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Deep roots of admixture-related cognitive differences in the USA

John Fuerst[1], Meng Hu

1 Cleveland State University

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Abstract

This study attempted to determine if the association between genetic admixture and cognitive ability among African, European, and Amerindian descent groups in the USA holds across a large time period. First, we used the large and nationally representative Adolescent Brain Cognitive Development Study (ABCD) sample to examine the association between cognitive ability and parental-reported race, genetically-predicted color, and genetic ancestry among Puerto Ricans, non-Hispanic Whites, Blacks, and American Indians in the 21st century. Second, we use the 1850 to 1930 US censuses to trace ancestry-associated cognitive differences back to the early 19th and early 20th century among African American, American Indian, and Puerto Rican groups by using age-heaping-based numeracy as a proxy for cognitive ability. In the ABCD sample, we found that European ancestry is positively associated with cognitive ability within race/ethnic groups. In the census data, among African Americans and American Indians but not Puerto Ricans, we find that greater apparent European admixture is associated with higher numeracy, and this holds when we subset by age, sex, and literacy status. Therefore, we established that admixture is associated with cognitive ability in the 21st century as it was in the 19th and early 20th century. The implications of these findings are discussed.

John G. R. Fuerst[1,2] and **Meng Hu**[3]

[1] *Cleveland State University*

[2] *University of Maryland Global Campus, Bioinformatics*

[3] *Independent Researcher*

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1. Introduction

Differences in cognitive test scores exist between socially-identified racial and ethnic groups in the United States[1], with

disparities reported since the early 20th century [2]. The cause of these cognitive achievement gaps is of interest as academic outcomes are strongly tied to socioeconomic outcomes later in life and because cognitive test scores measured during adolescence can explain many disparities in educational attainment, income, and health later in life [3]. Therefore, the topic of racial/ethnic-related achievement gaps remains heavily researched.

Research mostly groups American individuals according to their own or their parents' identification with one or more of the main federally defined racial/ethnic categories. The National Assessment of Educational Progress (NAEP), which measures students' academic performance, uses eight racial/ethnic categories: American Indian/Alaska Native; Asian; Black or African American; Hispanic; Native Hawaiian or other Pacific Islander; Two or More Races; White. These categories are based on those of the U.S. Office of Management and Budget (OMB) [4], which recognizes that the race/ethnicity categories "may be viewed in terms of social and cultural characteristics as well as ancestry."

While race/ethnicity is frequently treated categorically, many early 20th-century researchers recognized that members of the same socially- and culturally-delineated racial/ethnic groups could differ substantially in genetic ancestry. The first admixture studies were conducted during the first half of the 20th century to determine if European admixture was related to better scholastic achievement and cognitive test scores among admixed African (e.g., [5][6][7][8][9]), Native American (e.g., [10][11][12][13][14]), Puerto Rican (e.g., [15][16]) and other populations. Most studies found only a modest positive association between measures of European ancestry and cognitive/achievement test scores [17][18]. As a result, the correlations between ancestry and test scores were often interpreted as too small to be significant. This misunderstanding was found in some older studies (e.g., [19][20]) and also in narrative reviews (e.g.,[21]).

The results of many large-scale nationally representative studies have confirmed the findings of earlier 20th-century research. For instance, research has shown that there are higher general intelligence scores for African Americans with higher self-reported or parent-reported European ancestry, as well as those with lighter skin color [22][23][24]. Additionally, children with mixed heritage (e.g. a Black and a White parent) generally score somewhere in between the scores of children from each parental population, as has been shown in several large national studies [24][25][26]. More recently, 21st-century admixture regression studies have found a linear relationship between genetic ancestry and cognitive ability within self-identified racial and ethnic groups [27][28][29][30]. These studies also find small-to-modest correlations between ancestry and scores but demonstrate that such correlations are consistent with a large influence of ancestry on cognitive ability. Moreover, these studies have been supported by other research that has identified a linear relationship between educational attainment and genetic ancestry in mixed American groups [31]. Based on over 100 years of research, a very large body of evidence indicates that European admixture within American groups such as Hispanics, Blacks, and Native Americans is associated with academic and cognitive outcomes.

While this link between admixture and outcomes could be accounted for in a couple of different ways, one obvious scientific hypothesis concerns inherited disadvantage [23]. According to this hypothesis, there were original cognitive differences between source populations such as Europeans, Africans, and Amerindians; and differences are largely being vertically passed on along genealogical lines through cultural or genetic mechanisms. Given initial trait differences between parental populations, the inherited disadvantage model would predict, in admixed populations, a relation

between the number of ancestors from different parental populations and cognitive outcomes. This model of inherited disadvantage can be contrasted with a cultural-group model according to which race-related differences are due to common factors affecting members of the same race/ethnic groups (irrespective of ancestry). As an example of the latter, James Flynn, famous for popularizing the Flynn effect, argued that differences between Black and White Americans are due to the black subculture [32]. However, if differences were due to subculture effects common to all Blacks, then they would not be proportional to genetic ancestry among Blacks. So, the issue of whether academic and cognitive outcomes track admixture is relevant both to understanding the origin and transmission of cognitive differences. Focusing exclusively on OMB-defined racial/ethnic categories may leave a large portion of academic disadvantage undiagnosed if this disadvantage tracks genetic ancestry.

The earliest analyses of the relationship between admixture and cognitive ability date back to the 1910s and 1920s. However, these admixture results are based on small convenience samples. Since intelligence tests were first developed and employed in the early 20th century, it is not possible to determine if intelligence test scores are related to admixture, let alone in large national samples, before this time, However, we can gain some insight into these causes by using age heaping as a means of assessing human capital in the pre-mass testing era. Age heaping refers to measuring the tendency for individuals to inaccurately report their age and age heaping has been used in economic research to measure innumeracy [33][34]. The extent of age-heaping, measured in the 19th century, bears a strong relationship with national achievement scores from the late 20th and 21st centuries [35][36]. Moreover, the extent of age-heaping also strongly predicted provincial-level scholastic test scores, one hundred and fifty years later, in Italy [37]. Additionally, the extent of parents' age-heaping was also found to predict the children's mathematical achievement scores in 20th and 21st-century Sub-Saharan Africa at the family level [38]. Finally, using data from the Spanish Inquisition records, Baten and Nalle [39] found a positive association between age-heaping and a numerical measure on the individual level. So, there are several convergent lines of evidence indicating that age-heaping measures population-, family, and even individual-level numeracy.

Age-heaping has previously been used to compare the numeracy of ethnic groups. For example, Sohn[40] compared the numeracy of Black and White soldiers during the Civil War, while Pérez-Artés [41] compares the numeracy of Indians, Black, Mestizos, Mulattos, and Spaniards in 18th-century Mexico. Moreover, Juif and Baten [42] compared the age-heaping of 15th to 17th century Native Peruvians and Spanish.

