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Genetic and Environmental Determinants of Musical Ability in Twins

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Analyses of musical ability data from the Loehlin and Nichols National Merit Scholarship study are presented. Musical ability is indexed by four measures: interest in a profession in music, performance in school, performance outside of school, and receiving honors in music. These variables pose a challenge for behavior genetic analysis since they do not conform to the assumptions of traditional linear models. For example, there is a dependent relationship between the honors and the performance variables; one cannot obtain honors without performance. Several methods were employed to deal with these relationships, and the following conclusions appeared regardless of the method used. First, twin correlations were always high, ranging from 0.44 to 0.90 in monozygotic (MZ) twins and from 0.34 to 0.83 in dizygotic (DZ) twins. Second, although there was evidence for heritable variation, the effects of common environment were almost always larger than the effects of heredity. Third, marital assortment was not of sufficient magnitude to account for these common environment effects. In the young adults in this sample, musical ability is influenced more by shared family environment than by shared genes.

KEY WORDS: musical ability; genetics; family; heritability; genotype–environment interaction.

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INTRODUCTION

"Every child is born with the capacity for becoming richly musical so long as he or she is brought up properly . . . there is no inborn talent for music ability." So states Shinichi Suzuki (see Herman, 1981, p. 136), founder of the famous Suzuki method for teaching music to young children. C. E. Seashore, developer of a widely used test of musical ability, would strongly disagree: "Not only is the gift of music itself inborn, but it is inborn in specific types" (1919, p. 6). Musicologists, psychologists, and behavior geneticists have engaged in this debate since Francis Galton's *Hereditary Genius* fired the opening salvo by including 120 "eminent" musicians in his study. Galton found that 26 of the 120 (22%) had "eminent" kinsmen (however, these included 9 members of the same Bach family). Galton interpreted these data as indicating the importance of heredity in determining musical ability.

Galton's view was held almost without opposition until the 1920s. Family studies by Feis (1910; see Shuter, 1968), Seashore (1919), Stanton (1922), Mjoen (1926), Reser (1935), and Scheinfeld (1956) all purported to show the importance of heredity, but their evidence was weak. Like Galton, these researchers used pedigree data from musically talented families, interpreting the relatively high correlations found between close relatives as the result of heredity alone without considering the probable environmental effects of living in a rich musical environment. Similarly, studies by Fry (1948), Kalmus (1949), and Ashman (1952) show that a lack of musical ability (or "tune deafness") also clusters in families; however, environmental influences are again largely ignored.

Research supporting the position that musical talent is environmentally acquired also lacked rigor. Musell (1937), Lundin (1953), and Revesz (1954) all presented their cases mainly by showing the weaknesses in the arguments for heredity; they present no original data to support their own hypotheses. Neu (1947), in a critical review of the literature on "absolute pitch," emphasizes evidence for improvement with training. However, he does not acknowledge the possibility of differential responses to training due to genetic differences.

There are few twin studies involving musical abilities, and our literature search uncovered no relevant adoption data. Simons (1964) studied 12 infant twin pairs but made no attempt to determine zygosity. Vandenberg (1962) analyzed data on 33 monozygotic (MZ) and 43 dizygotic (DZ) twin pairs from the Michigan Twin Study, using both Seashore's and Wing's music test batteries. Heritability was low for both the Seashore and the Wing tests that involve pitch recognition. However, the Seashore Loudness and Rhythm measures and the Wing Memory scale gave evidence for genetic effects, with estimates of heritability of about .40 to .50. Shuter (1968) replicated these results with 28 monozygotic and 33 dizygotic twin pairs of children, plus 11 adult twin pairs. She tested the twins on the same two test batteries and obtained similar results. Stafford (1965) found significant heritabilities for both pitch recognition and rhythm.

From a survey of the behavior genetic research on musical ability, Fuller and Thompson (1978) conclude that "musical talent in general is a highly complex character depending on both genetic and environmental support" (p. 262). It seems that the central question of this debate has now shifted from whether musical ability is inherited to a more sophisticated question: To what degree are various types of musical ability influenced by genetic and environmental variation? Here we try to answer this question using a large set of twins and a wide variety of items pertaining to interest and ability in music.

