- Nasal Breadth (al-al): Maximum width of the nasal aperture, the points identified as alare. (Steele and Bramblett, 1988: 67-68)

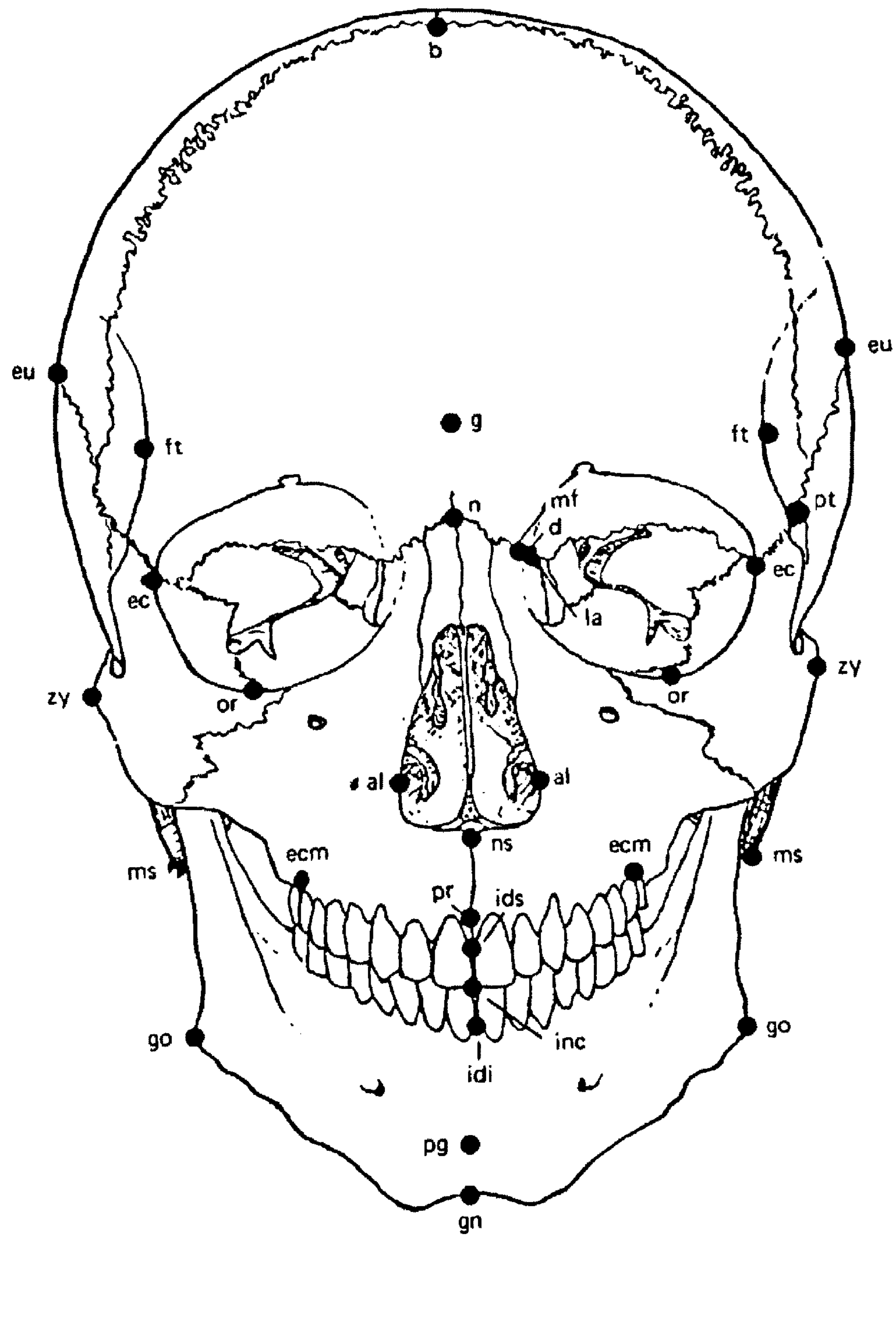
Figures 1-3 (Bass, 1987) depict the anthropometric landmarks used by Giles and Elliott (1962).

There are limitations to the Giles and Elliott discriminant functions. First, all eight measurements are necessary in order to use the function. In cases where the skull is fragmentary, it may be impossible to obtain all eight. In addition, the functions were created to classify a specimen into one of three groups. If the researcher wishes to compare the specimen to other known groups, these functions can not be used.

To address the limitations of the Giles and Elliott discriminant functions, Jantz and Ousley, from the University of Tennessee developed a computer software program called FORDISC (1993). "Using FORDISC allows an investigator to construct a sample framework consisting of two to none groups, using one to twenty-one measurements" (Jantz et. al., 1993:1). The obvious downside to the FORDISC problem is that one must have access to both a computer and the program.

Using a combination of both visual assessment and discriminant analysis is preferable to using either technique alone because the combination allows for both subjective and objective conclusions. However, there are circumstances when only one technique is possible. For example, when the crania is incomplete or damaged, it may be impossible to take all the necessary measurements to employ the Giles and

Figure 1. Frontal view of selected anthropometric landmarks of the skull (Bass, 1987:63).



Figures 2. Lateral view of selected anthropometric landmarks of the skull (Bass, 1987:64).

