Mental Abilities of Children of Incross and Outcross Matings in Hawaii

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ABSTRACT

Two studies in Hawaii failed to reveal evidence of heterosis in mental abilities when the offspring of incrosses and outcrosses from various ethnic groups were compared. The first study utilized tests of educational achievement and aptitude applied to all children in grades 4 through 12 in public schools in Hawaii in the period 1967-1970. The second study used the Hawaii Family Study of Cognition cohort of 1818 Honolulu area families given fifteen paper and pencil tests of cognitive ability during 1972-1976. In both studies significant differences in test scores were evident among the ethnic groups, while the HFSC revealed confounding generational differences.

When domesticated plants or animals of different varieties or breeds are crossed it is commonly found that the progeny of outcrosses are superior to those of incrosses with respect to some useful character. Schull seems to have been the first to call this heterosis. The appropriate contrast between incross and outcross progeny depends on the definition of heterosis chosen by the investigator. Falconer (1960) considers heterosis to be the difference between the F_1 and the mid-parent values, i.e. the difference between the pooled means for the two incrosses compared with the corresponding outcross. This outcross-incross measure is the one given by dialled cross analysis and is the more usual estimate of heterosis and the one tested in this paper. An alternative definition, which is more in keeping with Schull's original concept, is given by Mather and Jinks (1971), who consider heterosis to be the amount by which the mean of an F_1 family exceeds its better parent.

The possibility of heterosis in man has been a matter of speculation for some time. Distinction must be made between pseudo-heterosis created by crossing inbred racial isolates, and true heterosis created through recombination of the gene pools of different non-inbred populations. Recent claims for heterosis which fall into the first category are represented by Strouhal's (1971) study of three ethnic groups in Nubia, and by Wolanski et al.'s (1970) study of the relationship between geographical distance between parental birthplace and biological attributes of the off-

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spring. Only one published study, that of Morton, Chung, and Mi (1967) on interracial crosses in Hawaii, has attempted to measure heterosis created by recombination. These investigators analyzed a variety of vital and medical records in Hawaii with respect to ethnicity. They concluded that hybrid progeny of the ethnic groups studied were intermediate in size, mortality and morbidity between the progeny of parental incrosses.

The possibility of heterosis for mental abilities among interethnic crosses in Hawaii was studied by Trimble (1973). Part of his data was reported (Trimble and Mi, 1973) but his data and conclusions relating to the progeny of incross and outcross matings have not, due in part to his untimely death. Trimble's data, and data from the Hawaii Family Study of Cognition relating to incross-outcross progeny comparisons for mental abilities are presented here.

Requirements and Methodology of Heterosis Detection

A test for heterosis requires a comparison of progeny from incross and outcross matings. It is therefore important to define rather carefully what an incross and outcross is in human terms, especially in a society subject to waves of immigration. Morton, Chung, and Mi (1967) have drawn attention to the diversity of the population of the State of Hawaii, and to the difficulty of assigning a "race" to many of its inhabitants. This is due not only to complex intermarriage between descendants of the original inhabitants of Hawaii and successive waves of migrants, but also to variation in degree of acculturation of successive influxes into the social structure of Hawaii. It is now more realistic to speak of "ethnic groups," with varying consistency of genotype and degrees of acculturation (Table 1). Among these are (1) Americans of Japanese ancestry (AJA) representing mainly the second- and third-generations of original migrants from Japan, now fully acculturated and constituting the largest resident group in the State of Hawaii, (2) Caucasians, constituting the second largest group, whose origins are mainly from Europe via the United States mainland and are conveniently termed Americans of European ancestry (AEA), and whose acculturation depends in large part on how long they or their families have lived in Hawaii, (3) Americans of Chinese ancestry (ACA), a numerically smaller group with characteristics analogous to the AJA group, (4) Filipinos, representing a more recent and not yet fully assimilated immigration and (5) the original Polynesian inhabitants of the islands and their descendants, comprising a group of Hawaiians and part-Hawaiians. The distinction between Hawaiians and part-Hawaiians is one of degree, and usually self-determination. At the present time an individual with any demonstrable fraction of Hawaiian ancestry is acceptable to the private school charged with the provision of education to children of Hawaiian ancestry.