METHODS

The twin sample used in this study is the National Merit Twin Sample (Loehlin and Nichols, 1976). From the appendix to Loehlin and Nichols (1976), one of us (H.C.) extracted all items relating to musical interests or ability. Twenty-six items from the twin questionnaire and one item from the parental questionnaire were selected. A previous analysis of these data was based on a rational scaling of the items into three groups reflecting interests, performance, and honors (Coon and Carey, 1987). Here, we use principal-components analysis to reduce the number of variates in a more objective manner. Separate analyses were performed for male and female twins, and each member of a twin pair was treated as a statistically independent individual. We accepted a four-component solution because the components were of substantive interest and replicated fairly well across the genders. Although there were six eigenvalues greater than 1.0 for males and seven for females, the vectors associated with the lower eigenvalues had loadings on only one or two items and did not replicate across the genders. Because of a positive manifold in the item correlation matrix, the components were rotated to an oblique solution using the Promax method. The four variables used here are the component scores from this analysis, computed using the formula $F_j = \sum (f_{ij})(z_i)$, where F_j indicates the jth factor score, f_{ij} is the factor score coefficient for the ith variable, and z_i is the standardized value of the ith variable. Because gender differences were found for several of the items, and because our interest was in constructive replication across genders, not gender differences per se, component scores were calculated separately for males and females. Table AI (Appendix) presents the items selected for analysis, the component pattern matrices for males and females, and the correlations between components.

For both males and females, the first component clearly denotes career interests. It is simply called Interests here. The third component also agrees well between males and females. Its loadings are largely on items related to singing and it is called Vocal Performance. The second and the fourth components reflect different aspects of instrumental performance. The second component seemed to denote performance such as playing in a high-school band or orchestra. The fourth component loads on items such as composing or playing for wages and might reflect a more advanced level of performance or, possibly, performance in a rock or jazz band. These two are called, respectively, School and Nonschool Performance. In order to index a high level of performance, we also rationally constructed a binary variable called Honors by considering any honor won as indicating the presence of a high level of performance.

The twin analysis of self-reported music variables is complicated by the possibility of genotype–environment (GE) interaction. That is, genotypic values that increase the probability of winning honors for musical ability will do so only if there has been some training in music and some performance in music. To account for this possible GE interaction, we used the approach of Heath, Eaves, and Martin (Heath, personal communication) by conditioning twin pairs for concordance on a relevant environmental variable.

For the purposes of this data analysis, we adopted a linear model that permitted both a univariate analysis and the analysis of GE interaction. Let Y and X denote the scores for members of a twin pair and let R denote the correlation between genotypes for the pair; thus, $R = 1.0$ for MZ pairs and $R = .5$ for DZ pairs. Let M denote a moderating variable coded 0 for its absence in both twins and 1 for its presence. M may denote an environmental variable with which genotype might interact, but for explanation of the model, we let M denote gender, coded 0 for females and 1 for males. The model states that

$$Y = \beta_1 R + \beta_2 M + \beta_3 RM + \beta_4 X + \beta_5 RX + \beta_6 MX + \beta_7 RMX + U + \propto,$$

where U denotes a residual and $\propto$ an intercept. Writing the equation this way permits least-squares estimates of the β's using standard linear regression methods. The first three β's and the intercept define the expectations of Y for the four possible zygosity-by-gender groups. The proportions of variance due to shared environment and to genes in females (i.e., when the moderating variable is absent) are given by the terms β_4 and β_5, respectively. The quantity ($\beta_4 + \beta_6$) equals the common environment effect for males, and ($\beta_5 + \beta_7$) is heritability for males (i.e., when the moderating variable is present). β_6 tests whether the common environment effect is the same in men and women, and β_7 tests for differential heritability between the sexes. With this moderating variable, the model is equivalent to the extended model given by LaBuda *et al.* (1986, Eq. 11).

We used a double entry procedure for twin pairs and considered an effect statistically significant by a test of significance for the relevant β weight. Tetrachoric correlations were used in the analysis of the dichotomized Honors variable, with parameter estimates and statistical tests based on the log likelihood of predicted and observed cell frequencies.

To investigate the potential effect of marital assortment on our conclusions about heritability and common environment, we also analyzed the items from the Colorado Adoption Project (Plomin and DeFries, 1983) that related to interest, performance, and training in music. A component analysis of these items was done in order to reduce the dimensions of the problem. Adoptive and control parents were pooled, although analysis was done separately for males and females. Four components were selected and obliquely rotated. The first two components had very similar loadings for the items relating to self-rated musical ability and performance. They differed, however, on the type of musical training. The first component reflected formal instruction in music; the second was characterized by self-instruction. The third component was marked by interests in music. The fourth was a singleton component marked by an item relating to perfect pitch.

