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Becoming an expert in the musical domain: It takes more than just practice

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Abstract

Previous research has supported the theory that acquisition of expertise in any domain is possible for healthy individuals with sufficient deliberate practice, but such an extreme environmental position brings the existence of innate talent into question. The present study investigates the effects of both environmental factors and talent on expert performance in both high school and conservatory-level musicians. Audition scores and accumulated practice time were recorded, and correlated with scores on Gordon's Advanced Measures of Music Audiation and Raven's Progressive Matrices. Higher-level musicians report significantly higher mean levels on innate characteristics such as general intelligence and music audiation, in addition to higher levels of accumulated practice time. These factors together accounted for more of the variance in music performance than practice alone. A multi-factor view is thus shown to be the best explanation for the acquisition of musical expertise.

Keywords: Expert performance; Intelligence; Practice; Domain-specific skills; Musical domain

Currently accepted research and theory suggests a single factor, deliberate practice, as the necessary component for acquiring expertise in a given field (Ericsson, Nandagopal, & Roring, 2005). However, as originally proposed by Detterman and Ruthsatz (1999), the process of becoming an expert may be better understood through a combination of factors. For example, general intelligence, domain-specific skills, and deliberate practice are all factors that have been separately implicated as important components that contribute to achievement. The present study applies this kind of multiple-factor approach to the prediction of musical achievement in two different groups, a sample of high school band members and a group of conservatory musicians.

1. Introduction

1.1. General intelligence

Often the center of much controversy in the field, the notion of general intelligence has nonetheless withstood the test of time as a valid predictor of achievement. While it has been argued that IQ tests are only valid predictors for school achievement (Gardner, 1983), other research has demonstrated real world validity for measures of general intelligence (Herrnstein and

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Murray, 1994; Jensen, 1998). The current understanding of musical achievement would predict that individuals who are exceptional musicians on the level of Mozart, Bach, and Beethoven are likely to possess elevated levels of general intelligence. According to Cox (1926) the group estimate on these individuals for intelligence was between 125 and 155. Perhaps Seashore (1919) said it best: "It is possible for a person, strong in other capacities, but with relatively low intellectual power, to assume fairly important roles in music within restricted fields of activity; but the great musician is always a person of great intellect".

Recent research has supported a positive relationship between general intelligence and musical achievement. Lynn, Wilson, and Gault (1989) tested 217 ten year olds in a primary school and found a positive relationship between musical achievement, as measured by the Bentley (1985), and intelligence that ranged from .27 to .40. A positive correlation between general intelligence and three separate tests for musicality was also reported by Lynn and Gault (1986). Shuter (1968) in his review of 65 independent research projects reported a similar relationship between general intelligence and musical achievement of around .35.

Converging evidence from studies of people with mental retardation validate the relationship between intelligence and musical ability. People with mental retardation have been found to have delayed musical achievement (DiGiammarino, 1990). People who were profoundly retarded had fewer musical skills than individuals who were only moderately retarded and individuals with mild mental retardation were found to possess the most elevated musical skills within this group.

1.2. Domain-specific skills

Gardner states in his book, *Frames of Mind* (1983), that there are intelligences independent of what is known as general intelligence, and that musical ability is one such intelligence. Even though known research disagrees with the notion of music achievement being totally unrelated to general intelligence, (DiGiammarino, 1990; Lynn & Gault, 1986; Shuter, 1968; Lynn et al., 1989), it would be unfair not to credit Gardner's (1983) work as one of the impetuses of the present investigation.

An interesting example of musical achievement in the absence of normal general intelligence is the occurrence of autistic musical savants. For example, Sloboda, Hemelin, and O'Connor (1985) tested a musical savant who they refer to as NP. The researchers found that his ability to listen and play unfamiliar musical melodies was exceptional when compared to an age-matched professional pianist. The authors attributed this talent to an exceptional musical memory, however the authors report that his memory skills did not generalize to verbal tests. Young and Nettelbeck (1995) also tested an autistic musical savant known as TR. In their study, the savant displayed a remarkable memory for musical pieces, as in Sloboda et al. (1985). However, TR's memory generalized to the digit span test (8 forwards and 7 backwards) which is beyond what is expected for a 13-year-old autistic savant. Unusual memory has been repeatedly implicated in several studies that have investigated the precocious musical development of musical savants. Young and Nettelbeck (1995) also tested TR using the Measures of Musical Ability (Bentley, 1966) and the authors concluded that TR had perfect pitch, a rare ability even among talented musicians. TR's memory for musical melody was superior to both the musical savant tested in the Sloboda et al. (1985) study and a professional pianist.

