Psychomusicology, 16, 40-58

RESEARCH ON EXPERT PERFORMANCE AND DELIBERATE PRACTICE: IMPLICATIONS FOR THE EDUCATION OF AMATEUR MUSICIANS AND MUSIC STUDENTS

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Following an overview of the current knowledge about the structure and acquisition of expert performance in the arts, sciences and sports, we discuss practical implications for music training, focussing on the development of levels of instrumental skill typically attained by high school students and amateurs. Recent studies found that even the highest levels of music achievement are primarily the result of skill acquisition and physiological adaptation in response to extended deliberate practice. Increases in performance over historical time also document the importance of training and practice. Although learning conditions encountered by music students and amateurs often may be less favorable than learning environments in which experts develop, the quality of training can be increased at all levels of performance by incorporating features commonly found in the training of experts (individualized practice assignments, improved monitoring of feedback).

During the last several decades there has been a growing interest in the study of complex everyday activities and their development. More specifically within cognitive psychology, scientists are studying the structure and the acquisition of expert performance in many domains of expertise including chess, medicine, and sports. One of the goals of this research was to better understand the development of high levels of performance in order to improve training for future experts as well as for amateurs and other individuals aspiring to more modest levels of mastery. One of the most extensively researched domains of expertise, besides chess, has been instrumental music performance.

The influence of practice, training and innate musical talent on performance has been examined several times in recent reviews (Ericsson, 1996; Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Römer, 1993; Howe, Davidson, & Sloboda, 1998). The general conclusion from results obtained in many domains of expertise is that practice and training is important, that is, predictive of performance at all levels including the elite levels. Clearly, the highest levels of performance in a domain require optimal training conditions and learning environments. It is thus possible that deficiencies in training environment and learning resources account for some of the failures of even highly motivated individuals to reach the expert level. This paper intends to bridge the gap between the research done by psychologists and the implications that this research might have for the teaching and learning of music in instructional settings such as the music studio and classroom.

We will first explore why individual differences in observed performances are not always attributed to practice and training. Then we will describe aptitude testing in music as a logical consequence of the concept of innate talents. In the third section we will offer evidence for the importance of practice and training for attaining high levels of performance. The fourth section reviews different training activities and their effectiveness in skill development. For example, we describe active forms of deliberate learning which provide more effective methods for improving the structure of music performance than mindless repetition and drill. Finally, we discuss the application of expertise and practice research to learning situations of the studio and classroom.

The Practitioner's Dilemma of Explaining Skill Differences

In the world of music and in many sports, teachers and students often believe that some people have "it" (whatever "it" is) and that some do not. According to this view, even large amounts of practice will not be sufficient to reach high levels of performance for those people who lack "it." The idea that abilities are genetically determined has a long tradition, and it has spawned psychometric attempts in every area of human performance, especially intelligence and related concepts. Later, we will show three separate lines of evidence that support the theory that high levels of music performance can be enhanced through practice, and that the notion of innate talent may not be necessary.

There are several reasons why beliefs in innate musical talent are so common among musicians. There is a historical tradition from as early as the Renaissance when artists claimed that God-given gifts made them predestined for artistic careers. Examples include geniuses such as Michelangelo and Leonardo da Vinci (Ericsson & Charness, 1994). Also, around the turn of the 19th century, when many musicians' biographies were written, philosophical ideas consistent with the talent concept made their way into the common understanding of creative and re-creative artistic behavior (e.g., Einstein, 1947; DeNora, 1995). Finally, music teachers in classrooms and studios try to provide their students with the same instruction and practice assignments, but they still observe large individual differences in their students' attained performance that they believe cannot be attributed to external training conditions.

Explanations of individual differences in performance often depend on the specific situation and also on our beliefs. When two students give a music performance, differences in their skills often are noticeable even to the untrained observer. An explanation based on acquired skills, practice, and training is more likely when certain cues are available, that is, when one of the players is older and has had several more years of training than the other. However, when two students taught by the same music teacher are similar in age and years of training, then it is difficult to explain observable differences in performance in terms of differences in external conditions. In this case, it would seem more likely that the individual differences are due to inborn capacities for music (innate talent). As the next example from the domain of sports demonstrates, the factors influencing observed differences in skill are sometimes very subtle and difficult to notice.