RESULTS

Table I presents the twin correlations and estimates of heritability (h^2) and percentage of variability explained by common environment (c^2). With the exception of Interests and Nonschool Performance in males, the twin correlations for these music variables are high, approaching the magnitude of twin resemblance for cognitive abilities. All estimates of heritability are positive, although they do not reach significance for Interests. Gender differences in h^2 are evident for Vocal Performance and Honors. For both of these variables, genetic effects are stronger for males than for females.

Some common environment effects are present for all five music variables. Except for the Interest variable, there are significant gender differences for common environment, with females uniformly more

Table I. Intraclass Correlations, Heritability, Common Environmentality, and Gender Differences in Muscial Interests and Performance

	Males				Females			
	Correlation				Correlation			
Variable	MZ	DZ	h^2	c^2	MZ	DZ	h^2	c^2
Interest[b,*]	.44	.34	.21	.23	.48	.39	.17	.30
School Performance[abd]	.88	.73	.30	.59	.90	.83	.14	.76
Vocal Performance[acd]	.80	.44	.71	.08	.79	.69	.20	.59
Nonschool Performance[abd]	.56	.37	.38	.18	.73	.68	.10	.63
Honors[abcd]	.90	.71	.38	.52	.90	.80	.20	.70

* (a) significant overall effect of h^2 ($p < .05$); (b) significant overall effect of c^2 ($p < .05$); (c) h^2 for male significantly different from h^2 for female ($p < .05$); (d) c^2 for male significantly different from c^2 for female ($p < .05$).

strongly influenced by shared environment than males. A comparison of estimated h^2 with c^2 suggests that shared environment may be more important than shared genes in promoting twin similarity. This holds for all five variables for females and for three variables in males. Because of the significant gender differences in these data, all subsequent analyses were done separately for males and females. Note that the calculation of component scores separately by gender necessarily results in small differences in measurement between males and females. For this reason, genetic interpretation of gender differences may be slightly confounded.

Do environmental training and performing experience interact with genotype to change this general picture? Table II gives the tetrachoric correlations for Interest and Honors in those twin pairs in which both members performed (i.e., endorsed at least one item pertaining to musical performance). Although the sample size is reduced (98 MZ and 70 DZ

Table II. Intraclass Correlations, Heritability, and Common Environmentality in Twin Pairs Who Perform

	Males				Females			
	Correlation				Correlation			
Variable	MZ	DZ	h^2	c^2	MZ	DZ	h^2	c^2
Interest	.71	.63	.16	.55*	.62	.47	.30*	.32*
Honors	.88	.80	.16	.72*	.89	.78	.22*	.67*

* Significantly different from 0 ($p < .05$).

Table III. Heritability, Common Environmentality, and Effects of Private Lessons Versus No Private Lessons on Muscial Interest and Performance

	Males				Females			
	Lessons		No lessons		Lessons		No lessons	
Variable	h^2	c^2	h^2	c^2	h^2	c^2	h^2	c^2
Interest[ce,*]	.63	−.07	−.04	.35	.07	.36	.34	.19
School Performance[abd]	.28	.57	.56	.25	.24	.50	.32	.52
Vocal Performance[abd]	.57	.21	.84	−.07	.14	.63	.36	.43
Nonschool Performance[abcefgh]	−.21	.73	1.16	−.61	.16	.57	1.04	−.32
Honors[bcde]	.16	.66	.43	.51	.22	.67	.29	.64

* (a) Significant overall effect of h^2 for males ($p < .05$); (b) significant overall effect of h^2 for females ($p < .05$); (c) significant overall effect of c^2 for males ($p < .05$); (d) significant overall effect of c^2 for females ($p < .05$); (e) h^2 for lessons significantly different from h^2 for no lessons in males ($p < .05$); (f) h^2 for lessons significantly different from h^2 for no lessons in females ($p < .05$); (g) c^2 for lessons significantly different from c^2 for no lessons in males ($p < .05$); (h) c^2 for lessons significantly different from c^2 for no lessons in females ($p < .05$).

males, 193 MZ and 132 DZ females), there is little change in the estimates of h^2 and c^2 from those given in Table I. The hypothesis that environmental training in music might permit the expression of genotypic effects was not supported here.