To ensure that the validity of the admixture effect holds across time, we employ two independent samples. The first analysis examines the relationship between genetic ancestry, skin color, and general cognitive ability among 10-year-old individuals from different racial and ethnic groups, including Whites, Blacks, American Indians, and Puerto Ricans by using data from the Adolescent Brain Cognitive Development Study (ABCD). The second analysis examines age-heaping numeracy scores based on the 1850-1930 censuses data, which made distinctions based on ancestral admixture among Blacks, Mulattos, and Native Americans. The results from the ABCD sample were compared to those based on the 1850 to 1930 censuses.

Our hypothesis is that, within American race/ethnic groups, admixture will predict cognitive ability, in the 19th, early 20th,

and 21st centuries. More specifically, we predict that European ancestry will be positively associated with higher cognitive ability in admixed African-European-Amerindian descent groups. This would be in line with the inherited disadvantage model, according to which inequalities are primarily being inter-generationally transmitted.

2. Method

2.1. Analysis of the Adolescent Brain Cognitive Development (ABCD) study

2.1.1. Data

The Adolescent Brain Cognitive Development Study (ABCD) is a recent collaborative longitudinal project involving 21 collection sites across the USA, created to research the psychological and neurobiological bases of human development. At baseline, around 2016, approximately 11,000 9-10-year-old children were sampled, mostly from public and private elementary schools. The sample, when weighted, is nationally representative of 9-10-year-olds.

2.1.2. Variables for ABCD analysis

For the purpose of analysis using the ABCD data, various variables were computed. These are listed below.

2.1.2.1. Ethnic group

In this study, the categorization of individuals into race/ethnicity groups was based on parent-reported data. Four mutually exclusive race/ethnicity groups were created: non-Hispanic White (referred to as White), non-Hispanic Black (referred to as Black), non-Hispanic American Indian (referred to as American Indian), and Hispanic Puerto Rican (referred to as Puerto Rican). The White group was composed of individuals who were identified solely as White without belonging to another race/ethnicity category. The Black group was defined as those individuals who were reported as Black but not Hispanic. The American Indian group included individuals who were reported as American Indian and were not also identified as Black or Hispanic. This classification approach is broadly in line with how groups are typically classified in the USA.

2.1.2.2. Admixture estimates

The ABCD Research Consortium conducted the imputing and genotyping using Illumina XX. Quality control was conducted using PLINK 1.9; a total of 516,598 variants survived the quality control. The ABCD Research Consortium pre-computed a genetic ancestry variable using a $k = 4$ solution (European, African, Amerindian, and East Asian). The ABCD researchers used 1000 Genomes populations as the reference samples and fast structure as the algorithm [43]. We divided the ancestry estimates by the sum of European, African, Amerindian, and East Asian ancestry so that the sum of the four ancestries added up to 1. Based on the European admixture estimate, we additionally computed European ancestry quartiles (75 to 100% European; 50 to < 75% European; 25 to < 50% European; < 25% European).

2.1.2.3. Fitzpatrick Category

The data did not include measures of appearance, so we opted to impute these based on genotypes, using the HIrisPlex-S web application. (https://hirisplex.erasmusmc.nl/). The HIrisPlex-S web application was developed for use in forensic investigations by the U.S. Department of Justice. This application has been validated on thousands of people from various parts of the world [44][45][46]. It uses 41 SNPs that are functionally related to traits associated with skin, hair, and eye color to impute probabilities for these physical characteristics. Of the 41 SNPs, 36 are related to skin color, 22 to hair color, and 6 to eye color. HIrisPlex-S provides probabilities that an individual falls into one of five levels of the Fitzpatrick Scale skin type. These levels include Type I, which represents the palest and freckled skin (scores 0-6); Type II (scores 7-13); Type III-IV combined (scores 14-27); Type V (scores 28-34); and Type VI, which represents deeply pigmented dark brown to darkest brown skin (scores 35-36). Based on the Fitzpatrick scores, we also computed three broad color categories (Type I-IV, “palest to moderate brown”; Type V, “dark brown”, Type VI, “deeply pigmented dark brown”).

2.1.2.4. General cognitive ability

The dataset used in this study, known as ABCD, includes data from 11 cognitive tests primarily obtained from the NIH Toolbox battery. These tests include Picture Vocabulary, Flanker, List Sorting, Card Sorting, Pattern Comparison, Picture Sequence Memory, Oral Reading Recognition, the Matrix test from the WISC-4, Little Man Test, and Rey’s Auditory Learning immediate and delayed recall tests. To ensure that age and sex differences did not impact the study’s results, the test data were adjusted for these variables. We utilized the IRMI algorithm to impute missing data, as this approach has been validated and produces reproducible results. Only 10.3% of the cells were missing, and 48% of the cases had some missing data. We imputed data for subjects with no more than five missing data points. After the data were imputed, 1.3% of the cells were missing, and 98.2% of the subjects had complete data. Subjects with remaining missing data were not included in the analyses. To create a single measure of color, we calculated the weighted medium score of each type using the probability of each type. For our study, we employed exploratory factor analysis (EFA) utilizing the **psych** package [47] to extract the first factor from the 11 neurocognitive tests administered at baseline. The resulting general factor accounted for 35% of the variance in test scores, which is slightly lower than the typically observed percentage of >40%. We attributed this finding to the inclusion of a larger number of working memory tests in our set. In contrast to multigroup confirmatory factor analysis (as used in previous studies e.g., [29]), we opted to use EFA. The reason for this decision was that we did not want to commit to a specific model regarding the nature of cognitive differences between race/ethnic groups, such as the popularly known Spearman’s Hypothesis. Thus, our approach allowed for a more exploratory and flexible analysis, which is particularly relevant when investigating complex constructs such as cognitive ability.

2.1.3. Statistical approach

We computed sample-weighted means and standard deviations for ancestry, skin color, and *g* using the **survey** package. We additionally reported the unweighted sample sizes. When relevant, means and standard deviations were computed for each ethnic group by parent-identified race, Fitzpatrick color category, and European-ancestry quartiles.

We also ran regression analyses, with skin color, SIRE, and genetic ancestry predicting*g*. In accordance with the recommendation of Heeringa and Berglund (2021), we utilized a linear mixed-effects model instead of ordinary least squares. This entailed breaking down the residual term into linear random effects components linked to the identifiers of the data collection site and same-family identifiers within the sample. This approach enables the possibility of correlations in the error term within data collection sites or families with multiple tested individuals. Additionally, this model aligns with the one used in the ABCD Data Exploration and Analysis Portal (DEAP), as noted by Heeringa and Berglund (2021). Consequently, using this multilevel model facilitates replication. To execute the mixed-effects regression models, we utilized the lmer command from the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). For these analyses, Fitzpatrick color scores were standardized on the study sample of $N = 8344$ individuals.

2.2. Census-based age-heaping analyses

2.2.1. Data

Age-heaping was computed using USA census records. The census data were drawn from the Integrated Public Use Microdata Series (IPUMS) US population census. The IPUMS USA collects decennial censuses from 1790 to 2010 and American Community Surveys (ACS) from 2000 to the present. Selected years for the present study include 1850, 1860, 1870, 1880, 1990, 1910, 1920, and 1930.

2.2.2. Variables for age-heaping analyses

For the purpose of the analysis using the census data, various variables were computed. These variables, which are detailed in Table 1, are listed below.