Boucher and Mutimer (1994) found that Canadian hockey players in the National Hockey League (NHL) were much more likely to be born in January-March than in October-December. The explanation for this surprising phenomenon relies on relative age effects and is rather simple. When children start playing hockey they are grouped according to age. Since the playing season starts in winter, the players born early in a given year would be many months older and have advantages in strength, motor skills, size, and experience over their younger teammates, who were born later in the same year. [1] The coach is likely to attribute some of the older players' better performance to innate talent and thus probably will give them more support, playing time, and better training opportunities. Whatever the selection mechanism may be, over time it favors those born in the first half of the year. A similar age effect was documented in tennis and soccer (Dudlink, 1994). Yet in soccer there is no size advantage for adult elite soccer players, and one study found that the better adult soccer players were shorter than other athletes (Medvet, 1966). In this case, the initial advantage of increased relative body size as a child eventually would turn into a disadvantage for the adult performer. The benefit of relative age effects are not linked to the beginning of the year (January through March), but rather coincide with the start of the cycles relevant for a certain domain, regardless where in the course of the year those cycles start and end (e.g., fall for academic activities).

Teachers who have to make judgments about the potential of certain students should be advised to carefully review the above criteria. Furthermore, knowledge about the child's family background, current developmental situation of a child, and hidden factors may well influence a decision with far-reaching educational consequences.

Aptitude Testing as an Alternative to Simple Attribution of Innate Talent

When music students have reached a sufficient level of skill it is possible to observe and evaluate their music performance as well as identify the students showing exceptional achievements and promise. However, it is far more difficult to uncover alleged music talent among children and adults who do not play an instrument. Although we now know that even early signs of "promise" are often disappointingly elusive (e.g., Howe, Davidson, Moore, & Sloboda, 1995), researchers in the field of musical talent long have tried to design psychometric tests of aptitude or potential for music training. Much of the current evidence cited in support of the validity of these aptitude tests comes from studies where large groups of children are tested in order to discover those individuals with "hidden talents." If these "talented" children were given appropriate training, presumably they would improve far more rapidly than other randomly selected children receiving the same training. However, this evidence may not necessarily show that the tests of music aptitude measure innate capacities and talents.

Most developers of aptitude tests claim that their tests can predict future performance (e.g., Gordon, 1967, but see Boyle, 1992, for a different view). However, research on prediction of performance in areas other than music has shown surprisingly low predictive validity of aptitude scores (such as intelligence) for many types of job performance after many years of work experience (e.g., Hulin, Henry, & Noon, 1990). Is it possible that music aptitude tests measure psychological or physiological characteristics of children lacking music training that may not have reliable consequences for future achievement in music? Let us consider the following example involving the seemingly obvious disability of being flat footed!

To assess deformities of the foot, orthopedists use an index called the arch index, which is derived by making a footprint and dividing the measured width of the heel area by the width of the arch area. Although the individual variability of this index in the general population is large (Staheli, Chew & Corbett, 1987), researchers found no evidence that the flexible flat foot in any variation produced disability in the absence of other clinical problems (Harris & Beath, 1948, cited in Staheli et al., 1987, p. 427). More directly relevant to music performance, Henson and Wyke (1982) showed that professional orchestral players scored higher than the average population on only three of the six subtests of Seashore's Measurement of Musical Talent, and even significantly worse than the average for the test of timbre. Thus, even professional musical achievements may not be meaningfully related to scores on music aptitude tests. In a recent review Lehmann (1997a) found that correlations between musical aptitude test scores and musical achievements are consistently low. The primary exception to this rule is mentioned in Gordon (1995), where the music aptitude test scores showed moderate predictive validity after two and three years of music instruction. However, this study did not assess the prior music training of the students taking the music aptitude test. If high scoring students indeed had received more music instruction, and if formal instruction improved the test score—which is likely (Lehmann, 1997a)—then the high predictive validity of the aptitude test for future music performance may be confounded with the effects of formal instruction, or for that matter, the effects and informal musical training prior to the test. In the area of development of oral and written language, such informal training in the form of targeted parent activities, such as storybook reading and parent teaching about literacy, have been shown to influence young children's performances on standardized measures of achievement (Sénéchal, LeFevre, Thomas, & Daley, 1998). Similar effects may be observed from musical activity in the home of the students (cf. Bamberger, 1991). We know of no experimental studies on the effects of informal musical training on music aptitude scores.