In summary, then, Gardner's proposal and a limited number of case studies place into question the degree of association between general mental ability and specific musical abilities. The measures we have included in our studies provide an excellent opportunity to investigate this issue.

1.3. Practice

Ericsson and Charness (1994) have stated that the only difference between expert musicians and lower-level musicians is the amount of time spent in deliberate practice. Deliberate practice is defined as time spent with the intention of improving one's performance in a specific domain and differs in content from both work and play. According to Ericsson, to become an expert in any domain all one must do is begin young and then engage in ten years of deliberate practice. A study of violinists by Ericsson, Krampe, and Tesch-Romer, (1993) found support for this hypothesis in data collected on the musicians' historical practice habits. There was a monotonic relationship between the amount of time spent in deliberate practice and the level of achievement. The most acclaimed violinists historically reported engaging in the largest amount of deliberate practice.

However, upon further analysis other factors emerged that must be considered. Ericsson was kind enough to send his original data for further analysis, which revealed that the group of elite violinists won more open competitions from the time they were 8 years old, 67% of the time, than the second level violinists who reported winning only 54% of their early competitions. The lowest group of violinists reported winning

only 18% of their early competitions, which is statistically significant at the .05 level. The groups, therefore, differed in musical ability long before ten years of deliberate practice had accumulated.

Ackerman (1987) states that practice effects depend on the type of skill being acquired. Skills that Ackerman describes as consistent, those with unchanging rules and repetitive, rather than novel stimuli, report performance levels which converge with increased practice time, despite initial individual differences. Ackerman argues that when tasks are novel, performance levels are influenced more by individual differences in cognitive ability, and individuals tested for the effect of practice time on tasks that continually present novel conditions did not find their participants performance converging with practice time (Ackerman, 1987).

This presents reason to question whether Ericsson's theory would apply to cognitively demanding tasks such as musical performance. If Ericsson's practice theory is true, then general intelligence and musical ability should not add predictive value after accounting for practice time, nor should expert musicians differ from lower-level musicians in general intelligence or raw musical talent. However, as we have already shown, there is strong evidence that both general intelligence and musical ability are important predictors of musical achievement. This brings us to the Summation Theory as proposed by Detterman and Ruthsatz (1999).

The present study makes use of a regression equation, $Y' = Xg + Xds + Xp$, suggested in the article by Detterman and Ruthsatz (1999) to test its ability to account for expert performance. The equation states that musical achievement (Y') will be influenced by these three factors, Xg (general intelligence), Xds (domain-specific skills), and Xp (practice). Only those individuals who are bright (high IQ), exceptionally talented (enhanced domain-specific skills), and highly motivated (deliberate practice) will be able to reach experts levels of performance.

Past research has shown that using multiple relevant factors rather than a single composite factor allows for better predictive power (Brogden, 1951). If the Summation Theory is correct, and these three factors are all relevant to musical performance, then two statements will be true. First, domain-specific skills and practice will add incremental validity to general intelligence as valid predictors of musical achievement within each group. This will allow more of the variance in individual musical achievement to be explained. Second, there will be significantly higher group means on each of the factors involved in the equation for conservatory musicians compared to high school students.

2. Methods

To test the Summation Theory, two groups of musicians were investigated: a high school band and a conservatory orchestra, the second group being comparable to the students tested by Ericsson et al. (1993). The present study hypothesizes that musical achievement will be significantly related to all three of the previous variables within both groups. When individual differences are examined across a wide range of ability, such as that found in a representative high school band, all three variables will be important in understanding the underpinnings of individual differences in musical achievement. The study also predicts that the summation approach will be the best explanation of expert performance. Individuals who rise to world class levels of performance will be significantly different in general intelligence, domain-specific skills and deliberate practice when compared to high school band members.