2.2.2.1. Sex

Interviewers were asked to record the sex of the household inhabitants (Male =1; Female =1).

2.2.2.2. Age

Interviewers were notified about the tendency for individuals to age-heap and were instructed to ascertain exact ages if possible. Based on the age variable, we created five age cohorts: 23-62; 23-32; 33-42; 43-52; 53-62.

2.2.2.3. Color or Race

Interviewers were asked to record “Color” (1850-1880) or “Color or Race” (1900-1930). We focus on the White, Black, and American Indian groups. In the 1850-1880 and the 1910-1920 census, interviewers were also asked to carefully distinguish between Blacks who were “full-blooded negroes” and Mulattoes who were “Negroes having some proportion of white blood” (1920). Dummy variables for Black, Mulatto, White, and Indian were created. Note, while some may find the term “Mulatto” offensive, we retain the term since it was the official designation used for the admixed group in the original

datasets.

2.2.2.4. Blood Quantum

In 1900 and 1910, special Indian schedules were included in the census. Interviewers were asked to ascertain, through inquiry with older men of the tribe, if an individual was a full-blooded American Indian. If not, interviewers were instructed to record the fraction of White blood that the individual had. Following Thornton and Young-DeMarco [48], we created four blood quantum categories for American Indians: Full-blooded Indians, greater than 0% White and less than 25%, greater than 25% White and less than 50%, and greater than 50% White and less than 100%. The Indian Schedule samples include Whites living with Native American families on reservations, which may account for individuals marked as 100% White.

2.2.2.5. Full-blood and Mixed-blood Indian

Using the Blood Quantum data in the 1900 and 1910 censuses, we coded American Indians (excluding Whites living on reservations) as Full-blooded (meaning 0% White blood) and Mixed-blood Indians (meaning greater than 0% White blood). In 1930, interviewers were asked to record if Indians were Full-blooded or Mixed-blooded. Some interviewers reported % of Indian blood. For 1930, we coded American Indians as Full-blood if they were either reported as having 100% Indian blood or as being Full-blooded and as Mixed-blood Indians if they were either reported as having less than 100% Indian blood or as being Mixed-blooded.

2.2.2.6. Resides in free-state and Resides in slavery-state

We coded the 50 USA states by whether they corresponded with a slave state/territory in 1861 or a slavery-free state /territory. We then created two dummy variables for residence, Free-state & Slave-state.

2.2.2.7. USA-born

Interviewers were asked to record the state, territory, or nation of birth of the household members. We created a dummy-coded USA-born variable, coded “1” if the respondent was born in a contemporaneous US state and “0” otherwise.

2.2.2.8. Literate

Interviewers assessed whether respondents were literate. How this was done was not reported. Respondents were coded as literate if they could both read and write.

Table 1. Variables Description for the Study Sample.

Variables	Description	Code
Sex	respondent sex	Sex = 1 (male) Sex = 2 (female)
Age	Respondent age	Age = 023 to 062
White race/color		raced = 100 & 120
Black race/color	“negro or of negro descent” (1900); “all Negroes of full blood” (1920)	raced = 200
Mulatto race/color	“word is here generic, and includes quadroons, octoroons, and all persons having any perceptible trace of African blood” (1880); “includes all Negroes having some proportion of white blood” (1920)	raced = 210
American Indian race/color		raced = 300
Full-blood (1910-1920)	0% White blood	BLOODW == 0000 & raced = 300
Mixed-blood (1910-1920)	> 0%White blood	1000 <= BLOODW > 0000 & raced = 300
Full-blood (1930)	Full-blooded Indian	BLOODI = 1000 & raced = 300
Mixed-blood (1930)	Mixed-blooded Indian	BLOODI = 9995 & raced = 300
% White Blood	Proportion of White blood in Indians	BLOODW
Resides in free state or territory	Slavery was not legal in the state or territory in 1861 in which individual resides	STATEICP == -c (11; 34; 40-49; 51-54; 56; 61; 65-66)
Resides in slave state or territory	Slavery was legal in the state or territory in 1861 in 1861 in which individual resides	STATEICP == 11; 34; 40-49; 51-54; 56; 61; 65-66
Indian Schedule	Special Inquiries Relating to American Indians	SAMP1900 == 4; SAMP1910 == 4
USA born	Person was born in a currently recognized state of the USA	BPL < 100
Literate	The respondent could read and write in any language	LIT = 4

2.2.3. Samples

2.2.3.1. 1850 and 1860 Black and Mulatto Slave samples

The 1850 and 1860 Slave samples are representative 5% samples of slaves enumerated in those years. On separate slave schedules, as part of the 1850 and 1860 census, interviewers reported the age, color, sex, and number of slaves held by a slave-holder. The source of information, specifically whether it was based on interviews with the slaves or with the slave owners, is not noted, so we treat results based on these samples tentatively. For these samples, we computed numeracy for enslaved Mulattos and Blacks by census year and by age cohort. Literacy levels were not reported for

slaves, so we could not decompose results by literacy level. In addition to the 1850 and 1860 5% samples, we analyzed data from the 1860 complete sample which is not representative of the slave population but which has a higher count number. This dataset includes all individuals in a random selection of census reels from the Southern States.

2.2.3.2. 1850, 1860, 1870, 1880, 1910, 1920 free White, Mulatto, and Black samples

We computed numeracy for USA-born Whites, free Mulattoes, and free Blacks for the 1850 to 1920 censuses. First, we analyzed individuals aged 23-62 using the 10% random sample, and then we analyzed individuals aged 33-42 using the 40% random sample. We only computed numeracy for the 23-62 and 33-42 age cohorts since the subsample was large, making it unnecessary to compute numeracy for all age groups. Estimates were decomposed by residence (slave vs. non-slave state/territory) and literacy.

2.2.3.3. 1900 & 1910 Indian schedule samples and the 1930 5% Indian sample

Beginning in 1890, all American Indians, including those on reservations, were enumerated. However, the 1890 data were mostly lost due to a fire, so data on all American Indians were first available in 1900. In the 1900 and 1910 censuses, information on Indians on reservations and in the general population was added to an Indian Schedule (along with information on non-Indians living with Indian families on reservations). Those listed on the Indian Schedule were uniquely asked questions about tribal affiliation and blood quantum. For these analyses, we first computed numeracy for American Indians by census year, blood quantum, and literacy. We also similarly computed numeracy for Whites living on reservations with Indian families. Whites were marked as having 100% White blood. Next, we divided the Indian samples by age cohort. Owing to small numbers for older age groups we computed numeracy only by Full- or Mixed-blood when splitting the data by age cohorts.

In 1930, interviewers were asked to report if an American Indian was Full-blooded or Mixed-blooded. While some interviewers reported blood quantum, most simply categorized American Indians as either full-blooded or mixed. As such, we did not compute numeracy by blood quantum for the 1930 census. Instead, we divided the Indian samples by age cohort and we computed numeracy by Full- or Mixed-blood status and by literacy.