Only AJA, ACA and AEA ethnic groups approximate the requirements for "pure" parental groups, comparison among whose incross and outcross progeny might reveal heterosis. Even these groups are geographically diverse in their individual origins.

Detection of heterosis in plants and animals typically involves a diallel cross comparison of the F_1 progeny of incross and outcross matings *reared*

Table 1

Ethnic Composition of State of Hawaii, Spring 1976, Source: State Department of Health Survey

	(1)* %	(2)** %
Unmixed		
Caucasian (≡ AEA)	21.5	27.8
Japanese (≡ AJA)	30.2	26.6
Hawaiian	1.5	1.3
Filipino	10.7	10.1
Chinese (≡ ACA)	4.9	4.3
Korean	1.4	1.3
Samoan	0.5	0.5
Negro	0.3	0.9
Puerto Rican	0.4	0.4
Other and unknown	1.0	1.1
TOTAL "unmixed"	72.4	74.4
Mixed		
Part-Hawaiian	18.2	16.4
Non-Hawaiian	9.4	9.2
TOTAL "mixed"	27.6	25.6

*(1) Armed forces and military dependents excluded.

**(2) All persons in Hawaii, other than visitors, those institutionalized, and those resident in Niihau.

in the same environment at the same time. This comparison assumes that the parental varieties or breeds rank consistently in each generation within the limits of normal biological variation, i.e. that breed A always is superior to breed B, which is always superior to breed C, and so on. This implicit assumption of generational ranking consistency is subject to violation in humans because human hybridization is usually preceeded by self-elected or forced migration. This means a change in environment for at least one of the parental groups, and this change may involve social and cultural acclimatization intimately associated with the trait being measured and not fully implemented for several generations. This is presently true in Hawaii for many factors of interest to human geneticists, including behavior.

It is therefore important in human studies to check for this fundamental assumption of constancy of relationship between pure lines in each generation before drawing conclusions from data restricted to one generation.

Heterosis in animals and plants is usually detected by analysis of the variance components of a diallel cross, that is, a symmetrical design in which all possible incross and outcross progeny of preferably at least four parental varieties or breeds are represented (Henderson, 1952; Hayman, 1954; Harvey, 1960). The same methodology has been used by Morton, Chung and Mi (1967) and Trimble and Mi (1973). However, in applying diallel analysis to human data, it is desirable first to perform stepwise multiple regression analysis to identify and adjust for the effects of significantly contributing biological, social, and cultural covariates.

Trimble's Study of Mental Abilities

The data for Trimble's (1973) study came from two main sources: namely, 252,504 records from the statewide minimum testing program administered to all students in all the public schools of Hawaii during the period 1967-1970, and 308,785 vital statistics records relating to children born in the State of Hawaii during 1944-1966. The latter sources have been described by Mi (1966, 1969) and by Mi and Wong (1972). Variables from the vital statistics records included in Trimble's study included age at testing, father's age and mother's age at time of tested individual's birth, parental age difference, birthweight, birthdate, gestation period in months, number of previous living sibs at time of birth of the tested individual, number of previous sibs born alive but dead at the time of testing, number of previous sibs stillborn, birth order of the tested individual, and father's occupation subsequently allocated to one of four groups defined as professional, managerial, clerical, or other.

The educational records provided the individual's age and grade at time of testing. The educational test scores were derived from performance on the Cooperative School and College Ability Tests (SCAT), measuring verbal and quantitative aptitudes as percentile scores, and on the Cooperative Sequential Tests of Educational Progress (STEP) for mathematics, reading and writing achievement, also as percentile scores. These tests were administered to children in the even-numbered grades 4 through 12 in the years 1967-1970; therefore a given child might have had either one or two records depending on the year of entry or departure from the program. The details and nature of SCAT and STEP tests may be found in the appropriate reviews in Buros (1972). There is good evidence that both tests measure many of the same mental attributes (Bailey, 1959; Fortuna, 1963), and that there is a high correlation between these tests and tests of measured intelligence (Traxler, 1956; Mayer, 1958; Goldman, 1960).