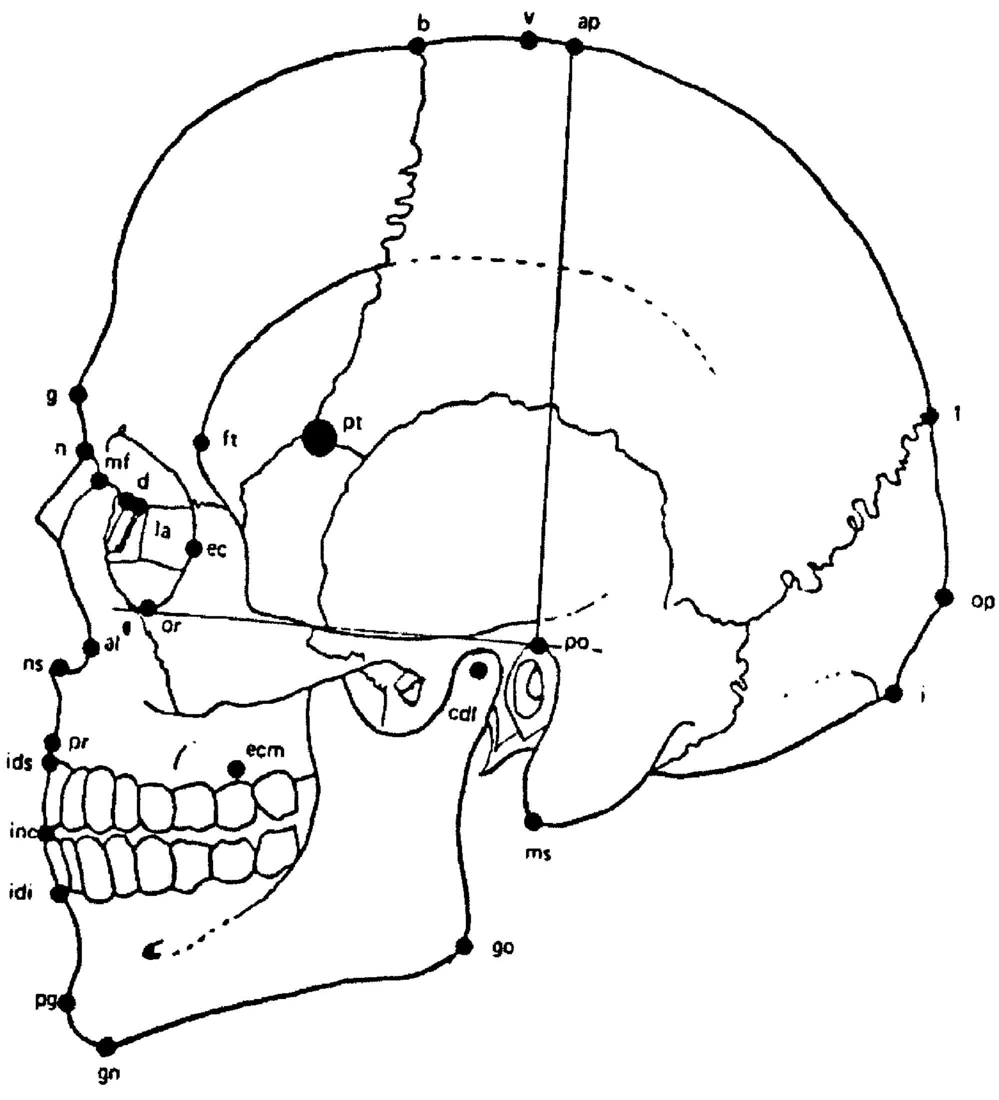
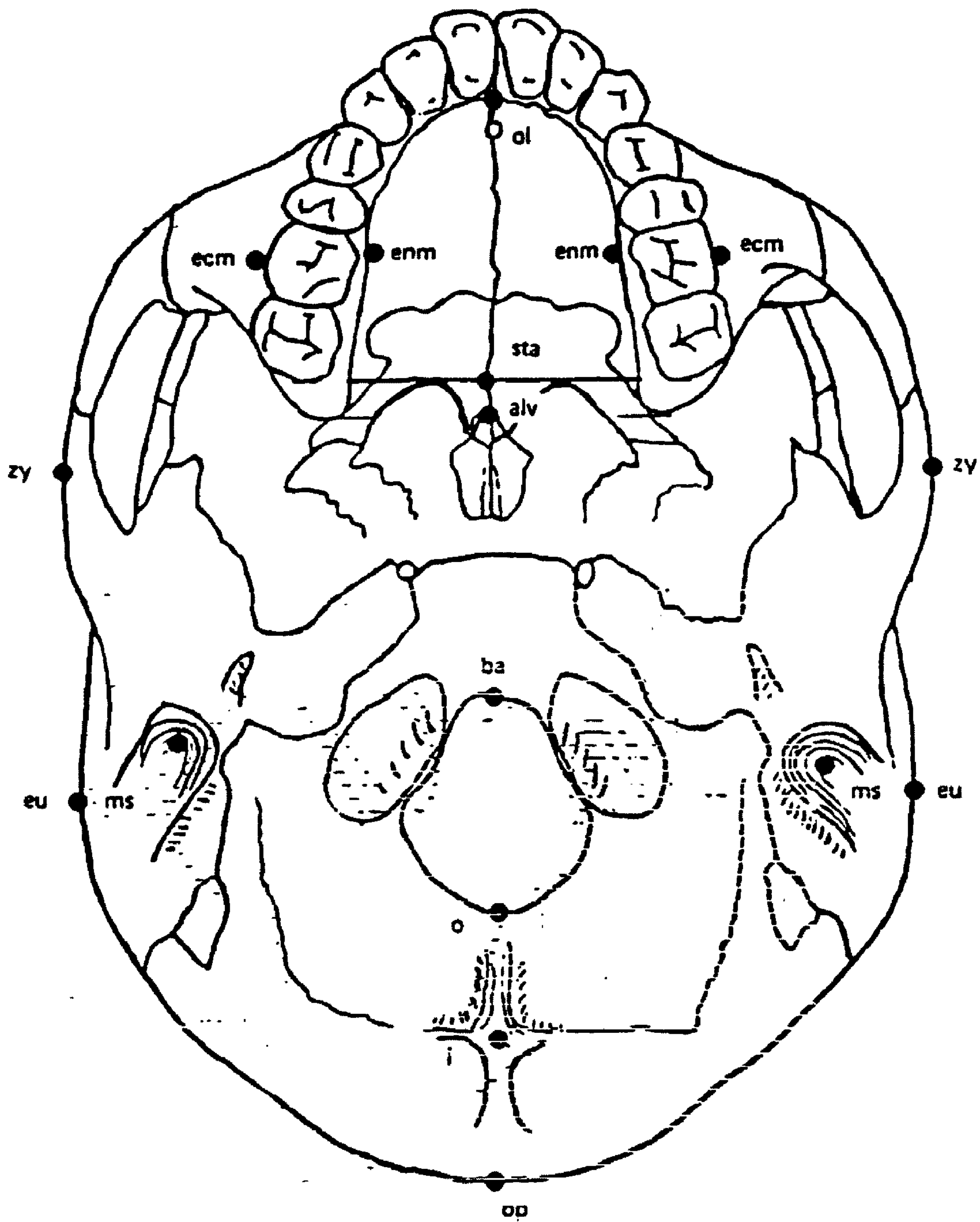