2.2.3.4. 1910 & 1920 12% Puerto Rican sample

The first USA-based census for Puerto Rico was conducted in 1910. We computed numeracy for USA-born Whites residing in Puerto Rico, and Puerto Rican-born individuals identified as White, Mulatto, or Black in the 1910 and 1920 censuses. The USA-born Whites would be mostly of European ancestry in origin, while Puerto Rican-born individuals were an admixed African, European, and Amerindian group.

2.2.4. Analyses

2.2.4.1. Calculation of numeracy

We limited ourselves to individuals aged 23 to 62 since these are the most stable age groups for computing age-heaping

using the Whipple Index [49]. Age heaping was computed for both males and females separately. We focus on the results for males and provide those for females in the Supplementary Material. This is because during this time period, the head of the household was more often male and because the census questions were directed to the household head.

The Whipple index, which is applied to test for age-heaping, is calculated as the sum of the number of persons who report ages ending in 5 or 0, divided by the sum of the total number of persons and then multiplied by 5. The formula is:

$$W = 5 * \frac{P25 + P30 + P35 + \cdots + P60}{P23 + P24 + \cdots + P61 + P63}, \quad (1)$$

where Px is the population of age x in completed years.

The Whipple index can be transformed into an index, called ABCC, which is an estimation of the proportion of the population that can accurately report ages, without rounding. The formula is:

$$ABCC = 1 - \frac{W - 100}{400}, \quad (2)$$

where W is the Whipple index. The ABCC value represents the fraction of the population who know their correct age. The ABCC index can be transformed into a standard-deviation-unit metric using an inverse cumulative transformation, which Reardon and Ho [50] denote as dtpac. The formula is:

$$dtpac = \Phi - 1(ABCCa) - \Phi - 1(ABCCb), \quad (3)$$

where $ABCC_a$ and $ABCC_b$ are the ABCC variables for population a and b, respectively. On the assumption of normality and equal variances, dtpac is equivalent to Cohen's d [50].

2.2.4.2. Analyses

Sampling weight (variable PERWT) was applied as recommended by the IPUMS because the person-level analysis is conducted on "flat" samples in which each observation, whether a household or individual, represents a fixed number of persons in the general US population. The analysis was performed in R, using the following packages: ipumsr, dplyr, simPop, and psych. We used the whipple () function of the simPop package.

3. Results

3.1. 21st-century results based on the ABCD sample

Table 2 presents the means and standard deviations for genetic ancestry, Fitzpatrick scale color, and*g* for Whites, Blacks, American Indians, and Puerto Ricans. Whites with less European ancestry have darker skin color and lower *g* scores. Similarly, among Blacks, those with lighter skin tones (Type I-IV) have higher *g* scores compared to those with darker skin tones (Type V and VI). Moreover, Blacks who were identified as both Black and White by their parents have higher *g*

scores than those who were not identified as such. Additionally, Blacks with higher percentages of European ancestry scored higher on cognitive tests compared to those with lower percentages. Regarding American Indians, those who were identified as White by their parents have higher *g* scores than those who were not identified as such. Furthermore, American Indians with higher percentages of European ancestry have higher cognitive test scores compared to those with lower percentages. Concerning Puerto Ricans, those classified as White have more European ancestry, lighter skin tones, and higher *g* scores compared to those classified as White and Black or Black. Puerto Ricans with higher percentages of European ancestry have higher cognitive test scores than those with lower percentages. However, surprisingly, Puerto Ricans with lighter skin tones (Type I-IV) nonetheless scored worse on cognitive tests than those with darker skin tones (Type V and VI).

Table 2. Genetic Ancestry, Color, and *g* for Whites, Blacks, American Indians, and Puerto Ricans by Identified Race, Color Category, and Ancestry Quartile.

	N	European		Amerindian		African		East Asian		Fitzpatrick Score		*g*	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
White	5803	0.98	0.05	0.00	0.03	0.01	0.03	0.01	0.02	18.22	4.96	0.23	0.90
Ancestry group													
75 to 100% European	5751	0.98	0.03	0.00	0.01	0.01	0.02	0.01	0.01	18.14	4.85	0.23	0.89
50 to < 75% European	52	0.61	0.16	0.17	0.22	0.12	0.17	0.10	0.15	25.53	8.51	-0.21	0.94
Black	2142	0.24	0.16	0.00	0.02	0.72	0.16	0.03	0.04	33.31	4.38	-0.79	0.99
Identified race													
White-Black	411	0.57	0.12	0.01	0.03	0.40	0.12	0.02	0.05	27.87	6.70	-0.33	0.99
Black	1731	0.19	0.10	0.00	0.02	0.77	0.10	0.03	0.04	34.10	3.25	-0.86	0.97
Fitzpatrick Category													
Type I-IV	295	0.46	0.22	0.00	0.02	0.50	0.21	0.03	0.05	21.62	3.56	-0.59	1.15
Type V	676	0.27	0.16	0.01	0.03	0.69	0.16	0.03	0.04	33.42	1.69	-0.72	1.00
Type VI	1171	0.18	0.10	0.00	0.02	0.78	0.10	0.03	0.03	35.37	0.13	-0.87	0.94
Ancestry group													
75 to 100% European	54	0.80	0.04	0.00	0.01	0.18	0.04	0.01	0.01	22.43	7.39	-0.27	0.93
50 to < 75% European	332	0.59	0.05	0.00	0.02	0.39	0.05	0.02	0.02	28.12	6.30	-0.31	0.98
25 to < 50% European	334	0.33	0.07	0.01	0.03	0.63	0.09	0.03	0.04	33.08	4.07	-0.73	0.94
< 25% European	1422	0.16	0.05	0.00	0.02	0.80	0.06	0.04	0.04	34.35	2.91	-0.89	0.98
American Indian	189	0.80	0.26	0.09	0.15	0.08	0.20	0.03	0.08	22.23	7.20	-0.25	1.05
Identified race													
White-Indian	152	0.91	0.13	0.05	0.08	0.02	0.03	0.03	0.09	20.09	5.68	-0.04	0.92
Indian	37	0.71	0.31	0.13	0.19	0.13	0.26	0.03	0.07	24.06	7.93	-0.44	1.14
Ancestry group													
75 to 100% European	152	0.95	0.07	0.03	0.06	0.01	0.02	0.01	0.02	18.83	4.76	0.00	0.86
50 to < 75% European	23	0.64	0.00	0.19	0.00	0.06	0.01	0.11	0.01	27.45	5.48	-0.32	1.00
< 50% European	14	0.29	0.13	0.25	0.27	0.39	0.36	0.07	0.11	32.36	4.28	-1.31	1.25
Puerto Rican	210	0.67	0.20	0.08	0.07	0.24	0.20	0.02	0.03	27.68	6.64	-0.45	0.95
Identified race													
White	125	0.79	0.11	0.08	0.07	0.12	0.07	0.01	0.02	25.12	6.47	-0.33	0.97
White-Black	13	0.59	0.11	0.04	0.02	0.35	0.12	0.02	0.03	31.39	4.32	-0.46	0.82
Black	39	0.37	0.11	0.05	0.07	0.55	0.15	0.03	0.05	31.99	5.20	-0.64	0.92
Fitzpatrick Category													
Type I-IV	94	0.77	0.16	0.07	0.06	0.15	0.14	0.01	0.01	20.73	3.41	-0.55	0.97
Type V	91	0.64	0.17	0.09	0.08	0.25	0.18	0.02	0.02	32.20	1.94	-0.36	1.00
Type VI	25	0.41	0.17	0.06	0.07	0.49	0.23	0.04	0.07	35.29	0.15	-0.43	0.67
Ancestry group													
75 to 100% European	91	0.86	0.06	0.04	0.03	0.09	0.04	0.01	0.01	23.93	6.31	-0.24	0.95
50 to < 75% European	80	0.64	0.07	0.12	0.07	0.23	0.10	0.02	0.03	28.92	5.74	-0.47	0.91
< 50% European	39	0.35	0.09	0.06	0.09	0.56	0.15	0.03	0.05	32.59	4.58	-0.84	0.93