In sum, although some music aptitude tests show a degree of predictive validity for the performance of traditional Western instruments, formal or informal training may possibly account for most of this predictive validity. In the absence of experimental studies we cannot clearly distinguish the relative contribution of innate aptitudes and acquired skills for the performance on the aptitude tests. Moreover, there may exist measurable individual differences among untrained children that lack significant consequences for future levels of music achievement. In the next section we review the evidence showing that performance can be enhanced greatly through practice and training independent from assumptions of aptitudes and innate talents.

Three Types of Evidence Demonstrating Effects of Practice and Training

Practice and Experience are Necessary for Elite Performance

Recent reviews show that extended engagement in performance activities is absolutely necessary to attain an expert level (Ericsson & Charness, 1994; Ericsson & Lehmann, 1996). Longitudinal studies have shown that performance does not increase in sudden jumps, but rather gradually. This implies that very high levels of performance are reached only through steady progress over many years of engagement in domain related activities. This also might apply to child prodigies, whose performance is vastly superior to that of their peers (see Wagner & Stanovich, 1996, p. 202, for a claim regarding reading achievements; see also Howe, 1990, for a general argument). Also, with maintained intense engagement in their field, expert performers continue to improve their performance beyond the age of physical maturation (the late teens in industrialized countries) for many years and even decades. In fact, the age at which performers typically reach their career peaks in the arts and sciences extends about two decades beyond their performance maturation in the 30s and 40s (Ericsson, 1990; Lehman, 1953). This clearly implies that experience in one's field is absolutely necessary for individuals to improve their performance. The final and most compelling evidence for the necessity of vast experience prior to attaining high levels of performance is that even the most "talented" individuals in a wide range of sports, science, and arts require about ten years of intense involvement before they reach an international level (Simon & Chase, 1973; Ericsson et al., 1993). However, extensive experience, by itself, is not sufficient for attaining elite performance and the correlation between amount of mere experience and level of performance often is surprisingly low (Ericsson & Lehmann, 1996).

A closer association has been found between attained level of performance and a particular type of practice which Ericsson et al. (1993) called *deliberate practice* (practice activities involving specific goals and strategies). The investigators found a high correlation between indicators of attained performance of musicians and the amount of deliberate practice accumulated during their musical development. By age 20, the best violinists in their study had spent an average of over 10,000 hours in deliberate practice. This number was about 2,500 hours greater than the accumulated practice times of the violinists in the study's intermediate group and about 5,000 hours greater than the expert violinists in the least accomplished group. Sloboda, Davidson, Howe, and Moore (1996) showed that for music students, higher achieving students practiced significantly more than lower achieving students. Additional work has shown that the relation between deliberate practice and performance holds for domains of expertise other than music, such as individual and team sports and chess (Ericsson, 1996; Helsen, Starkes & Hodges, 1998).

Adaptations Observed in Experts

The second type of evidence for the acquired nature of abilities refers to observed physiological, cognitive and psychomotor characteristics that are associated with very high levels of performance. For a long time those characteristics were believed to reflect innate talent. A few of the many striking examples concern the larger hearts of elite endurance athletes and the larger number of capillaries supplying blood to their muscles (Ericsson & Lehmann, 1996). However, we now know that the vast majority of these anatomical and physiological characteristics are consequences of the intense training. On a small scale, we all experience physiological changes in response to engaging in everyday activities. For example, many days of yard work may bring about calluses and maybe even slightly firmer biceps. Of course, some of the physiological changes found in different domains of expertise, such as the larger hearts of athletes, have been shown to revert back to normal values when training ceases and there is no further demand for that type of extraordinary heart capacity.