Figure 3. Base view of selected anthropometric landmarks of the skull (Bass, 1987:65).



Elliott (1962) discriminant functions. However, in some cases visual assessment may be possible on the portions that are intact. In other cases, such as the Boas data, only measurements are available therefore, visual assessment is impossible because there are no bones present to analyze.

Admixture and Racial Classification

Although there are problems associated with racial categories, it is important to recognize their continued usefulness in forensic anthropology. Examining the relationship of admixture to racial classification using subjects of known ancestry proportions may help reconcile the disparity between cultural and biological concepts of race. Because the police are trying to find out where the deceased fit in to society, forensic anthropologists are attempting to use biology to determine a social/cultural category. In a biological sense, I would expect that individuals with mixed ancestry would be classified within the group that comprises the greater percentage of their ancestry. In a social sense, I would generally expect an individual to be classified as a member of the group whose lifestyle they practice. Therefore, because the goal of forensic anthropology is to address a social question in the estimation of race, I was also interested in whether there is a degree of admixture that prevents the examination of the biological from being productive.

Whether it is termed admixture, hybridization, or gene flow, the topic is raised in almost every discussion of race. If we have a discussion of race, we must address the effect of between-population breeding. When races were thought to be permanent, (Blumenbach, 1776; Broca, 1864; Nott, 1865) hybridization was viewed as the mechanism of change in bodily form. Extensive scientific research has been performed to examine the effects if crossbreeding, not only in animals but plants as well. The genetic effects are far too complex and poorly understood to attempt to address in this paper. Most agree that breeding between two distinct populations usually results in a blending of the features, generating offspring that are intermediate, physically, between the two parent stocks (Brues, 1990). This is not true of all physical characteristics.

MATERIALS AND METHODS

Materials

In this project, I used Boas' data set, which contains information on Native Americans. The data were the result of a project directed by F. W. Putnam in 1891. Putnam was hired to set up an exhibit for a Chicago museum that would deal with the history of the United States before European contact. He hired Boas to collect biological, ethnographic, and historical information from Native American tribes throughout North America. Putnam hoped that the Boas project would lay a solid foundation for an anthropological exhibit that would rival those of the east. For Boas, the project was "an opportunity to obtain data on a vanishing peoples and way of life" (Jantz et. al., 1992:436).

Researchers traveled to tribal locations throughout the United States and Canada and collected several pieces of information from nearly 15,000 individuals in over 200 tribal groups. The data collected were grouped into tribes. Included in the data was ancestry information. Each subject was asked to report his or her mother's tribe and father's tribe. From that information, a purity percentage was assigned to each subject.

In addition, 50 researchers, following standardized measuring techniques, collected anthropometric measurements. Twelve measurements were collected in all, 6 cranial and 6 post-cranial. Each measurement to be collected was defined by skeletal landmarks. In this way Boas tried to ensure consistency and comparability.

I narrowed the data to one tribe in order to have as homogeneous a sample as possible. I selected the Sioux tribe because they had the greatest number of individuals. I further narrowed the scope to include only adult males, 18 years or older, who were either 100% Sioux or any mixture of Sioux and European ancestry. From the purity percentage reported by each subject, I assigned a numeric value between 1 and 8, which corresponded to the number of 8ths of Sioux ancestry he had. For example, "1" represented 1/8 Sioux ancestry and "8" represented 8/8 or 100% Sioux ancestry. The sample contained 645 subjects.

To evaluate the effects of admixture on racial classification using discriminant analysis, I needed a second data set that contained measurements from individuals of European ancestry. In addition, both sample sets had to have common anthropometric measurements. Furthermore, I felt it would be beneficial to have both samples collected from contemporaneous periods to help limit differences due to factors such as environment. Since the first data set was collected at the turn of the century, I thought the second set should be from roughly the same period.

I was fortunate to find as my second sample, data that were also collected under the direction of Franz Boas. These data, presented in the book Materials for the Study of Inheritance of Man (Boas, 1928), were collected in 1909-1910. The aim of that project was to compare body measurements of Europeans who had immigrated to the United States to body measurements of their offspring. The collection contains measurements from entire families. All the adults were European immigrants and their children were born both in Europe and in the United States.