3. Study 1

In the first study the underpinnings of musical achievement in two separate high school bands were investigated. Each of the band directors ranked their high school band members by musical achievement displayed during their musical auditions. The primary investigation analyzed the correlation between general intelligence, domain-specific musical skills, practice time and musical achievement. A further analysis employed a hierarchical multiple regression to account for the amount of variance each factor contributed to musical achievement. General intelligence, domain-specific skills, and accumulated practice time were entered in that order and analyzed.

3.1. Participants

178 high school band members were tested from two participating high schools. A letter to explain the purpose of the study and the testing procedures was sent home to the band members' parents, and students needed to receive parental permission to participate in the study. Because the students were old enough to understand the purpose of the study, they were also required to sign a consent form to participate. The subjects were given McDonalds gift certificates for participating in the study.

The number of students needed to detect a significant effect was estimated by the use of a power analysis for both a correlational analysis and for multiple regression. With power = .8, and a correlation = .30 used to detect a relationship between IQ and musical achievement, 84 subjects were determined to be required. The correlation

of .3 was used as a conservative estimate for the correlation between IQ and musical ability which has been shown in several studies (Lynn et al., 1989; Lynn & Gault, 1986; Shuter, 1968) investigating the relationship between musical achievement and general intelligence. Similarly musical achievement has shown about the same correlation, .30, with musical aptitude measured by the Gordons Advanced Measure of Music Audiation (1986). If practice is an equally significant factor in musical achievement the effect should be found using the same number of subjects. The second power analysis was for an *F*-test in multiple regression, with a medium effect size, .15, and power set at .8, 77 participants would be required.

3.2. Materials

The participants were asked to complete two tests and a questionnaire. The tests were The Advanced Raven's Progressive Matrices (Raven, Court, & Raven, 1998), an intelligence test, a test for musical ability, The Gordons Test of Music Audiation (1986), and a questionnaire developed by Ericsson (1993) about their involvement in musical training.

3.2.1. Intelligence test

All subjects were given an untimed Advanced Raven's Progressive Matrices test (Raven et al., 1998). The Advanced Raven's Progressive Matrices test was chosen because it is thought to be culturally fair and a good estimator of general intelligence (Paul, 1985) but is easy and much quicker to administer then a full scale IQ test.

3.2.2. Music aptitude test

All subjects were given the Advanced Measures of Music Audiation (1986). Edwin E. Gordon developed this test and it is intended to measure musical aptitude or the potential to learn in the musical domain. Individuals who have not received musical instruction can, and do score well on these tests of music audiation because they are not thought to be measures of musical achievement. The test has two subtests, tonal ability and rhythm, plus a composite score. Each of the subtests measures an ability that is thought to be important to musical achievement.

The test of tonal ability is comprised of short taped segments of musical tones, ranging between two and five notes. The tape plays pairs of musical segments after which the individual must indicate if the pair is identical in composition or if the second one has been slightly altered. Alterations in this segment are only in the tones. The tempo and length are not changed from the original musical statement. The tonal test has a test–retest reliability of .81 using the raw scores for high school students.

The test for rhythm follows a similar pattern. Musical statements are presented and the student must decide if the first and second musical segments are similar or different. Both segments use the same tone throughout the presentation of the paired musical melodies only the rhythm may be changed. The rhythm test has a .82 test–retest reliability using the raw scores of students tested in high school.

The final score for the Advanced Measures of Music Audiation is a composite total. The composite total is thought to be the best indicator of musical talent. Any high school student who places at or above the 80th percentile on their composite score should be considered musically talented. The identification of musically talented children is not intended to exclude any children from musical instruction, it is intended to identify those students who would benefit the most from additional musical instruction and could contribute to the musical community. The test–retest reliability for the raw composite score for high school students is .84.