Table 3 shows mixed-effects regression results for the models, including ancestry, SIRE, and Fitzpatrick scale color as predictors of *g*. Among Whites (Model 1), both African and Amerindian ancestry were predictors of lower*g* scores. Among Blacks (Model 2), African ancestry was associated with lower *g* scores. In this group, White SIRE, but not color, was also statistically significantly related to *g*. Among American Indians (Model 3), African ancestry was associated with lower*g* scores. Among Puerto Ricans (Model 4), both African and Amerindian ancestry were negatively associated with *g* scores, while the reverse held for color. Across all groups, we see that African ancestry tends to be related to lower *g* scores, whereas this is not the case with color when also taking into account ancestry.

Table 3. Mixed-effect Regression Results for Models Predicting *g* from Genetic Ancestry, SIRE, and Fitzpatrick Scale Color.

	SIRE: White: g ~ ancestries + color			**SIRE: Black: g ~ ancestries + color**			**SIRE: American Indian: g ~ ancestries + color**			**SIRE: Puerto Rican: g ~ ancestries + color**		
Predictors	*b*	*S.E.*	*P*	*b*	*S.E.*	*p*	*b*	*S.E.*	*p*	*b*	*S.E.*	*p*
(Intercept)	0.33	0.04	**<0.001**	-0.07	0.17	0.69	0.01	0.21	0.98	0.08	0.25	0.76
Amerindian ancestry	-1.69	0.41	**<0.001**	-1.75	0.96	0.07	-1.02	0.72	0.16	-2.85	0.98	**0.00**
African ancestry	-1.20	0.53	**0.02**	-0.95	0.21	**<0.001**	-2.18	0.66	**0.00**	-1.73	0.50	**0.00**
East Asian ancestry	0.42	0.54	0.44	0.87	0.45	0.05	-0.20	0.69	0.77	0.33	1.84	0.86
Fitzpatrick Score	0.00	0.02	0.98	0.03	0.04	0.42	-0.01	0.11	0.96	0.23	0.09	**0.02**
White SIRE				0.23	0.09	**0.02**	0.13	0.19	0.51	0.06	0.19	0.75
Random Effects												
σ^2	0.43			0.49			0.79			0.4		
τ_{00}	0.31 $_{site\_id\_l:rel\_family\_id}$			0.42 $_{site\_id\_l:rel\_family\_id}$			0.08 $_{site\_id\_l:rel\_family\_id}$			0.40 $_{site\_id\_l:rel\_family\_id}$		
	0.02 $_{site\_id\_l}$			0.05 $_{site\_id\_l}$			0.00 $_{site\_id\_l}$			0.00 $_{site\_id\_l}$		
ICC	0.43			0.49								
N	22 $_{site\_id\_l}$			22 $_{site\_id\_l}$			20 $_{site\_id\_l}$			21 $_{site\_id\_l}$		
	4756 $_{rel\_family\_id}$			1820 $_{rel\_family\_id}$			166 $_{rel\_family\_id}$			192 $_{rel\_family\_id}$		
Obs.	5803			2142			189			210		
Marginal R^2	0.005			0.06			0.116			0.206		

Notes: Beta coefficients (b) and p-values (p) from the mixed-effects models, with recruitment site and family common factors treated as random effects, are shown. The marginal R^2s of the mixed-effects model are shown at the bottom. ICC = Intraclass Correlation Coefficient. Model 1 does not include SIRE, since individuals with only White SIRE were included in the White group.

3.2. 19th and early 20th-century census-based results

3.2.1. Results for White and African Americans

Table 4 reports the results for African American slaves in 1850 and 1860. The results for the 1860 complete sample are similar to those of the 1860 representative 5% sample, so we concern ourselves with the representative 5% samples. In the 1850-1860 slave sample, the Black-Mulatto gap, expressed in Cohen's *d,* is small and ranges between -0.08 and 0.32, with no clear pattern by age. Across all ages, the gap is approximately *d* =.18. For comparison, the average difference between free Blacks and free Mulattos during the same years and in slave states is *d* =.28. So, the age-heaping gap among slaves is about 64% the size of that among free individuals. If the Black-Mulatto gap in 1860 was truly smaller than that among free individuals, one would expect the Black-Mulatto gap to decrease in 1870, seven years after the emancipation proclamation freed large numbers of slaves in the South. However, instead, the Black-Mulatto gap stays the same in slave states at *d* =.30. So, it is likely that numeracy differences in the slave samples were underestimated, probably due to the slaves not being interviewed in every case.

Table 4. Results for 1850 and 1860 Slave samples

		Mulatto		Black			M/B *d*
		N	ABCC	*N*	ABCC		
1850	All	1515	63.33	23613	56.27		0.18
1850	23-32	806	74.41	10699	68.90		0.16
1850	33-42	402	57.46	6516	52.71		0.12
1850	43-52	217	44.38	4196	42.10		0.06
1850	53-62	90	36.12	2202	32.47		0.10
1860	All	2835	64.50	30829	57.72		0.18
1860	23-32	1423	73.26	13862	69.75		0.10
1860	33-42	819	63.92	8619	53.54		0.27
1860	43-52	406	42.23	5447	45.18		-0.07
1860	53-62	187	48.81	2901	36.27		0.32
1860 Complete	All	7660	61.10	89702	54.51		0.17
1860 Complete	23-32	4085	72.71	40914	67.50		0.15
1860 Complete	33-42	2038	53.42	25194	49.97		0.09
1860 Complete	43-52	1059	41.08	15656	38.80		0.06
1860 Complete	53-62	478	38.96	7938	32.91		0.16

Note: A positive M/B d-value indicates that Mulattoes perform better.