The collection was organized by national/regional origin. The groups represented were listed as follows: Sicilian, Central Italian, Bohemian, Hungarian and Slovak, Poles, Scotch, and Hebrew. I chose to use the measurements of the *Scotch* (Boas' term). Again, I limited the sample to adult males, ranging in age from 18 to 69 years. The Scotch sample was assigned the numeric value of "0" or 0/8th Sioux. This sample contained 78 individuals.

The data collected in the two studies were not identical. There were four measurements common to both data sets. They are as follows: (a) standard height/stature (distance from floor to top of head); (b) head length (maximum length of head); (c) head breadth/width (maximum width of head), and (d) facial breadth (distance between zigomatic arches). These measurements were used in my analysis.

Methods

In this study, I tested the following hypotheses:

H_1: People of mixed ancestry will be classified as members of the group that comprises the larger percentage of their ancestry.

H_0: In people of mixed ancestry, the proportion of admixture will have no effect on racial classification.

H_2: An individual's proportion of ancestry in a group corresponds roughly to the probability that he or she will be classified as a member of that group.

H_0: There will be no relationship between the racial classification of people of mixed ancestry and the proportion of their admixture.

I selected discriminant analysis as the method to test my hypotheses for two reasons. First, I was interested in how admixture would affect an objective method of categorization. Secondly, my data were measurements, which disallowed the use of visual assessment. I utilized the SPSS-X discriminant analysis program to generate a discriminant function using the Scotch (0) and Sioux (8) samples. I then used that function to predict group classification for the individuals of mixed ancestry. Because my hypotheses were related, I was able to test both using a single set of results.

Discriminant analysis uses metric independent variables to determine a non-metric dependent variable (Hair et. Al, 1995). In discriminant analysis, independent variables can be selected for inclusion using two different methods: (a) the stepwise method and (b) the direct entry method (Hair et al., 1995). In the stepwise method, each independent variable is evaluated and the predictive value assessed. The combination of variables determined to be the most predictive is used to calculate the discriminant function. The direct entry method allows the analyst to select the variables to include without any preliminary evaluation.

There are benefits to both methods. Using the stepwise method, the variables selected represent the most predictive combination. Therefore, any variable determined to be of poor predictive value is eliminated. This method is particularly good for studies with a large number of variables (Hair et. al., 1995). Because I had only four variables, I used the direct entry method first, including all four variables. I then used the stepwise method. Using the stepwise method, standard height was eliminated from the analysis.

I performed several tests to evaluate the significance of the classification results for each of the trials. I tested the classification results of the following subsets: 0, 2, 4, 6, and 8. I did not test the classification results for subsets 1, 3, 5, and 7 because the sample sizes were too small. I performed three separate *t*-tests using a different calculated value for chance in each test. The different levels of chance were to compensate for the unequal sample sizes (Hair et al., 1995). In the first *t*-test, chance was equal to .50. In the second test, I applied the calculated proportional chance criterion, which is .7018 (Hair et al, 1995). In the third test, I applied the calculated maximum chance criterion, which is .77 (Hair et. al, 1995). In all of the *t*-tests, the tabled value is for a one-tailed test with $\alpha = .05$.

In addition, I performed Press's Q statistic on each of the subsets (Hair et. al, 1995). Like the *t*-test, this statistic tests the discriminatory power of the classification matrix when compared to chance. The calculated value is compared with a critical value. The critical value is the Chi-square value for 1 degree of freedom at .05 confidence level or in this case, 3.841 (Hair et al., 1995).

A calculated canonical correlation is provided on the results report generated by SPSS-X. When that number is squared and multiplied by 100, the resulting number represents the percentage of the variance in the dependent variable (classification category) that can be accounted for by the independent variables (Hair et al., 1995).

RESULTS

Direct Entry Method (4 Variables)

The classification results for the direct entry method using all four variables (standard height, head length, head width and facial breadth) were high for subsets 0 and 8, with nearly 87% of the subjects in those subsets classified correctly. Due to the small sample sizes of the mixed ancestry subsets, only subsets 2, 4, and 6 were included in the significance tests. Subsets 1, 3, 5, and 7 were not tested due to limited sample size.

In subsets 2, 4, and 6, the classification percentages never exceeded 60%. In performing the *t*-test, first defining chance as .50, only the calculated *t* values for subsets 0 and 8 exceeded the tabled *t* value. However, because the sample sizes of the subsets were not equal, I performed two additional *t*-tests: first using the proportional chance criterion of .7018, then using the maximum chance criterion of .77. Because chance increased in each of the two subsequent tests, I only tested subsets that were significant at the previous level. The calculated *t* values in the second *t*-test, using a calculated proportional chance criterion, remained significant for both subsets 0 and 8. In the third *t*-test, using the maximum chance criterion, only the calculated *t* value for subset 8 remained significant.

Using Press's Q statistic, I calculated the Q value for each subset and compared the results to the critical value, 3.841 (critical value from chi-square table for 1 degree of freedom at .05 significance level). As in the first two *t*-tests, the results for subsets 0 and 8 were significant, but none of the classification results for the subsets with mixed ancestry were significant. The summary of the classification result, the t-tests and the Q value are presented in tables 1a-1e.

Using the canonical correlation calculated by the SPSS-X program, 32% of the variance in the dependent variable can be accounted for by the independent variables.