Many thousands of hours of training also lead to measurable adaptations in musicians. For example, violinists and pianists maintain certain typical body positions when playing their instruments, and their respective abilities to rotate their forearms is modified in an instrument-specific way (Wagner, 1988). Violinists have a larger forearm supination (i.e., rotation so that the palm faces upward), while pianists have a larger forearm pronation (rotation so that the palm faces downward). Adaptations observed in experts even include very specialized structural changes in the brain. For example, the area of the cortex associated with control of the left hand fingers, especially the little finger, is enlarged for advanced stringplayers who started training at young ages (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1996). Also, practice related enlargements of the cortical areas activated by the presentation of complex tones have been found in musicians but not in nonmusicians. These and other results suggest a use-dependent functional reorganization in the sensory cortex (Pantev, Oostenveld, Engelien, et al., 1998). All those physiological characteristics that include changes to muscles, bones, and brain structure appear to be adaptations that experts acquire through extensive training in response to task demands.

There also are mental abilities that have been associated with high levels of performance, in particular extraordinary memory performance. Experts are known to deliberately increase their ability to plan and reason as well as their knowledge and the ability to access memory (Ericsson & Kintsch, 1995). In the process, and without training memory performance for its own sake, experts' domain-specific memory performance increases.[2] However, this memory advantage over less skilled individuals is restricted to meaningful stimuli in the domain and essentially disappears when experts are asked to recall random configurations of the same stimuli (for a review, see Ericsson & Lehmann, 1996). In summary, most of the physical and mental characteristic features of experts appear to be domain-specific adaptations to the typical demands, induced through practice and training.[3]

Historical Increases

The final type of evidence showing how even high levels of performance can be increased further comes from historical changes in performance which can be demonstrated in music, but to date have been mainly documented in other domains of expertise such as sports and sciences. For example, Johnny Weissmuller (early "Tarzan" actor), won on Olympic gold medal in 1924 by swimming the 100 m freestyle in under 60 s. This world record was matched some 40 years later in 1964 by a woman (Dawn Fraser). Today, the same swimming time is no more than a very good time for a student athlete from a typical high school. Although the goal of musicians is not to play their musical instrument faster or louder than previously done, historical developments in skill akin to those in sports have been documented.

Recently we investigated historical changes in music performance by focusing on the complexity of performed music (Lehmann & Ericsson, 1998a). We correlated the dates of composition for the piano sonatas by Haydn, Clementi, Mozart, Beethoven, and Schubert, with contemporary complexity ratings published for those works. The results showed that sonatas from later periods tended to be rated more difficult than those from earlier ones. In a different analysis we documented an increase in the levels of achievement of child prodigies over a comparable time period. We collected information on the degree of precocity of piano prodigies from the last three centuries and found that more recent prodigies had played more difficult pieces at younger ages than their famous predecessors. Both these increases in the level of music performance can be explained by changes in training which have allowed later performers to achieve higher levels of technical performance faster than previous performers. In sports and music alike, the level of achievement that only a century ago was attributed by contemporaries to the unique innate talents possessed by a performer, is today regularly achieved by a large number of individuals after extended training. These previous levels of expert performance do not appear to require special innate talents, at least by today's standards, but they are viewed as predictable consequences of appropriate instruction and extended deliberate practice.

In conclusion, three types of evidence reveal the plasticity of human performance. The highest levels of performance are not fixed and immutable as shown by steady historical increases in elite performance. The level of attained performance rarely is constrained by anatomical, physiological or mental characteristics because those characteristics are shown to adapt and change in response to appropriate types of extended deliberate practice.