Next, Table 2 presents the results for the 1850-1920 free samples. We see that the White-Mulatto difference tends to be

larger than the Mulatto-Black difference for all years and all regions. This is not surprising, since we would expect the difference in European ancestry, and thus ancestry-associated traits, to be less between Blacks and Mulattos than between Whites and Mulattos for the simple reason that, owing to anti-miscegenation laws, Blacks and Mulattos would more frequently mate together and thus be more similar in ancestry. For literates and illiterates aged 23-62, the across-year average of the White-Mulatto gap is $d = 0.61$ while the Mulatto-Black gap is $d = 0.27$. When we restrict the sample to literates only, the White-Mulatto gap is $d = 0.55$ while the Mulatto-Black gap is $d = 0.26$. Among 32-to- 43-year-olds, the gaps are about the same as for all age cohorts, so the results are not due to age-structure confounding. Regions with legal slavery generally display larger numeracy gaps but only between Whites and Mulattos. This pattern holds true regardless of census year or whether the sample includes illiterates. We notice that both group differences become larger during the period 1870-1880. This is likely because these censuses enumerate the newly freed slave population. With respect to the difference over time between Whites and Mulattos/Blacks, the ABCC index increased rapidly after 1880, and by 1910 and 1920 a very large portion of individuals among Mulattos and Blacks know their age, but this does not necessarily mean that Blacks and Mulattos reduced the numeracy gap with Whites because a ceiling effect masks the true numeracy score of Whites who had an ABCC of 98 by 1920.

Table 5. Results for 1850 to 1920 Free Samples.

Sample	Age	Year	Region	N	ABCC	N	ABCC	N	ABCC		W/M *d*	M/B *d*
Literate & illiterate	23-62	1850	All	4260	87.32	2347	75.84	5649	66.69		0.44	0.27
Literate & illiterate	23-62	1850	Slavery legal in 1861	2227	84.31	1338	69.97	2575	60.24		0.48	0.26
Literate & illiterate	23-62	1850	Slavery illegal (1861)	2033	90.63	1009	83.62	3074	72.10		0.34	0.39
Literate & illiterate	23-62	1860	All	411271	90.96	3019	75.60	6295	67.30		0.64	0.25
Literate & illiterate	23-62	1860	Slavery legal in 1861	134059	89.38	1561	69.67	2704	58.57		0.73	0.30
Literate & illiterate	23-62	1860	Slavery illegal (1861)	277212	91.72	1458	81.96	3591	73.87		0.47	0.27
Literate & illiterate	23-62	1870	All	487996	92.07	9837	76.54	75423	64.61		0.69	0.35
Literate & illiterate	23-62	1870	Slavery legal in 1861	151247	89.89	8154	74.26	69473	63.71		0.62	0.30
Literate & illiterate	23-62	1870	Slavery illegal (1861)	336749	93.05	1683	87.32	5950	75.13		0.34	0.46
Literate & illiterate	23-62	1880	All	678234	94.33	15946	79.75	98466	70.77		0.75	0.29
Literate & illiterate	23-62	1880	Slavery legal in 1861	218287	92.66	13089	78.71	89266	69.91		0.65	0.27
Literate & illiterate	23-62	1880	Slavery illegal (1861)	459947	95.13	2857	84.33	9200	79.09		0.65	0.20
Literate & illiterate	23-62	1910	All	1481176	97.32	39606	91.14	167590	86.36		0.58	0.25
Literate & illiterate	23-62	1910	Slavery legal in 1861	487509	96.95	32079	90.71	146038	85.62		0.55	0.26

illiterate												
Literate & illiterate	23-62	1910	Slavery illegal (1861)	993667	97.50	7527	92.82	21552	91.36		0.50	0.10
Literate & illiterate	23-62	1920	All	1794866	98.00	30702	93.15	203389	89.62		0.57	0.23
Literate & illiterate	23-62	1920	Slavery legal in 1861	578670	97.88	24279	92.52	166403	88.68		0.59	0.23
Literate & illiterate	23-62	1920	Slavery illegal (1861)	1216196	98.05	6423	95.43	36986	93.86		0.38	0.14
Literate & illiterate	33-42	1850	All	4650	85.35	2837	69.13	6601	61.81		0.55	0.20
Literate & illiterate	33-42	1850	Slavery legal in 1861	2420	83.01	1602	64.45	2844	55.60		0.58	0.23
Literate & illiterate	33-42	1850	Slavery illegal (1861)	2230	87.89	1235	75.20	3757	66.51		0.49	0.25
Literate & illiterate	33-42	1860	All	461924	89.56	3719	73.78	7382	64.23		0.62	0.27
Literate & illiterate	33-42	1860	Slavery legal in 1861	148337	88.10	1908	67.28	3222	56.45		0.73	0.29
Literate & illiterate	33-42	1860	Slavery illegal (1861)	313587	90.25	1811	80.62	4160	70.25		0.43	0.33
Literate & illiterate	33-42	1870	All	536097	90.75	10917	70.44	82302	58.05		0.79	0.33
Literate & illiterate	33-42	1870	Slavery legal in 1861	164522	88.36	9106	67.92	75492	57.04		0.73	0.29
Literate & illiterate	33-42	1870	Slavery illegal (1861)	371575	91.81	1811	81.82	6810	69.24		0.48	0.41
Literate & illiterate	33-42	1880	All	717246	92.50	17725	75.35	101619	64.05		0.75	0.33
Literate & illiterate	33-42	1880	Slavery legal in 1861	230004	91.12	14169	74.22	90463	62.91		0.70	0.32
Literate & illiterate	33-42	1880	Slavery illegal (1861)	487242	93.15	3556	79.25	11156	73.32		0.67	0.19
Literate & illiterate	33-42	1910	All	1721856	96.52	45949	90.44	194660	84.87		0.51	0.28
Literate & illiterate	33-42	1910	Slavery legal in 1861	562866	96.19	36334	89.76	165680	84.00		0.51	0.27
Literate & illiterate	33-42	1910	Slavery illegal (1861)	1158990	96.68	9615	93.00	28980	89.84		0.36	0.20
Literate & illiterate	33-42	1920	All	2059336	97.69	36800	92.55	242317	88.12		0.55	0.26
Literate & illiterate	33-42	1920	Slavery legal in 1861	679754	97.75	28333	92.30	192331	87.05		0.58	0.30
Literate & illiterate	33-42	1920	Slavery illegal (1861)	1379582	97.66	8467	93.33	49986	92.21		0.49	0.08
Literate	23-62	1850	All	3560	89.68	1477	77.78	3262	70.55		0.50	0.22
Literate	23-62	1850	Slavery legal in 1861	1578	88.56	737	70.39	1183	63.61		0.67	0.19
Literate	23-62	1850	Slavery illegal (1861)	1982	90.57	740	85.14	2079	74.49		0.27	0.38
Literate	23-62	1860	All	386311	91.28	2037	76.83	3953	69.92		0.63	0.21
Literate	23-62	1860	Slavery legal in 1861	117130	90.10	943	70.52	1357	59.78		0.75	0.29