Stepwise Method (3 Variables)

Similarly, the classification results from the stepwise method, which excluded standard height, were significant for subsets 0 and 8 with approximately 86% of the individuals in those subsets classified correctly. There is virtually no difference in the classification results for subsets 0 and 8 between the direct entry method and the stepwise method. However, with the stepwise method, 65% of the subjects in subset 4 were classified as Scotch. I calculated *t* values for subsets 0, 2, 4, 6, 8. The sample sizes for subsets 1, 3, 5, and 7 were too small to allow significance tests to be performed. The calculated *t* value, with chance equal to .50, was significant for subsets 0, 4, and 8. I then calculated *t* values for the subsets 0, 4, and 8, using the calculated proportional chance criterion, .7018, and the calculated maximum chance criterion, .77. Again, I only tested the subsets that were significant at the lower level. Subsets 0 and 8 remained significant at .7018 and only subset 8 remained significant at .77.

Using Press's Q statistic, I calculated the Q value for each subset and compared the results to the critical value, 3.841. (Critical value from chi-square table for 1 degree of freedom at .05 significance level). The results were the same as the first *t*-test where chance was equal to .50. Subsets 0, 4, and 8 were all significant. Subsets 2 and 6 were not significant.

Using the canonical correlation calculated by the SPSS-X program, 32% of the variance in the dependent variable can be accounted for by the independent variables. A summary of classification results, *t*-tests, and Press's Q test are presented in Tables 2a-2e.

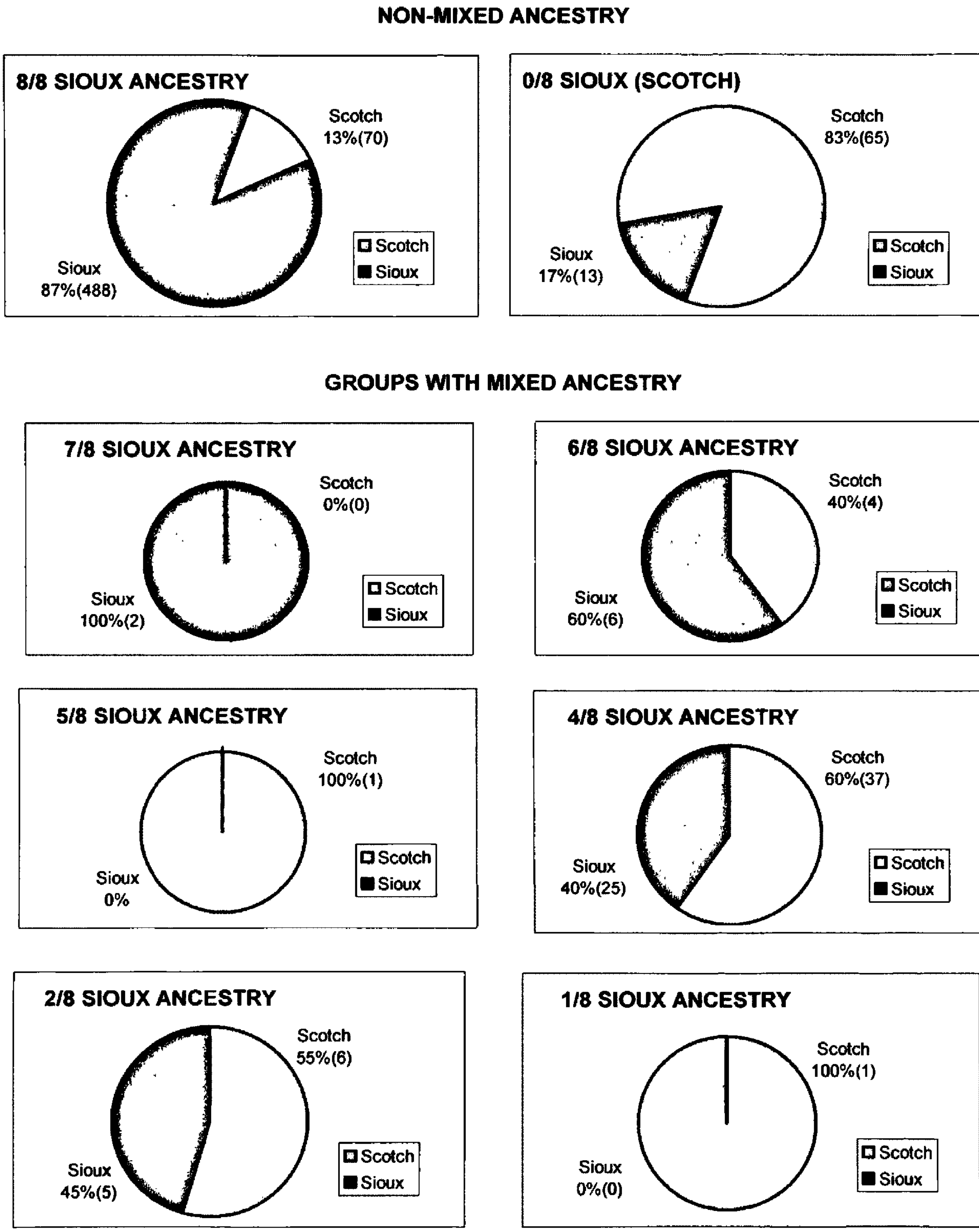
Table 1a. Classification results from the direct entry method of discriminant analysis.

4 Variables: standing height, head length, head breadth and facial breadth

Ancestry	Scotch	Sioux	Total Cases
8	70 12.50%	488 87.50%	558
7	0 NA	2 100%	2
6	4 40%	6 60%	10
5	1 100%	0 NA	1
4	37 60%	25 40%	62
3	0 NA	0 NA	0
2	6 55%	5 45%	11
1	1 100%	0 NA	1
0	65 83.30%	13 16.70%	78
			723

Figure 4. Graphic representation of classification results from the direct entry method of discriminant analysis.