3.2.3. Musical questionnaire

A questionnaire developed by Ericsson (1993) was used to obtain a musical history including an estimate of accumulated practice time with all subjects in this study. Dr. Ericsson was kind enough to send the interview procedures and diary instructions titled "Interview Procedures and Diary Instructions" (1993) that he has used in his studies on the acquisition of musical achievement.

Students answered questions about the amount of musical instruction they received both outside and during school and their accumulated musical practice. The total time devoted to musical practice and lessons was used to establish the impact of practice on musical achievement.

3.3. Procedures

The band director supplied the investigator with audition scores and the subsequent rank order for the members in his band. This was done to establish individual levels of musical achievement within this group. The band members' rank is the dependent variable used as an estimation of musical achievement in the statistical analysis of the data. The reliability of the dependent variable is unknown. In every instance only one person, the head band director, was familiar with all of the members in his band. Therefore, calculating

interrater reliability was not possible. However, musical studies in the literature have typically relied on this type of evaluation for reporting levels of musical achievement, and the validity of music instructors as raters of musical achievement is well-accepted in both musical test interpretations and entrance examinations to musical institutes.

All high school students were tested in a group setting. The Advanced Raven's Progressive Matrices Test was administered first. The students were given a Set One booklet to familiarize themselves with the nature of the test problems. Only the first two items in Set One were used to explain the procedure and field any questions the students had. Although the administration was not timed, the test did not exceed 40 min for any of the students involved.

On the same day the Advanced Measures of Music Audiation was administered. The entire test is pre-taped on a cassette and lasted between 20 and 25 min. Students again were instructed to mark their responses directly on the answer sheet by circling the appropriate answer. After both tests were administered the primary investigator conducted a group interview with the children who participated in the study. The interview procedures developed by Ericsson (1993) were used to assess the total amount of time that each child had engaged in musical practice.

3.4. Results

Data from the two high schools was compared on each of the three independent variables. An independent groups *t*-test was performed comparing the mean intelligence score from the first high school (X=21.70, SD=5.80) to the mean intelligence score of the second high school (X=21.71, SD=4.92). The mean intelligence scores between the schools were not found to be significantly different, $t(176)=.02$, $p>.05$. A second *t*-test was performed to test for significant differences on The Gordons Test for Music Audiation. The first high school recorded a mean (X=50.6, SD=7.91) and was compared to the mean of the second high school, (X=51.50, SD=6.49). The means between the high schools for music audiation was not significantly different $t(176)=.35$, $p>.05$. The final *t*-test also did not find a significant differences between the means of the two high schools for practice time. The first high school reported a mean practice time (X=1033.04, SD=557.55) compared to the second high school (X=1089.35, SD=550.57), $t(176)=-.68$, $p>.05$.

Because the high school samples were not significantly different on any of the three independent variables the data were combined and analyzed using the total number of high school band participants.

3.4.1. Intelligence test

The level of general intelligence for the combined sample of 178 high school band members tested was (M=21.71, SD=5.39) which has an IQ equivalent of 105. The mean for the Advanced Raven's Progressive Matrices at this age is (M=19, SD=6).

3.4.2. Music audiation

The Advanced Measure of Music Audiation test results reported after the data were combined found, (M=51.30, SD=7.05) which is similar when compared to the mean reported for high school band members in the Advanced Measure of Music Audiation (M=50.6, SD=7.91).

3.4.3. Practice

The average amount of time high school band students have accumulated in practice was also calculated after the data were combined (M=1062.77, SD=553.03). The three variables, general intelligence, domain-specific music ability, and practice were then correlated using Pearson's product moment correlation with musical achievement to analyze the relationship that exists between them. The correlation for general intelligence, $r(176)=.25$, $p<.01$, domain-specific skills, $r(176)=.22$, $p<.01$, and practice time $r(176)=.34$, $p<.01$ were all found to have a significant correlation with musical achievement. Table 1 shows the complete correlation matrix.