Literate	23-62	1860	Slavery illegal (1861)	269181	91.80	1094	82.27	2596	75.21		0.47	0.24
Literate	23-62	1870	All	440261	92.56	3286	83.23	13266	68.99		0.48	0.47
Literate	23-62	1870	Slavery legal in 1861	121252	90.79	2060	79.73	10024	65.87		0.50	0.42
Literate	23-62	1870	Slavery illegal (1861)	319009	93.24	1226	88.59	3242	78.66		0.29	0.41
Literate	23-62	1880	All	627243	94.69	6721	83.53	26862	76.13		0.64	0.26
Literate	23-62	1880	Slavery legal in 1861	184762	93.30	4644	82.28	21118	74.62		0.57	0.26
Literate	23-62	1880	Slavery illegal (1861)	442481	95.27	2077	86.43	5744	81.65		0.57	0.20
Literate	23-62	1910	All	1427593	97.42	30752	92.59	110036	89.20		0.50	0.21
Literate	23-62	1910	Slavery legal in 1861	448692	97.20	23717	92.25	90775	88.64		0.49	0.21
Literate	23-62	1910	Slavery illegal (1861)	978901	97.52	7035	93.51	19261	91.80		0.45	0.12
Literate	23-62	1920	All	1751029	98.05	25256	94.11	149738	91.48		0.50	0.19
Literate	23-62	1920	Slavery legal in 1861	545099	98.02	19104	93.49	115131	90.70		0.54	0.19
Literate	23-62	1920	Slavery illegal (1861)	1205930	98.06	6152	96.03	34607	94.04		0.31	0.20
Literate	33-42	1850	All	3946	87.62	1843	71.28	3829	64.28		0.59	0.20
Literate	33-42	1850	Slavery legal in 1861	1775	87.39	954	65.38	1271	55.47		0.75	0.26
Literate	33-42	1850	Slavery illegal (1861)	2171	87.81	889	77.83	2558	68.66		0.40	0.28
Literate	33-42	1860	All	434598	89.86	2550	74.90	4672	67.21		0.60	0.23
Literate	33-42	1860	Slavery legal in 1861	129967	88.65	1194	66.37	1642	58.08		0.79	0.22
Literate	33-42	1860	Slavery illegal (1861)	304631	90.38	1356	82.41	3030	72.15		0.37	0.34
Literate	33-42	1870	All	485804	91.28	3625	78.90	14376	62.71		0.56	0.48
Literate	33-42	1870	Slavery legal in 1861	133623	89.45	2342	75.04	10793	59.12		0.57	0.45
Literate	33-42	1870	Slavery illegal (1861)	352181	91.97	1283	85.93	3583	73.51		0.33	0.45
Literate	33-42	1880	All	666691	92.83	7469	79.76	27535	68.66		0.63	0.35
Literate	33-42	1880	Slavery legal in 1861	196878	91.72	4924	78.77	20694	66.37		0.59	0.38
Literate	33-42	1880	Slavery illegal (1861)	469813	93.29	2545	81.13	6841	75.59		0.62	0.19
Literate	33-42	1910	All	1666839	96.61	37396	91.62	136797	87.28		0.45	0.24
Literate	33-42	1910	Slavery legal in 1861	523388	96.39	28252	91.10	110278	86.58		0.45	0.24
Literate	33-42	1910	Slavery illegal (1861)	1143451	96.71	9144	93.17	26519	90.19		0.35	0.20
Literate	33-42	1920	All	2010834	97.73	31124	93.26	185327	89.70		0.50	0.23
Literate	33-42	1920	Slavery legal in 1861	641757	97.85	22921	93.18	138066	88.78		0.53	0.27
Literate	33-42	1920	Slavery illegal (1861)	1369077	97.67	8203	93.39	47261	92.37		0.48	0.07

Note: Positive W/M and M/B d-values indicate that, respectively, Whites and Mulattoes perform better.

3.2.2 Results for American Indians

Results for American Indians are shown in Table 6 and Table 7. As can be seen in Table 6, among American Indians there is a linear positive relationship between the percentage of White blood and numeracy scores. Additionally, we see that non-Indian Whites living on reservations with Indian families are more numerate than the American Indian average.

Unlike with the free samples of Whites, Mulattos, and Blacks, discussed previously, the gaps are substantially reduced among the literate. However, the positive correlation between White blood and numeracy is nonetheless present in the literate groups.

Table 6. Results for American Indian Samples across all Age Cohorts.

American Indians				**% White Blood**							**Whites**	
Sample			***0%***		***>0% to 25%***		***>25% to 50%***		***>50%***			
	Age	**Year**	**N**	**ABCC**	***N***	**ABCC**	***N***	**ABCC**	***N***	**ABCC**	***N***	**ABCC**
Literate & illiterate	23-62	1900	6136	77.39	520	90.87	961	95.34	379	102.57		
Literate & illiterate	23-62	1910	6228	80.48	466	94.69	1112	96.22	1163	98.13	446	98.93
Literate	23-62	1900	1364	89.35	335	94.78	604	96.85	325	102.69		
Literate	23-62	1910	2335	90.26	299	96.99	788	97.87	1046	99.31	417	99.22

Table 7 shows the results for Mixed and Full-blooded American Indians by age group. As seen, there is substantial variability across ages. This could be due to the modest sample sizes in conjunction with ceiling effects for some of the groups. Nonetheless, the Mixed/ Full-blooded gaps were large in 1900 and 1910, with an average d =.97 in the samples with illiterates included and an average d =.82 in the samples with literates only. In contrast, the gaps in 1930 are much smaller, at d =.30 in the sample with illiterates included and d =.24 in the sample with literates only. Generally, those Indians identified as Mixed-blooded are more numerate than those identified as Full-blooded.

Table 7. Results for American Indian Samples Decomposed by Age Cohort.

			Mixed-blood		Full-Blood			M/ F *d*
Literate & illiterate	All	1900	1860	95.56	6136	77.39		0.95
Literate & illiterate	23-32	1900	805	95.96	2096	84.51		0.73
Literate & illiterate	33-42	1900	494	98.18	1713	75.53		1.40
Literate & illiterate	43-52	1900	378	94.58	1454	72.64		1.00
Literate & illiterate	53-62	1900	183	88.80	873	71.88		0.64
Literate	All	1900	1264	97.80	1364	89.35		0.77
Literate	23-32	1900	645	95.93	752	92.92		0.27
Literate	33-42	1900	316	102.85	340	84.56		NA
Literate	43-52	1900	214	100.47	195	83.33		NA
Literate	53-62	1900	89	87.08	77	90.91		-0.21
Literate & illiterate	All	1910	2741	96.77	6228	80.48		0.99
Literate & illiterate	23-32	1910	1146	96.31	2010	87.50		0.64
Literate & illiterate	33-42	1910	787	98.32	1820	80.98		1.25
Literate & illiterate	43-52	1910	477	97.75	1310	74.62		1.34
Literate & illiterate	53-62	1910	331	93.28	1088	73.76		0.86
Literate	All	1910	2133	98.45	2335	90.26		0.86
Literate	23-32	1910	992	96.90	1094	92.44		0.43
Literate	33-42	1910	639	100.16	726	92.63		NA
Literate	43-52	1910	306	99.26	338	82.47		1.50
Literate	53-62	1910	196	99.49	177	81.92		1.66
Literate & illiterate	All	1930	1144	96.14	1625	92.94		0.30
Literate & illiterate	23-32	1930	427	97.92	583	94.53		0.44
Literate & illiterate	33-42	1930	335	91.12	451	93.98		-0.20
Literate & illiterate	43-52	1930	215	96.59	329	86.84		0.71
Literate & illiterate	53-62	1930	167	101.06	262	95.27		NA
Literate	All	1930	1021	96.69	1004	94.47		0.24
Literate	23-32	1930	393	98.43	406	96.36		0.36
Literate	33-42	1930	303	92.06	314	92.75		-0.05
Literate	43-52	1930	187	98.36	182	91.89		0.74
Literate	53-62	1930	138	99.60	102	96.79		0.80

Note: A positive M/F d-value indicates that Mixed-blood Indians perform better.