4 Variables: standing height, head length, head breadth and facial breadth



* NUMBER OF INDIVIDUALS APPEARS IN PARENTHESES

Tables 1b-1e. Significance tests for the classification results of the direct entry method of discriminant analysis.

4 Variables: standing height, head length, head breadth and facial breadth

Table 1b.

t-TEST RESULTS
chance =.50

Ancestry	Calculated t	Tabled t
8	***26.79**	1.65
6	0.628	1.837
4	1.61	1.65
2	0.33	1.81
0	***7.89**	1.65

Table 1c.

t-TEST RESULTS
chance =.7018 (Proportional Chance Criterion)

Ancestry	Calculated t	Tabled t
8	***11.73**	1.65
0	***3.12**	1.65

Table 1d.

t-TEST RESULTS
chance =.77 (Maximum Chance Criterion)

Ancestry	Calculated t	Tabled t
8	***6.857**	1.65
0	1.5	1.65

Table 1e.

PRESS' Q STATISTIC RESULTS
Critical Value =.05 sig. Level 1 degree of freedom

Ancestry	Calculated Q	Critical Value
8	***313.12**	3.841
6	0.4	3.841
4	2.322	3.841
2	0.0909	3.841
0	***34.66**	3.841

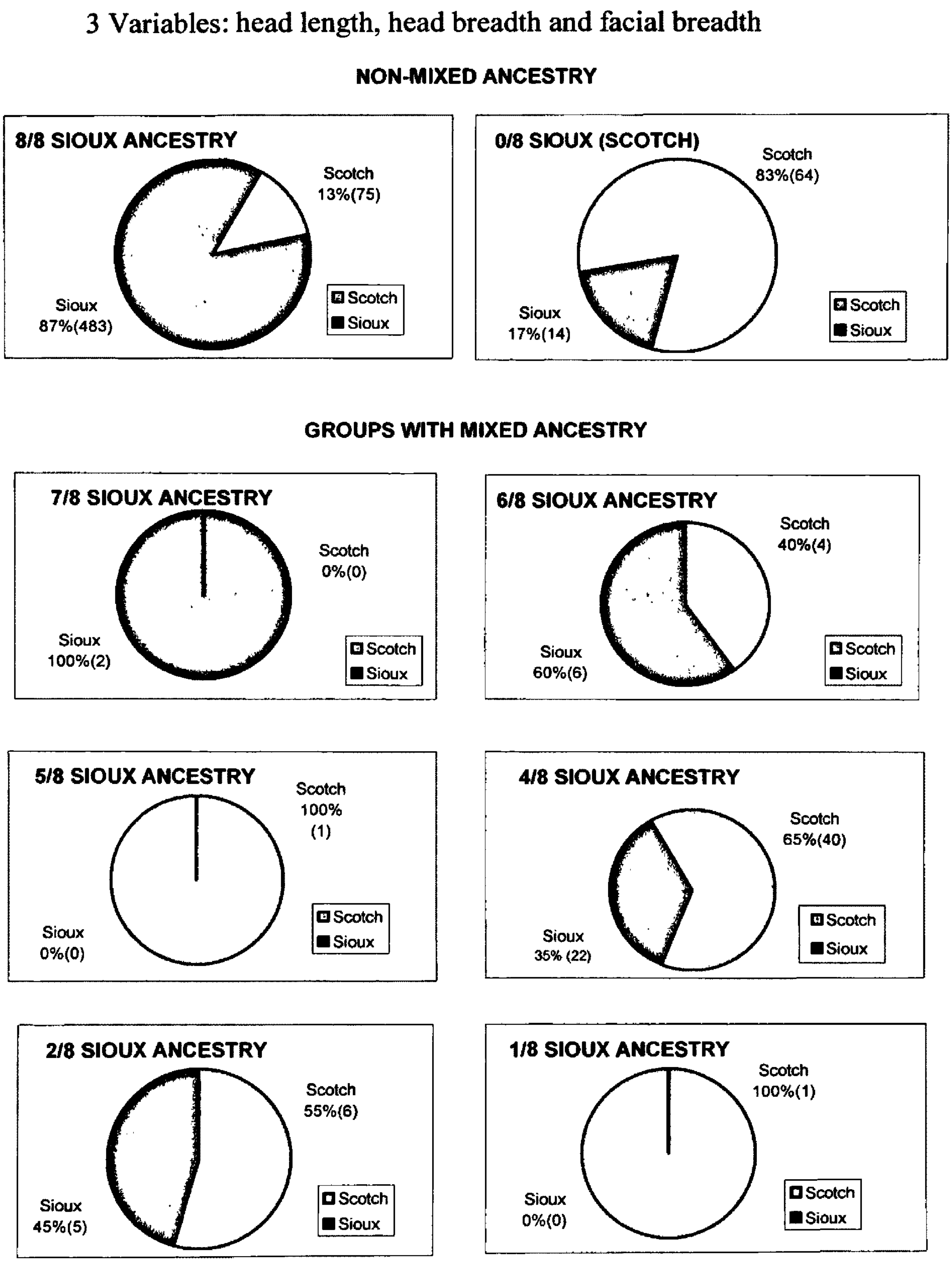
* Calculated value exceeds the tabled value, therefore these results are significant

Table 2a. Classification results from the stepwise method of discriminant analysis.