Hierarchical multiple regression was performed using the combined data set. General intelligence, domain-specific music skills and practice time were entered in that order as independent variables. An analysis was performed using SPSS. After the initial step, with general intelligence entered into the equation, $R^2=.06$, $F(1,174)=11.95$, $p<.01$. After the second step with domain-specific musical ability entered into the equation, $R^2=.09$, $F(1,174)=8.97$, $p<.01$. After step 3,

Table 1
Correlations between musical achievement, intelligence, musical ability, and practice for high school band members

	IQ	Music ability	Practice
Rank	*.25*	*.22*	*.34*
IQ		*.20*	.06
Music ability			*.20*

The significance levels for variables listed are significant with rank at the .01 level for IQ, musical ability and practice. IQ and musical ability are significant at the .01 level. Practice and musical ability are also significantly correlated at the .01 level.

with practice added to the prediction of musical achievement, $R^2 = .18$, $F(1,174) = 12.84$, $p < .001$. The change in R^2 was significant at the end of each step.

Of additional interest is the relationship of both musical ability and practice time with general intelligence. The relationship between general intelligence and musical ability $r(174) = .20$, $p < .01$ was statistically significant. This is evidence against the theory that musical ability is totally independent of general intelligence, as suggested by Gardner (1983) in his book *Frames of Mind*. Of additional interest is that the data supported the independence of practice time and general intelligence $r(174) = .06$, $p > .05$.

3.5. Discussion

The significant relationship found between musical achievement and the three independent variables, general intelligence, domain-specific musical skills and practice, in a self-selected high school band confirm the initial hypotheses of this study, that musical achievement will be best understood from a multi-factored analysis. In addition, the amount of variance accounted for by each predictor is relevant to the understanding and prediction of expert performance. The amount of variance that could be accounted for with just general intelligence was significantly enhanced by the addition of music audiation scores and further, adding the variable of practice also significantly changed the predictive ability of the equation.

This finding expands upon the work of scientists such as Ericsson and Charness, who have posited that practice is the only mediating factor in the acquisition of expert musical performance. This first study indicates that general intelligence and domain-specific skills are also major factors responsible for musical achievement within a self-selected population of high school musicians. The implications from this study point to the importance of innate characteristics such as general intelligence and music audiation in conjunction with practice in the acquisition of musical expertise.

Furthermore, while the domain-specific skill or "musical ability" did add significant increment to general intelligence it was not found to be totally independent of general intelligence. General intelligence and domain-specific musical ability were significantly correlated. The relationship shown in this study between musical ability and intelligence speaks in direct opposition to Gardner's statement that there are several independent intelligences of which music is one.

The second hypothesis of the Summation Theory states that as groups of musicians become elite within their domain there will be increases on the means for general intelligence, domain-specific skill, and practice time. In order to test this hypothesis, the next study looks at higher-level conservatory and university musicians. This study is aimed, first, at understanding the individual differences within a more competitive group of musicians and, second, at comparing the first group of high school members to the second group of more competitively selected conservatory musicians.

4. Study 2

In this study the factors that are involved in musical achievement at the conservatory level were investigated. A first analysis was done to compare competitively selected conservatory orchestra members to the self-selected high school band members. The Summation Theory predicts that as individuals rise up the ladder of musical success, the means for each of the three variables, general intelligence, domain-specific skills, and accumulated practice will be significantly different when compared to the means reported in a less accomplished group. The second analysis studied the relationship between musical achievement, general intelligence, domain-specific skills, and practice time within a conservatory orchestra.

4.1. Participants

Eighty-three conservatory music majors were recruited, nineteen from a Midwestern University, and sixty-four from a major institute of music also located in the Midwest. All subjects signed a consent form stating that they understood the procedures involved and the purpose of the study.

4.2. Procedures

The participants were asked to complete the same two tests and questionnaire as the participants in the first study. The tests again included the Advanced Raven's Progressive Matrices (Raven et al., 1998), The Advanced Measures of Music Audiation developed by Gordon (1986) a test for musical ability, and the Interview and Dairy Instructions developed by Ericsson (1993) to assess each individuals involvement in musical training.