The education and birthdate files were linked by computer (Mi and Wong, 1972) on the basis of surname, given name, initials, birth month and birth year. The resultant files were subdivided into a population file and a sibling file. The sibling files included all individuals who had one or more siblings tested in the program, and this file was used for determination of phenotypic and genetic correlations and derivation of heritabilities. These results have been reported (Trimble and Mi, 1973). The population file consisted of the records of all individuals without siblings in the program, plus one sibling drawn at random from sibships with two or more tested children (Table 2). The population file was further subdivided into individuals tested once, and those tested twice. In the latter case the first- and second-test results were analyzed separately, giving three separate and relatively independent analyses and thereby providing for tests of homogeneity.

The SCAT and STEP records were expressed as percentile scores. There are a number of limitations associated with analysis of percentile scores (Allen and Yen, 1979). The distribution of individual scores is rectangular not bell-shaped, since 1% of the tested population if it complies with the reference population is at each percentile. The means and variances presented relate to the properties of percentiles, and not to the distribution of original scores.

Table 2

Number of SCAT and STEP Records in Trimble's Diallel Analysis with Respect to Parents' Ethnicity. The Numbers Include Single Records, and One Record Chosen at Random from the Two-Record File

Paternal Race	Maternal Race				
	AEA	Pt. Hawaiian	Filipino	AJA	Total
AEA	3050	821	231	710	4812
Pt. Hawaiian	366	2490	162	369	3387
Filipino	178	712	3661	335	4886
AJA	176	265	66	15360	15867
Total	3770	4288	4120	16774	28952

Results of Trimble's Analysis

Test scores in the population data subfiles were individually corrected for the effects of all covariates in the data set and their squared and first-order interaction terms by stepwise multiple regression. Significant effects of maternal age at the time of birth, number of living sibs, and birthweight were found for all five tests scores. Sex of the tested individual had a significant effect on all test scores except mathematics, month of birth affected mathematics, writing and quantitative scores, and school district affected the three achievement scores but not the two aptitude scores. A pronounced effect of father's occupation was evident for all tests. The proportions of variance explained by these covariates were r^2 = .02, .03, .07, .08, and 0.10 for the mathematics, quantitative, verbal, reading, and writing scores respectively, and the results for the three subfiles were homogeneous.

Results of the diallel analysis following removal of the effects of covariates are shown in Table 3. In this table, based on the single test subfile of the population file, the component scores (two aptitude, three achievement) of the SCAT and STEP tests are pooled, although in Trimble's (1973) analysis each score was treated separately. The three subfiles of the population file were analyzed individually. However, the results were sufficiently consistent that a separate discussion of each is not warranted. Large and significant differences among progeny of incrosses were found, with AJA having the highest mean score for all tests, followed in order by

Table 3

Least Squares Estimates of Deviations from Mean STEP and SCAT Scores for Offspring of Parents of Different Ethnic Groups after Covariate Adjustment. All Values Differ Significantly from Zero. Adapted from Table 5.6, Trimble (1973). AEA = Americans of European Ancestry; AJA = Americans of Japanese Ancestry

Father's Ethnic Group	Mother's Ethnic Group: AEA	Pt. Hawaiian	Filipino	AJA
	STEP[1] Scores			
AEA	3.3	−6.7	−4.7	6.6
Pt. Hawaiian	−3.2	−11.0	−4.8	6.5
Filipino	−5.5	−9.1	−4.2	4.2
AJA	7.3	3.7	5.7	11.8
	SCAT[2] Scores			
AEA	3.9	−6.4	−6.6	6.3
Pt. Hawaiian	−4.8	−8.8	−5.8	7.0
Filipino	−7.6	−8.5	−2.6	4.3
AJA	5.9	5.0	4.9	13.8

[1]Mean for mathematics, reading and writing scores.
[2]Mean for verbal and quantitative scores.

the AEA, Filipinos, and part-Hawaiians. Significant differences between progeny from incross and outcross matings were also consistently detected. Although not apparent from Table 3, the differences between progeny from incross and outcross matings were consistent for all three subfiles of the population file for the mathematics test, in most analyses for the verbal and quantitative aptitude scores, and inconsistent for the reading and writing scores.