3 Variables: head length, head breadth and facial breadth

Ancestry	Scotch	Sioux	Total Cases
8	75 13.40%	483 86.60%	558
7	0 0%	2 100%	2
6	4 40%	6 60%	10
5	1 100%	0 NA	1
4	40 65%	22 35%	62
3	0 NA	0 NA	0
2	6 55%	5 45%	11
1	1 100%	0 NA	1
0	64 82.10%	14 17.90%	78
			723

Figure 5. Graphic representation of classification results from the stepwise method of discriminant analysis.



*NUMBER OF INDIVIDUALS APPEARS IN PARENTHESES

Tables 2b-2e. Significance tests for the classification results of the stepwise method of discriminant analysis.

3 Variables: head length, head breadth and facial breadth

Table 2b.

chance =.50

Ancestry	Calculated t	Tabled t
8	*25.42	1.65
6	0.628	1.837
4	*2.47	1.65
2	0.333	1.81
0	*7.47	1.65

Table 2c.

t-TEST RESULTS

chance =.7018 (Proportional Chance Criterion)

Ancestry	Calculated t	Tabled t
8	*12.37	1.65
4	0.856	1.65
0	*3.12	1.65

Table 2d.

t-TEST RESULTS

chance =.77 (Maximum Chance Criterion)

Ancestry	Calculated t	Tabled t
8	*7.5	1.65
0	1.5	1.65

Table 2e.

PRESS' Q STATISTIC RESULTS

Critical Value =.05 sig. Level 1 degree of freedom

Ancestry	Calculated Q	Critical Value
8	*298.32	3.841
6	0.4	3.841
4	*5.225	3.841
2	0.0909	3.841
0	*34.66	3.841

* Calculated value exceeds the tabled value, therefore these results are significant

DISCUSSION

In this section, I will discuss several topics. First, I will report my analysis of the classification results. Next, I will address questions, concerns and criticisms of my materials and my methods. Finally, I will propose improvements on the research design.

Analysis of Results

Almost without exception, any degree of admixture in the subjects I tested resulted in classification percentages that were no better than would be expected by chance. The one subset of mixed ancestry that yielded classification results that were significant using the *t*-test (chance = .50) and Press's Q statistic (Hair et al., 1995), was subset 4 in version using the stepwise method in which standard height was eliminated. For subset 4, representing the population with 50% Sioux ancestry and 50% European ancestry, 65% of the individuals were classified as Scotch. This result is surprising. I would have expected that the an individual with equal proportions of Caucasian and Non Caucasian ancestry would have been classified in the non-Caucasian category. Culturally these individuals would likely be considered Native American (Grant, 1916; Kleg, 1993; Marks, 1995; Wolpoff and Caspari, 1997;). The sample size for subset 4 may have had an effect on the *t*-test and the Press's Q statistic results. Larger sample sizes are more likely to be deemed significant at lower classification rates (Hair et al., 1995).

The canonical correlates provided in the SPSS-X results for both the direct entry method and the stepwise method were ≈ 32%. That indicates that the independent variables accounted for only 32% of the variance in the racial classification. Therefore, 68% of the variance in the classification can be attribute to some other factor or set of factors. I have no way of knowing what that factor or factors might be. It could be simple random variation among individuals.

An explanation for the variance in the classification results becomes important after comparing the overall classification results of the subsets 0 and 8 to subsets with mixed ancestry. Eighty-six percent of the subjects in subsets 0 and 8 were classified correctly. In comparison, none of the remaining subsets exceeded 60% classification (with the exception of subset 4 using the stepwise method) into the group that comprised the greater proportion of ancestry. If only 32% of the variation in the dependant variable can be accounted for by the independent variables, how can the dramatic effect of admixture be explained?

I have three possible explanations for this phenomenon. First, the classification accuracy for subsets 0 and 8 might have been a result of sample size. Because the sample size was so large, the probability of accurate classification was already increased due to the fact that individual variation was less likely to skew the mean for the group (Blalock, 1979; Borg and Gall, 1989; Lindgren et al., 1978). In smaller sample such as the mixed ancestry subsets, individual variation becomes more important because it represents a greater proportion of the group (Blalock, 1979; Borg and Gall, 1989; Lindgren et al., 1978). Second, admixture might have had drastic effect on the measurements I used, making what predictive value they had diminish considerably. Third, admixture may have strongly affected the variable or variables responsible for the additional 68% percent of variance in the classification results.

Critique of Materials and Methods

Using data from two different sources presented several issues of concern. They are: (a) consistency of measuring techniques, (b) consistency in the measurements collected, and (c) factors, such as environment, that may have influenced between-group variation. Selecting collections that were both directed by Franz Boas helped eliminate the concerns about methodology. The measuring technique was described, as were the skeletal landmarks used for each measurement in both collections. They were the same for both collections.

Because I was limited by the measurements common to both collections, I was confined to four independent variables. Those measurements are standing height, head length, head breadth and facial breadth. Furthermore, the SPSS-X program determined standing height to be of poor or no predictive value. Therefore, when I used the stepwise method of discriminant analysis, only three variables were included. The number of independent variables I used in the analysis is important. While there are no hard and fast rules regarding the number of independent variables required to perform discriminant analysis, Hair et al. (1995) suggest that for each independent variable there should be twenty subjects. However, the number of independent variables required when estimating ancestry may be greater. Individual characteristics when taken alone are not necessarily indicative of racial classification but rather it is the normal combination of characteristics that needs to be considered (Brues, 1990). Therefore, three variables may not be sufficient.