The Development of Skill and Associated Mental Mechanisms through Training

Although the importance of practice may seem obvious to many musicians, it is necessary to consider it more systematically. As mentioned earlier, even among highly skilled musicians there is a close relation between attained performance and the amount of deliberate practice they have accumulated throughout their musical development. Consequently, a more detailed analysis of the structure of practice is needed to identify the essential mechanisms of effective training. We will first describe the characteristics and constraints of deliberate practice and contrast it with mere experience and engagement in music related activities. In the final section we will discuss implications for learning in the classroom and studio.

Characteristics of Deliberate Practice

The theoretical concept of deliberate practice is restricted to learning activities with specific goals and activities. A student who engages in drill while thinking about something else may experience only minor, if any, benefits for improvement in music performance. Ericsson, Krampe, and Tesch-Römer (1993) have defined deliberate practice as a structured activity designed to improve performance. Of course, this activity is embedded in the larger phenomenological context of practice. Deliberate practice has well-defined goals and the outcome is monitored carefully to see if the goals have been met. Although not all behaviors that a student displays during a practice session meet the requirements of deliberate practice, they may serve a multitude of different functions, such as maintaining interest and motivation through play and relaxation.

Some pedagogues do not acknowledge the effort and intentional nature of the development of expert skill which is inherent in the deliberate practice concept. For example, Kohut (1992) argues for a natural ability to learn-which supposedly is lost during socialization in today's society, and which rests on two main learning mechanisms, namely trial and error and imitation. From our theoretical perspective, this approach, which parallels contemporary views of general education (see Ericsson, 1998, for a critical commentary), is only part of what constitutes musical learning. Although trial and error and imitation might feel "natural" and effortless, they are not always efficient processes. Imagine a child learning to drive a car by trial and error or yourself trying to pole vault by imitation. Mere experience and spontaneous engagement in activities do not automatically result in the types of complex skills that experts acquire. The complex skills of expert performers appear to require the intentional, designed activities of deliberate practice for their acquisition.

Factors Constraining Deliberate Practice

Ericsson et al. (1993) identified several prerequisites for effective practice. First, an individual needs sufficient access to training facilities, appropriate training exercises and proper sequencing of instruction. Second, practice is an inherently effortful process that is limited by human attentional resources. We find that experts engage in deliberate practice for four to five hours on a daily basis. This seems to be the maximum that adult experts can maintain on an extended regular basis; children's daily practice times are even shorter. Finally, deliberate practice requires sustained concentration and effort and consequently differs form many other similar activities that are more inherently enjoyable, such as playful interaction with peers. Next we will turn to the question of motivation in deliberate practice.

Some critics of the theoretical framework of deliberate practice (e.g., Gardner, 1995; Sternberg, 1996; Winner, 1996) point out that not all children attain the same final level of performance even when they are given the same instruction and opportunities for deliberate practice. However, actual engagement in deliberate practice requires an active act on the part of the child to concentrate on the task and to monitor the performance; consequently motivation becomes a key constraint (Ericsson et al., 1993; Ericsson & Charness, 1994; 1995). Critics of the expert performance framework do not disagree with the close link between motivation and high levels of performance. However, most advocates of innate talent believe that the talented individual is motivated to practice because he or she can perform tasks better than the less talented individual. In contrast, proponents for the expert performance framework point out that deliberate practice requires individuals to set performance goals beyond their current level of achievement, thus leading to repeated failures until eventual mastery is achieved (Ericsson et al., 1993; Ericsson, 1998). Given that at least some of the factors determining the level of motivation are due to prior experiences and environmental influences, it is essential that teachers and home environments be examined carefully to establish their role in the acquisition of high levels of performance.

Some studies attest to the importance of first teachers. The best teachers for beginners, especially very young ones, need to know the children's personality well enough to keep them motivated to maintain practice by showing enthusiasm and ample encouragement. Therefore, it is not surprising to find that the first teachers of prodigious piano players most often were members of the prodigy's household (Lehmann, 1997a). Later teachers promote skill development more rigorously and rely more on the student's intrinsic motivation (L'Hommedieu, 1992).