The general pattern of the results can be appreciated from examination of the STEP scores for AEA and AJA incrosses and intercrosses in Table 3. The AEA incross progeny score 3.3 percentage points above the population mean, AJA incross progeny score 11.8 points, and the two classes of intercross progeny score 6.6 and 7.3, that is slightly below the unweighted mean for the incross progeny. Similar results are seen for the SCAT scores.

Least square estimates of the mean difference between progeny from incross and outcross matings were all significant and in favor of the incrosses, and were 2.5, 1.3, 1.2, 2.0, and 2.0 percentile points for the mathematics, reading, writing, verbal, and quantitative scores respectively. As pointed out earlier, percentiles provide analytical problems, especially in analysis of variance and these results must be interpreted with caution. However, the main finding is that there is no significant evidence of outcrosses exceeding the means of incrosses, and therefore no evidence of heterosis in Trimble's rather large data set.

As discussed earlier information from more than one generation is necessary to verify the assumption that the scores obtained by parents and offspring of incrosses of different ethnic groups rank similarly in both generations. It was possible to test this assumption by considering data from the Hawaii Family Study of Cognition (HFSC). Trimble's study covered school children in grades 4 through 12 in Hawaii's statewide public school system in the years 1967-1970, that is, children born in the period 1950-1961. The offspring in the HFSC were tested in the period 1972-1976 and ranged predominantly from 13-22 years of age i.e. born in the period 1950-1963. The offspring tested in the HFSC were therefore mainly a small subset of the children tested by Trimble.

Hawaii Family Study of Cognition (HFSC)

Aspects of the HFSC have been described elsewhere (DeFries et al. 1974; Wilson et al. 1975; Ashton et al. 1979). In summary 1818 families, resident in the environs of Honolulu in the period 1972-1976, which met the joint criteria that neither parent should be older than 60 years and that children presented for testing should be 13 years of age or older, were canvassed and paid to participate in the study. Subjects were given 15 tests of cognitive ability administered in group testing sessions and asked to complete a questionnaire relating to their educational, social, cultural and biological backgrounds.

The families participating in the HFSC were of various ethnic backgrounds reflecting the multiethnic composition of the State of Hawaii, but were not representative of this composition. In particular, families of Caucasian ancestry were over-represented with a corresponding under-representation of families of Oriental ancestry. For purposes of checking Trimble's results, the families were classified as follows:

(1) 330 families with both parents stating their ancestry as Japanese. These families were grouped as Americans of Japanese ancestry (AJA).
(2) 83 families similarly grouped as Americans of Chinese ancestry (ACA).
(3) 837 families with both parents of European ancestry (AEA).
(4) 64 families with one parent either AJA, ACA, or AEA and the other of different ethnicity but also AJA, ACA, or AEA. Offspring in these families were classified as outcrosses.

The remaining 504 families were not included in the analysis, either because the parents did not fit the category of marriages selected, or because of detected or disclosed non-nuclear family relationships (Ashton, 1980). The main aim was to provide an optimal test of generation differences by comparing ethnically definable groups. Grouping families in the manner described permitted comparison of the three major "pure" ethnic groups (AJA, ACA, and AEA) with their outcrosses (AJA × ACA, AJA × AEA, and ACA × AEA). This leaves out mixed marriages involving other ethnic groups, and marriages of Korean and Filipino ancestry because there were only 4 Korean × Korean, and no Filipino × Filipino marriages to use as incross controls. However, the major omission is marriages involving individuals one or both of whom claimed part-Hawaiian ancestry. Constructing the proper parental incross contrast groups for these complex marriages was not feasible in the present study.

Cognitive Tests Administered

The fifteen cognitive tests administered included (1) four tests primarily loading on a verbal ability factor (VOC = Vocabulary, TH = Things round and metal, WBE = Word beginning and endings, and SPV = Social perception, verbal). (2) six tests primarily loading on a spatial ability factor (MR = Mental rotations, CR = Card rotations, HP = Hidden patterns, LAD = Lines and dots, PFB = Paper form board, PM = Progressive matrices). (3) two tests primarily loading on a perceptual speed factor (SAM = Subtraction and multiplication, NC = Number comparisons). (4) two tests primarily loading on a memory factor (VMI = Visual memory-instant recall and VMD = Visual memory-delayed recall). (5) one test (PED = Pedigrees) loading on the verbal, spatial and percentual speed factors.