A slightly different picture emerges, however, when twins who have taken private music lessons are compared with those who did not take lessons (Table III). There was near-perfect concordance for taking private lessons in MZ and DZ males and females; tetrachoric correlations were uniformly above .90 regardless of gender or zygosity. Consequently, sample sizes did not allow the inclusion of a third group of twins discordant for private lessons.

Table III gives estimates of h^2 and c^2 for males and females in the Lessons and No-Lessons groups of twins. A comparison of h^2 between pairs who took lessons and those who did not shows that h^2 is higher for the latter type of twin pair in 9 of the 10 comparisons in Table III. The exception is the Interests factor in males. In contrast to this result, a comparison of c^2 shows that in 8 of the 10 comparisons, it is higher in twin pairs where both took lessons than in the no-lessons pairs. This difference is most striking for the Nonschool Performance factor. For twins who had private instruction, individual differences in this factor are almost entirely due to shared environment. Just the opposite happens for those pairs where neither have had private lessons; in fact, the difference between MZ and DZ correlations is so great that estimates of c^2 are less than .0 and estimates of h^2 exceed unity.

Finally, marital correlations for the parents in the Colorado Adoption Project (CAP) ranged from highs of .22 for ability with formal training and .14 for ability when self-taught to .04 for interest and .02 for perfect pitch. These results suggest significant but not strong marital assortment, comparable to findings reported by Shuter (1968), who found a marital correlation of .33 for musical ability in a sample of 63 spouses. The effect of assortment will increase the correlation between the genotypic values of siblings by $\frac{1}{2}mh^2$, where m is the marital correlation. The CAP data suggest that marital assortment is not large enough to alter substantially the estimates of heritability and common environment presented above.

DISCUSSION

In the National Merit twin data, Loehlin and Nichols (1976, p. 86) note that twin correlations for measures of general cognitive ability are generally about .85 and .65 for MZ and DZ pairs, respectively. Several music variables have correlations of similar magnitude, suggesting that aspects of musical ability have a strong familial component. This finding is consistent with several earlier family studies that report familial resemblance for musical ability (for reviews see Shuter, 1968; see Simons, 1986). Of course, not all of our music variables show this pattern. Twin similarity was consistently greater for the Performance factors and for Honors than for the Interests measure, suggesting that shared family influences have less effect on interest in a music profession than on actual participation and skill in music.

Gender differences were important, especially for Vocal Performance, where heritability was much higher in males than in females. Here, the difference between the genders may be due to negative peer attitudes toward some aspects of vocal performance in the age group of this sample (high school). Perhaps participation in activities such as singing in a school group, being in a church choir, and taking voice lessons may be stereotypically considered as a feminine skill in this age cohort. Thus, males might have to possess more interest and ability than females to engage in these activities.

The twin analysis suggests an important role for shared family environment in musical ability, probably a stronger role than many behavior geneticists would hypothesize a priori. We had suspected that musical ability, especially when indexed by winning honors for performance, would represent ability in a highly structured, abstract language and therefore show heritable effects similar to intellectual ability. While genes are not unimportant, they often play a role secondary to family environment. This was particularly true among twins who took private lessons. Indeed, is musical ability that elusive variable for behavior genetics—a domain of substantive, psychological interest where rearing environment is consistently more important than genetics?

There is one good theoretical reason to suspect that it is. Relevant environmental training for cognitive skills such as verbal and quantitative ability may operate as more of an environmental "constant" than does training for music. All twins in this sample were exposed to Pythagorus and Shakespeare. They were not all forced to play Mozart. Because heritability is a function of environmental variability, individual differences for a phenotype where everyone receives relatively equal training will be more heritable than for a phenotype where there is a great deal of variability in training. Thus, the relevant research problem might be to isolate those factors that contribute to musical training.

The differences between pairs who did and pairs who did not take private lessons suggest that parental influence might be one critical factor in training. There was almost-perfect concordance for taking private lessons in both identicals and fraternals. When parents send one twin off to a private music teacher, the cotwin goes as well—probably to the same teacher and possibly irrespective of the cotwin's initial interest in music lessons. Parental encouragement might also affect the twins' joint participation in such activities as school music groups. In this sense, the individual differences for the School Performance factor might reflect differences in the quality and length of instruction initiated by parental intervention.