Experience and Practice

As mentioned earlier, deliberate practice is different from mere experience. This distinction has become clear in research on expertise, where highly paid experts, such as medical experts, despite their large amounts of experience do not necessarily outperform less experienced professionals in the same domain on routine tasks. Related findings exist for those domains in which decision making is the crucial component, such as in selecting stocks (Ericsson & Lehmann, 1996). One likely factor limiting learning and improvement of performance in many professional settings is that immediate feedback on performance is typically not available. In the absence of guiding feedback, improvement of accuracy of performance might be nearly impossible. Although mere repetition of the same performance will not lead to better performance per se, it may lead to increased automaticity and reduced effort (Shiffrin & Schneider, 1977).

Let us, for example, consider sight-reading and piano accompaniment that involve performance of unfamiliar music after only limited rehearsal. We found that the time that pianists had engaged in regular sight-reading or accompanying activities was predictive of their sight-reading performance (Lehmann & Ericsson, 1993; 1996). Individuals who had accumulated more hours of regular sight-reading performed more accurately than the others. We also found that pianists' accompanying repertoire predicted sight-reading ability over and above experience. The accompanying repertoire contained pieces that the pianists had specifically rehearsed for accompanying purposes, and these pieces typically included accompaniments to string and wind sonatas and to operas and oratorios. Together, these results demonstrate well the interplay of experience and self-imposed challenge. Consider the church musician who sight-reads hymns for many years. Once the required level of mastery has been reached we would not expect this musician to improve beyond this level unless the complexity of the material is deliberately increased. In contrast, educational environments are typically designed to continuously challenge the students' level of achievement. In our sample of college age pianists, their accompanying activities forced them to constantly encounter and master new and more difficult pieces, thus confounding experience and practice opportunities. Also, they imposed challenges on themselves by specifically learning certain materials. Without knowledge about these additional challenges, we would overestimate the contribution of mere experience to improvements of performance. Put simply, the best sight-readers were those who challenged themselves and learned complex repertoire in addition to their regular sight-reading engagements in choir, church, or chamber music.

Emerging Mental Representations as a Result of Practice

Building mastery in a domain and finding the least effortful method to attain a specific performance goal are very different activities. This distinction is crucial for separating a performance that has been entrenched through mindless drill from one that is flexible and adaptable through the use of mental representations—a hallmark of expert performance (Ericsson & Lehmann, 1996; Ericsson, 1997; Lehmann 1997b). Everyday observations support this distinction. For example, a person can learn to pronounce perfectly a number of useful conversational phrases in a foreign language by rote and appear proficient when asking for the menu in a restaurant. However, when the waiter attempts to initiate a conversation, the real limits of language comprehension and production become evident. Similarly, some music students can play a few well-entrenched pieces from start to finish but cannot improvise, sight-read, or efficiently learn new pieces; whereas others who can play the same level pieces are also able to display all other aspects of musicianship. Thus, superficially similar performances, in this case the performance of a given piece, may be mediated by distinctly different underlying mechanisms.

To explain those contrasting mechanisms of performance, we have proposed a model of mental representation that implicates complex mental processes rather than assuming that rehearsed music is played in an automated fashion without conscious control by the musician. Three different types of mental representations are deemed necessary for expert musicians (see Figure 1). The first mental representation is that of the desired (goal) performance, which contains the musician's representation of how the piece should sound. The second representation is related to the musician's ability to implement the goal representation, and this production representation includes the knowledge of and control over the instrument. A third representation contains the current performance, and this representation is related to the musician's ability to monitor his or her own performance. These representations are interconnected but can be experimentally separated and studied. Think-aloud protocols (verbal reports) are an important data source in this process. In a laboratory experiment where subjects memorized a short piece of music and then reproduced it under changed performance demands from memory, we found evidence for the cognitive mediation of music performance. The verbal reports revealed the different mental representations, and subjects even described representational errors such as playing right hand notes with the left hand when they were asked to only perform the left hand (Lehmann & Ericsson, 1997).