The three measurements used in the stepwise method were cranial measurements. This is important because, as discussed previously, in forensic anthropology, cranial features are used almost exclusively in estimating ancestry. This is true in visual assessment as well as the FORDISC and Giles and Elliot (1962) discriminant analysis methods. Nonetheless, the three cranial measurements available are not necessarily the best predictors of racial classification. Moreover, this particular combination of cranial measurements may be of limited predictive value.

I had concerns about using measurements from two different data collections to represent my unmixed samples (subsets 0 and 8). I was particularly concerned because the subsets of mixed ancestry were from the Sioux sample. Therefore, I believe that if variation between the two samples were due to factors other than ancestry, the mixed subsets would behave more like the Sioux sample because they were exposed to the same outside influences.

I attempted to use data sets that were as similar to each other as possible. First, I chose two data sets collected around the turn of the century to limit the effect of environmental factors. The two collections span approximately twenty years but I hoped that the difference between them would be less drastic than if I had selected two less contemporaneous samples. Second, I limited the subjects in both samples to include only adult males, in order to minimize within-group variation.

In addition to problems associated with using two different data sources, both collections contained measurements from living people as opposed to skeletal remains. The effect of tissue depth on between-group variation is a concern when using non-skeletal measurements. If the average weight in one group varied dramatically from the average in the other group, the classification results could be influenced. The discriminant function most commonly used in forensic anthropology to estimate race was built on cranial measurement for skeletal remains (Giles and Elliott, 1962).

The purpose of the significance test is to determine if classification accuracy is significantly larger than would be expected by chance. Sample size can affect the significance tests used in this project in two ways. With both *t*-tests and Press's Q statistic, large sample sizes are deemed significant at lower classification rates than would be significant in small samples (Hair et al., 1995). The sample size in used in the denominator of the *t* ratio. As the sample size increases the value of the denominator decreases. This smaller denominator increases the value of *t* (Lipsey, 1990). However, the *t*-test is designed for sample sizes that do not exceed 30 subjects. For samples ranging from 30 to ∞, the tabled *t* value remains the same. The result is that lower rates of correct classification are significant. Therefore, the fact that subset 8 was significant at every level of chance I tested could simply be a result of a large sample.

The purpose of this project was not to test the classification results of subsets 0 or 8. However, because sample size affects the significance test results, the difference in classification rates between subsets 0 and 8 and the subsets of mixed ancestry may be a result of sample size rather than the effect of admixture. To compensate for variation in sample size, I calculated *t* values using additional measures for chance: (a) proportional chance criterion and (b) maximum chance criterion (Hair et al., 1995). Subsets 0 and 8 were both significant at the proportional chance criterion; subset 8 was also significant at the maximum chance criterion.

Recommendations

In conducting this research, I attempted to limit the factors that might influence or distort the results. However, I have learned of two additional measures I would take in the future. First, I would have chosen samples that were more nearly equal in size or limited the larger sample. The large difference in the sample sizes caused several problems I have outlined in this chapter, primarily concerns with the reliability of the significance tests. Second, I would have created a *hold out* sample to test the discriminant functions (Hair et al., 1995). A hold out sample is a representative subset of the groups that was not included in the actual analysis but held out and used for testing. Once the function is built, the hold out sample can be used to test for consistency of results.

It is important to stress that the focus of this project was to examine the effects of admixture on racial classification results. I used two populations that fit into the currently accepted racial categories used in forensic anthropology, but that was not necessary. I might have used two different Native American tribes as my "pure" populations and tested individuals who were varying proportions of those two tribes. By using Sioux and Scotch as the "pure" populations, I was able to increase the between-group variation, thereby increasing the likelihood that the available variables had more significant predictive power.

CONCLUSION

My objective in this project was to explore the effect of admixture on racial classification using discriminant analysis. The hypotheses I addressed in this project are as follows:

H_1: People of mixed ancestry will be classified as members of the group that comprises the larger percentage of their ancestry.

H_0: In people of mixed ancestry, the proportion of admixture will have no effect on racial classification.

H_2: An individual's proportion of ancestry in a group corresponds roughly to the probability that he or she will be classified as a member of that group.

H_0: There will be no relationship between the racial classification of people of mixed ancestry and the proportion of their admixture.

I can not reject either of my null hypotheses. I found in people of mixed ancestry no statistically significant relationship between predicted group membership and the proportion of admixture. In fact, any degree of admixture resulted in classification percentages that were no better than would be expected by chance. When I tested the significance of the result using both the *t*-test and Press's Q statistic, the only subsets that were significant at any level were subsets 0(direct entry and stepwise method), 4(stepwise method), and 8 (direct entry and stepwise method). The significance means that the classification results were not due to chance.

Using the stepwise method of discriminant analysis, 65% of individuals who reported equal proportions of Sioux and European ancestry, was classified as Scotch. While the result was significant in both the *t*-test, with chance equal to .50, and in Press's Q statistic (Hair et al., 1995), a classification rate of 65% is not high enough to be useful for forensic anthropologists.

I have outlined, in the previous chapter, several factors that may have affected my findings. Sample size, data collection and independent variables are a few examples. While all of these factors may have had an effect on the results I found in this project, the real problem is more likely the fact that we are using biology to answer a social question. In addition, it is difficult to test the effect of admixture because there are no "pure" biological races.

Additional research in this area may aid in our understanding of the effect of admixture on racial classification. Approaching the study from a biological and genetic perspective rather than a social perspective may be more interesting and more fruitful. The search for better techniques for estimating ancestry may be unnecessary. Since forensic anthropologists generally deal with contemporary bones, as time goes on and people continue to interbreed, question of race may eventually be irrelevant.

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