On the other hand, when training is left up to a child, the influence of genotype becomes more important. Among pairs who did not take private lessons, individual differences might reflect sufficient interest and ability in music to elect to receive training in school or to become a self-taught musician. A test of this hypothesis requires a measure of the extent to which initial training in music was parentally mediated or self-imposed and measures of the quality and length of instruction. Unfortunately, these kinds of data were not available in this sample.

These results must be tempered by a few unavoidable drawbacks in our analyses. The data consist of questionnaire responses, not direct measures of musical ability. In addition, a relatively low level of musical ability is tapped due to the young age of our sample. It is possible that genetic variation begins to play a more important role as musical ability matures. As Vandenberg suggests, "it may be that only the exceptional talent of great composers and musicians has an hereditary factor" (1962, p. 233). A more accurate, objective measure of a mature level of musical ability is needed to explore this hypothesis further. However, the present analysis suggests that musical ability is a cognitive and motoric skill where familial effects, especially familial environmental effects, are quite important.

APPENDIX

Table AI. Items from the National Merit Twin Questionnaire Used for this Analysis and the Rotated Component Pattern Matrices for Males and Females

Item	Booklet No.	Component pattern matrix							
		Males				Females			
Interest in becoming conductor	864	.85	−.04	.00	−.05	.81	.00	−.05	.02
Interest in becoming musician	874	.68	.19	−.02	.05	.77	.07	.05	−.03
Interest in becoming arranger	914	.67	.10	.06	.12	.83	.02	.03	−.02
Interest in becoming singer	944	.74	−.11	.15	−.14	.74	−.10	.17	−.04
Interest in becoming composer	954	.86	.05	−.05	.02	.89	−.03	−.06	−.06
Instrument(s) in the home	578	.06	.54	−.03	−.12	.06	.66	.06	−.17
Played an instrument	1029	.00	.83	−.06	.05	.08	.65	−.13	.22
Took private lessons	191	−.02	.76	.18	.28	−.11	.85	.16	−.26
Practiced an instrument	133	.06	.77	−.04	.13	.07	.69	.06	.18
Played in a school group	1028	.03	.77	−.06	.11	.08	.45	−.15	.42
Played in marching band	307	−.06	.73	−.10	.17	−.08	.41	−.25	.51
Accompanied on the piano	84	−.02	.52	.10	.25	.06	.56	.23	.11
Attended orchestra concert	148	.05	.55	.11	−.12	.23	.18	.07	.18
Played in orchestra	300	.10	.62	−.19	.15	.13	.23	−.28	.51
Sang in a church choir	105	−.04	.20	.62	.04	−.05	.16	.49	.12
Sang in a school choir	106	.03	.01	.73	.05	.00	.03	.68	.13
Sang in a small group	107	.06	.09	.72	.09	.09	.11	.67	.14
Took voice lessons	137	.23	−.16	.37	.13	.09	.04	.43	−.00
Gave a public recital	79	.10	.17	.25	.17	.02	.10	.37	.32
Played in a dance/jazz band	205	.04	.35	−.07	.58	−.11	−.04	.05	.69
Played music for wages	1030	.10	.06	−.05	.73	−.11	−.12	.06	.71
Played in pro orchestra	1027	−.07	−.05	.03	.75	.01	−.14	.06	.60
Composed performed piece	1026	.04	−.21	.21	.68	.01	−.14	.12	.34
Honors (national contest)	1032	−.11	−.05	.10	.65	.03	.02	.06	.22
Honors (regional contest)	1033	−.07	.43	.20	.20	.06	.14	.17	.50
Honors (city contest)	1034	−.06	.44	.15	.00	−.01	−.02	.28	.58
Honors (school contest)	1035	−.09	.23	.24	.22	−.01	−.14	.34	.57

Correlations between components

	Interest	School Performance	Vocal Performance	Nonschool Performance
		Males		
Interest	1.00	.37	.43	.15
School Performance		1.00	.30	.19
Vocal Performance			1.00	.07
Nonschool Performance				1.00
		Females		
Interest	1.00	.38	.28	.11
School Performance		1.00	.29	.05
Vocal Performance			1.00	.16
Nonschool Performance				1.00

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