3.2.2 Results for Puerto Ricans

Finally, Table 8 shows the results for the Puerto Rican samples and indicates that the Puerto Rican numeracy is very low. For comparison, the ABCC was approximately 77 in 1920 as compared to about 90 for mainland African Americans in the same year. Mainland-born Whites, who would be mostly European in ancestry, residing in Puerto Rico have a much higher ABCC-based numeracy than Puerto Ricans. Among Puerto Rican, Blacks had the highest numeracy, followed by Whites, followed by Mulattos. So, in clear contrast with the other findings, among Puerto Ricans, the European phenotype is not associated with numeracy. This holds true for both the samples with illiterates, and the literate-only samples. As seen in the Supplementary File, there is also no association between European phenotype and numeracy among Puerto Rican women.

Table 8. Results for Puerto Rican Samples.

			USA White		PR White		PR Mulatto		PR Black			PR W/M *d*	PR M/B *d*
			N	ABCC	*N*	ABCC	*N*	ABCC	*N*	ABCC			
Literate & illiterate	23-62	1910	119	98.05	17062	71.25	7063	69.01	1183	72.90		0.06	-0.11
Literate	23-62	1910	119	98.05	5460	84.84	1631	83.21	320	83.48		0.07	-0.01
Literate & illiterate	23-32	1910	45	100.90	5124	66.82	2059	64.47	333	69.77		0.06	-0.15
Literate	23-32	1910	45	100.90	1675	81.63	520	76.14	106	87.57		0.19	-0.44
Literate & illiterate	23-62	1920	74	97.63	22347	76.51	6056	76.23	1332	77.50		0.01	-0.04
Literate	23-62	1920	74	97.63	8740	86.45	1921	86.07	457	87.64		0.02	-0.07
Literate & illiterate	23-32	1920	21	98.68	6775	75.53	1814	75.94	405	79.62		-0.01	-0.12
Literate	23-32	1920	21	98.68	2508	86.24	545	84.52	156	87.07		0.08	-0.11

4. Discussion

A large amount of research indicates that ancestry covaries with cognitive outcomes in the Americas. In this article, we compared 21st-century cognitive differences in the USA to 19th-and early-20th-century differences. In particular, we examined the relation between cognitive ability and ancestry among socially-identified White, Black, American Indian, and Puerto Rican groups. We hypothesized that indices of European, in contrast to African and Amerindian, admixture will be positively related to cognitive ability in the 19th to early 20th century as it is in the 21st century. With the possible exception of early-20th-century Puerto Ricans, the findings very strongly supported our theory.

Among 21st-century Black Americans, African ancestry, relative to European, was negatively related to *g*. Regarding 19th- and early-20th-century African Americans, those classified as Mulatto had higher numeracy than those classified as Black. This was true for both slaves and freemen in 1850 and 1860 and for freemen thereafter. While the Mulatto-Black difference in age-heaping was lower in the 1850 and 1860 slave samples than in the free samples, this finding seems to be an artifact of the enumeration method. The White-Mulatto and the Mulatto-Black difference were similar in magnitude for the literate samples and the combined literate & illiterate samples. These numeracy results for African Americans are consistent with the 21st-century results.

Among 21st-century American Indians, African ancestry, relative to European, was also negatively related to *g*. Amerindian ancestry was also negatively associated with *g*, but non-statistically significantly so due to a small sample size. Regarding early 20th-century American Indians, we found that those with more European admixture tended to have higher numeracy than those with less. Differences between Mixed-Blood and Full-Blood Indians were large for both the literate & illiterate samples in 1900 and 1910, though much smaller by 1930. By 1930 the ABCC values were in the mid-90s for both groups, suggesting a ceiling effect. The finding of a linear relationship between American Indians' age-heaping and admixture is in accordance with the results of Thornton and Young-DeMarco [48], who found that American Indians had higher literacy levels in proportion to White ancestry in a model controlling for birth cohort, region, and cultural-integration.

Among 21st-century Puerto Ricans, both African and Amerindian ancestry, relative to European, were also negatively related to *g*. However, despite the negative correlation between non-European ancestry and darker color, a darker color was positively associated with *g*. Regarding early-20th-century Puerto Ricans, we did not find any association between race-associated phenotype and numeracy. These results from 1910 and 1920 are inconsistent with the two studies from the 20th century, specifically, Vincenty [15] and Green [16], which report that inhabitants of Puerto Rico rated as appearing more African have lower cognitive ability scores than those appearing more European. The lack of differences based on our analysis of census data could be due to classifications being based more on color than on ancestry. Loveman [51], for example, reports that Puerto Rican enumerators did not follow the Census Bureau's official instructions and, instead, brought their own assumptions regarding the meaning of race into classificatory decisions. If the classifications were based more on skin color than on ancestry, these Census-based results for Puerto Ricans may be consistent with the early-21st-century results.

Socially-identified race/ethnic groups, whether based on appearance or parent/self-report, need not track genetic ancestry well. This is especially the case after many generations of admixture, as in the case of Puerto Ricans. This is because self-identified ancestry and conspicuous ancestry-associated phenotype, such as skin color, can become uncorrelated with global ancestry. Due to this, modern methods using admixture regression can be used to statistically separate effects related to genetic ancestry from ones related to skin color and self-identified group as is done in the present study or in one other recent study [29].

Understanding the nature of self-reported race/ethnic-related differences in cognitive ability, and how differences are transmitted across generations**,** is necessary to reduce both these differences and their social impacts. Race/ethnicity is multifaceted and involves appearance, cultural background, self-identity, and genetic ancestry [52]. Therefore, evaluating

the independent contribution of factors related to genetic ancestry vs. factors related to socially defined race/ethnicity and color helps in identifying the source of group differences [53]. This issue is obviously also relevant to concerns about social inequality, as focusing exclusively on socially identified race/ethnicity, ignores possible race-related inequalities within socially defined groups.

Future studies on cognitive differences also need to consider genetic ancestry, since cognitive ability differences seem to be strongly related to genetic ancestry independent of socially-defined race/ethnicity and color [27][28][29][30]. Despite recognizing the importance of general cognitive ability, political factors such as the declining availability of public housing, which disproportionately affects minorities, can also account for the persistence of race and ethnic differences in economic outcomes to some extent [54]. That admixture predicts group differences in cognitive ability does not imply that it must also predict group differences in social outcomes. What remains to be seen is whether admixture predicts socio-economic outcomes within race/ethnic groups when controlling for background, cultural and political factors.

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