Prior to the analysis of any data, musical achievement scores were supplied for the sixty-four participants from the music institute and the nineteen music majors from the Midwestern University. The audition scores from the musical institute were used as the musical

Table 2
Means and standard deviations for high school band members and conservatory orchestra members on general intelligence, music audiation, and accumulated practice

	Intelligence	Music audiation	Accumulated practice time in hours
Combined high schools	X=21.71 SD=5.39	X=51.30 SD=7.05	X=1062.77 SD=553.03
University music majors	X=27.21 SD=6.04	X=56.74 SD=10.13	X=4074.84 SD=2690.55
Music institute	X=24.82 SD=5.59	X=61.92 SD=7.84	X=10055.20 SD=5386.06
Combined conservatory Sample	X=25.2 SD=5.74	X=60.5 SD=8.70	X=8583.70 SD=5671.98

The means between the high school band and the combined conservatory are all statistically significant at the .01 level in IQ, music audiation and practice time.

achievement scores. The institute students audition as part of their admissions criteria and are rated on a scale from one to five. The best musical performers are given the highest score of five and scores descend down to the number one, being the least accomplished musicians allowed admissions into the institute. The musical achievement rankings for the music majors from the university were obtained through a member of the faculty who was familiar with the musical achievement of all the students who participated in the study. The faculty member was asked to use the same scale as the institute and rate the most accomplished musical performers with a five and to descend down to a one for the least accomplished performers. The orchestra members' musical achievement score is the dependent variable used as an estimation of musical achievement in the statistical analysis of the data. As in the prior study, the reliability of the dependent variable is unknown.

Conservatory orchestra members were tested both individually and in group settings to accommodate their schedules. The Advanced Raven's Progressive Matrices Test was administered untimed as the first step in the data collection. The subjects were given a Set One booklet to familiarize themselves with the nature of the test problems. Only the first two items in Set One were used to explain the procedure and field any questions that the students had. The entire administration did not exceed 1 h.

On the same day the Advanced Measures of Music Audiation was given. The entire test is pre-taped on a cassette and lasted between 20 and 25 min. Students were again instructed to mark their responses directly on the answer sheet by circling the appropriate answer. After both tests were administered a short questionnaire was given to each participant to fill out. The interview and diary questionnaire developed by Ericsson (1993) was used to ask about their musical development in regards to the amount of time they engaged in lessons and practice.

4.3. Results

The means and standard deviations for both groups of the conservatory musicians were obtained. These scores are compared with the high school scores in Table 2 below. As predicted by the Summation Theory, the means for each of the predictor variables were significantly elevated for the competitively selected orchestra members when compared to the self-selected high school band members. The mean for general intelligence (X=25.2, SD=5.74) which is an IQ equivalent of 113 for the conservatory orchestra members was significantly different from the high school band members general intelligence score (X=21.71, SD=5.39) t=4.77, p<.01 and the mean reported for that age group in the United States (X=20, SD=6). The second independent variable, music audiation, was also significantly elevated when the conservatory group (X=60.5, SD=8.70) was compared to the high school band members ability to audiate music (X=51.30, SD=7.05), t=8.72, p<.01. The last variable, practice (as measured in accumulated hours over their lifetime) was again different at the conservatory level (X=8583.7, SD=5671.98) when compared to accumulated high school practice time (X=1062.77,SD=553.03) t=12.55, p<.01.

The three independent variables for each conservatory group were then separately correlated with their perspective musical achievement scores to analyze the relationship that exists between musical achievement, general intelligence, domain-specific skills and practice in a conservatory orchestra. Table 3 shows the complete correlation matrix for each conservatory group.

Table 3
Correlations between musical achievement, intelligence, musical ability, and practice for a conservatory orchestra

	IQ	Music ability	Practice
Conservatory orchestra			
Rank	.12	.15	*.31*
IQ		*.35*	.11
Music ability			*.51*
University music majors			
Rank	.24	.27	*.54*
IQ		*.47*	−.01
Music ability			.23

Rank and practice are significantly correlated at the .05 level. Practice and musical ability are significant at the .01 level. IQ and musical ability are significant at the .01 level.