Details of the tests and relevant references are given in Wilson et al. (1975), and Ashton et al. (1979), and an analysis of the similarity of factor structuring for the AJA and AEA ethnic groups may be found in DeFries et al. (1974). For the present analysis, however, it was considered preferable to utilize the original test scores for the 15 cognitive tests rather than the four factor scores which have been derived from transformed composite scores, with possible problems of unknown interactions between ethnicity, generation and sex hidden in the factor derivations.

Data Adjustment

Table 4 shows mean midparent and offspring values with respect to ethnicity for a number of variables collected in the study. For parents and offspring these included age, years of formal education completed at the time of testing, size of the individual's sibship, the tested individual's birth order, and the number of books and magazines read in a month (on a scaled response coded 1-10). Father's current occupation was rated on the National Opinion Research Council's (NORC) scale (Reiss, 1961). There were significant differences for each of these variables, and this indicates

Table 4

Mean Values for Biological and Cultural Parameters Associated with Mid-Parent (Mean Values for Father and Mother) and Offspring with Respect to Ethnicity. The Lines Join Subsets of Ethnic Groups Whose Means Do Not Differ at a Probability of 0.01 as Determined by Duncan's Multiple Range Test. In Parentheses, Ethnicity of Parents: AEA, N = 1353; ACA, N = 158; AEA, N = 2379; OUT = Outcross, N = 106

	Mid-Parent Characteristics			
Age (yrs.)	43.2 (AEA)	45.6 (AJA)	46.6 (OUT)	47.5 (ACA)
Education (yrs.)	14.1 (AJA)	14.7 (ACA)	14.7 (OUT)	14.8 (AEA)
NORC[1]	72.4 (AJA)	72.6 (AEA)	74.0 (OUT)	75.5 (ACA)
Books/magazines	6.5 (AJA)	6.6 (ACA)	7.9 (OUT)	8.4 (AEA)
Sibship size	3.4 (AEA)	5.1 (OUT)	5.7 (AJA)	6.4 (ACA)
Birth order	2.2 (AEA)	3.1 (OUT)	3.3 (AJA)	3.7 (ACA)
	Offspring Characteristics			
Age (yrs.)	16.7 (AEA)	16.9 (OUT)	17.0 (AJA)	17.5 (ACA)
Education (yrs.)	10.0 (AEA)	10.2 (OUT)	10.5 (AJA)	10.7 (ACA)
Books/magazines	2.6 (ACA)	2.7 (AJA)	2.9 (AEA)	3.0 (OUT)
Sibship size	3.2 (AJA)	3.3 (OUT)	3.6 (AEA)	4.0 (ACA)
Birth order	1.9 (AJA)	1.9 (OUT)	2.1 (AEA)	2.4 (ACA)

[1]National Opinion Research Council rating.

considerable heterogeneity in the HFSC population. Each variable was found to have a significant effect on some or all scores.

In order to assess the constancy of relationship of ethnic scores between generations the statistic "generation difference" was computed by subtracting offspring score from the mean of the parent scores. The "generation difference" scores were then adjusted by stepwise multiple regression analysis for the effects of the variables listed in Table 4, their squared terms, and first order interactions. The resulting corrected "generation difference" scores for each cognitive test were subjected to one-way analysis of variance and the significance of differences between ethnic means tested by Duncan's multiple range test.

Table 5 shows the corrected "generation difference" scores. There is a consistent pattern in the AJA ethnic class in which children are superior in test performance compared with their parents. The offspring of AEA parents on the other hand are inferior in adjusted test score compared to their parents. This is due to AJA offspring scoring higher in all tests than AEA offspring, consistent with Trimble's findings (Table 3), but with AEA parents scoring higher than AJA parents. ACA families show a mixed pattern of "generation differences", with offspring and parents differing little on average. Table 5 also shows that the largest "generation difference" scores are given by outcross matings, reflecting the fact that outcross progeny had corrected scores which were consistently higher than those for progeny from the three incross matings. The means for each of the three outcrosses (AEA × AJA, AEA × ACA, and AJA × ACA) did not differ significantly within any of the 15 tests, and so the three outcross groups were pooled to give one outcross group for ease of presentation. From Table 5 it may be seen that for 8 of the 15 tests (WBE, SPV, MR, CR, LAD, PM, VMI, and VMD) the adjusted "generation differences" for outcrosses do not differ significantly from those for the three incrosses. For 5 tests (VOC, TH, PFB, SAM, and PED), two of the three incrosses, AJA and ACA, do not differ from the outcross. For the remaining two tests, HP and NC, the incross adjusted "generation difference" differs significantly from that for AEA and ACA, but not from that for AJA. Therefore, 8 of the 15 tests provide no evidence for "generation differences". The remaining 7 do and this seems to be due mainly to Caucasian parents and their progeny not scoring in the same rank order in both generations.