A bivariate Pearson product moment correlation for general intelligence and musical achievement within a conservatory orchestra, $r(62)=.12$, $p>.05$ was not significant for the musical institute or for the music majors from the university, $r(17)=.24$, $p>.05$. A bivariate Pearson product moment correlation between domain-specific skills and musical achievement for the institute musicians, $r(62)=.15$, $p>.01$, was also not significant as was the case for the university music majors $r(17)=.27$, $p>.05$. However, the correlation between musical achievement and accumulated practice time $r(62)=.31$, $p<.01$ was significant at the .01 level for students from the institute and music majors from the university $r(17)=.54$, $p<.05$.

Hierarchical multiple regression was performed first for the musical institute. General intelligence, domain-specific music skills and practice time were entered in that order as independent variables. R^2 was not significantly different from 0 at the end of the first step. The addition of domain-specific skill as the second step did not add significant increment nor did practice time when it was entered as the third step. A second hierarchical analysis was performed with practice entered as the first variable. R^2 was different from 0 after the first step with accumulated practice entered. $R^2=.09$, $F(1,60)=6.54$, $p<.05$, this new regression result is due to all the variance shared between practice and musical ability being attributed to practice time because it was entered first in the hierarchical multiple regression. The addition of general intelligence as the second step, $R^2=.10$, $F(1,60)=.16$, $p>.05$, and domain-specific skills as step three $R^2=.10$, $F(1,60)=.27$, $p>.05$ did not add significant increment in either case.

Hierarchical multiple regression was then performed for the university music majors. Again with general intelligence entered first followed by domain-specific musical skills and accumulated practice time entered in that order. R^2 was not significantly different from 0 at the end of the first step. A second hierarchical analysis was again performed with practice entered as the first variable. After the first step with accumulated practice entered $R^2=.29$, $F(1,15)=7.04$, $p<.05$. The addition of general intelligence as the second step, $R^2=.35$, $F(1,15)=1.43$, $p>.05$, and domain-specific skills as step three $R^2=.36$, $F(1,15)=.03$, $p>.05$ did not add significant increment in either case.

4.4. Discussion

The data support the Summation Theory's prediction that as individuals enter into more competitively selected musical groups their mean ability on each of the three predictor variables will be elevated compared to individuals in less selective musical groups. However, the ability of the summation equation to account for individual differences in a highly selective conservatory orchestra was not entirely productive. Both higher-level groups failed to find a significant relationship between general intelligence and musical achievement or between musical ability and musical achievement.

There are several possible explanations for this. First, it should be noted that the presence of a significant relationship in one group and its absence in another does not imply that the correlation is different in the different samples. Notice that all variables are positively correlated with rank even in this elite sample, suggesting that power may have been an issue. A *t*-test comparing the two correlations also showed that they are not significantly different ($p=.94$). Furthermore, there is evidence from other studies for individual differences in elite groups predicting achievement when the sample size is large enough, for example in a study of close to 2000 intellectually precocious youth by Wai, Lubinski, and Benbow (2005).

If the two populations are in fact the different, the difference is most likely due to restrictions in range of talent in the second group. When individuals are selected for ability (including self-selection) the resulting correlations between ability measures and achievement will be attenuated. Remember that individuals in an orchestra are already highly selected for intelligence and musical ability compared to high school musicians, as reflected in the difference between the means for both groups. Therefore variables that are imperative to elite musical achievement fail at this point to discriminate effectively among orchestra members the way they did in the high school band.

It is also important to note that, because the performance scores used in this study were based on initial auditions, the performance scores were essentially collected prior to the ability and practice scores. Thus, it is possible that audition results may have subsequently affected practice and ability levels, rather than the other way around. Finally, although we did find significant correlations between practice time, ability, and rank, the exact causal relationship between these three variables remains unclear.

5. Conclusions

This finding illuminates some of the forces at work in the acquisition of musical expertise. Ericsson and Charness have previously stated that practice is the only mediating factor in the acquisition of expert

performance, and we have found that, in fact, it is a mediating factor, but only after the group in question has been highly selected for general intelligence and musical ability. Thus, we are forced to conclude that not everyone can be Mozart, even if they start at a young age and practice intensively. The extent to which students within a limited range of general intelligence and musical ability can improve their skills remains an interesting question, not only in music but in other areas as well, and this question certainly deserves the attention of serious research in the future.

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