A formal test for heterosis is valid for the 8 cognitive tests which did not show significant generation differences. None of the outcross scores

Table 5

Mean Adjusted Generation Differences for Incross and Outcross Matings

Cognitive Test	Code	Incross Matings			Outcross Matings	Significance of Outcross Compared with Incrosses[1]
		AJA	ACA	AEA		
Vocabulary	VOC	−1.24	.31	.63	−2.10	AEA
Things round & metal	TH	−2.39	−.67	1.42	−2.92	AEA
Word beginnings & endings	WBE	−.54	−.30	.47	−.91	—
Social perception, verbal	SPV	−.49	−.57	.38	−.46	—
Mental rotations	MR	−1.90	−.29	.63	−.07	—
Card rotations	CR	−5.04	−4.18	3.36	−5.64	—
Hidden patterns	HP	−1.02	1.32	1.83	−6.97	AEA,ACA
Lines and dots	LAD	−.08	−.48	.10	−.61	—
Paper form board	PFB	−.31	−.76	.34	−.84	AEA
Progressive matrices	PM	−.53	−.70	.48	−.63	—
Subtraction & multiplication	SAM	−2.44	.97	1.61	−4.15	AEA
Number comparisons	NC	−.31	1.13	.52	−2.89	AEA,ACA
Visual memory, immediate	VMI	−.18	.13	.14	−.20	—
Visual memory, delayed	VMD	−.32	.18	.06	.00	—
Pedigrees	PED	−.28	.06	.56	−2.00	AEA

[1]Computed at P = .01 using Duncan's multiple range test. Ethnic group(s) listed differ significantly from outcrosses, and from incrosses not listed.

differed significantly from the mean of the three incross scores. Given the significant generation reversals for the other 7 cognitive tests a formal test for heterosis is not valid for these.

Discussion

The main difference between Trimble's study and the HFSC lies in the relative ranking of offspring scores. In both studies AJA children or offspring scored higher than AEA children or offspring. However, in Trimble's study, AJA × AEA outcross children were intermediate in score, while in the HFSC outcross offspring generally exceeded the AJA offspring scores. The reasons for this difference are not known. It seems most likely that the manner in which families were solicited for the HFSC may have been the cause. In Trimble's study there were 25,226 children of whom 3,050 were AEA, 15,360 were AJA and 886 were AJA × AEA outcross children. In the HFSC study with 2,950 offspring, there were 1,353 AEA, 486 AJA, 158 ACA and 106 outcross offspring. The two samples are therefore very different in both numbers and ethnic composition, and there must be biases of unknown origin influencing sample selection in both studies. It should be noted that Trimble's study approached complete ascertainment of the public school population, and that the ratio of AJA to AEA children differs significantly from the ethnic composition of the State of Hawaii (Table 1). This is due to the tendency for AEA children to attend private rather than public schools when academically qualified.

It may be concluded that Trimble's study provides no evidence for heterosis for mental abilities in the tested population, that the HFSC in general provides no evidence to invalidate Trimble's study, and that for those cognitive tests in which a significant generation difference does not invalidate the analysis the HFSC data provide no evidence of heterosis either.

Both Trimble's study and the HFSC underscore problems associated with design of investigations seeking evidence of heterosis in humans. A large number of representative nuclear families from incross and outcross matings from defined ethnic groups obviously is required, together with full measurement of all contributing covariates. If heterosis exists it will be most evident in the F_1 generation of outcrosses, but this is also the generation most likely to be in cultural disequilibrium. This paradox may preclude unambiguous detection of heterosis in humans.

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