Implications of Research on Expertise and Deliberate Practice for Music Teaching

Can we apply what we know about expert levels of performance to the acquisition of skills at more modest levels of performance? To understand how such findings could be extrapolated to a typical classroom or studio situation, we must consider the differences between learning environments of expert performers and more common learning environments (see Table 1). The characteristic that most prominently distinguishes between the skill acquisition of experts and public music education is that group instruction prevails in the latter while one-on-one tutoring is the norm for the training of experts. Also, the early start of training of high achieving children contrasts with the relatively late start of instruction in public music education. Finally, the training of future expert performers is focused on an ultimate performance years away, whereas music schools are evaluated primarily by the

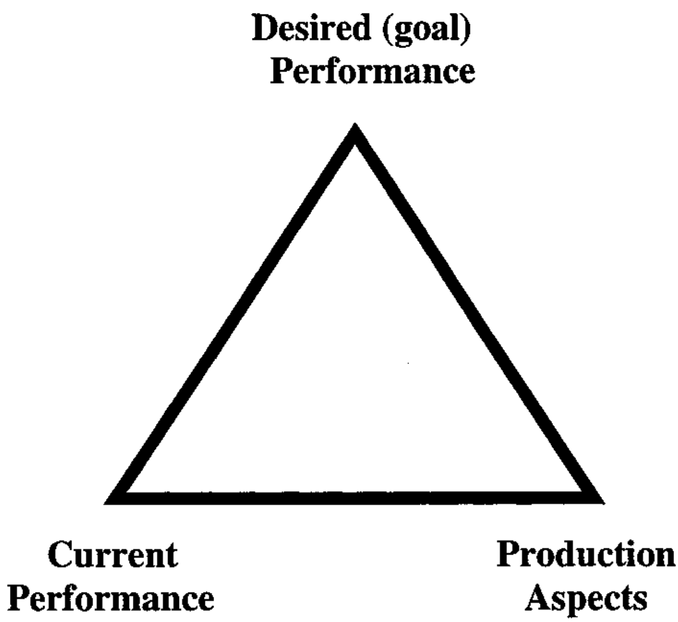

Figure 1. Mental representations necessary for expert performance in music.

success of public performances weeks or months away. However, we believe that by providing more supervised practice, more accurate feedback, varied training activities, and a clear goal as to what the final level of performance should be, group settings can provide some of the benefits that experts receive from their training environments.

Supervised Practice

In contrast to many sports in which the coach is often present during practice, music students typically retreat to the practice room and work by themselves. This also is true for public school situations in which students are encouraged to practice their parts at home. However, a recent study of past piano prodigies showed that virtually all the child pianists had engaged in practice under supervision of an adult (Lehmann, 1997a). An informal survey of biographies of contemporary prodigies including Yo-Yo Ma, Cecilia Bartoli, Evgeny Kissin, and Sarah Chang reveals similar patterns. It is probably not the musical ability of the supervising persons that is critical, but their aid in maintaining the child's concentration (on-task behavior) and monitoring as well as their occasional suggestions for improvement. In schools, improved supervision should be possible by encouraging students to practice in pairs. Some anecdotal evidence from teachers who advocate "practice partner" activities suggests that improved performance and motivation re-

Table 1

A Comparison of Learning Environments of Prodigies, Confirmed Experts, Amateur Musicians, and Music Students

Typical learning environments encountered by amateur musicians and music students	Typical learning environments encountered by prodigies and confirmed experts
Group instruction	Individual (one-on-one tutoring)
Relatively late start (sometime during schooling)	Very early start (usually before formal schooling)
Short training period with short-term goals	Extended training periods with long-term goals

sult. However, we are not aware of controlled experimental study evaluating those or similar claims. Some studio teachers, especially those teaching in the Suzuki tradition, include the parents in the practice process; others make their students keep a practice diary. The former may actually satisfy some prerequisites of deliberate practice, while the latter simply ensures that some practice time is spent at the instrument, whether or not this time is filled with beneficial activities. Systematic empirical research evaluating these suggestions is necessary before firm recommendations can be made.

Goal Setting and Feedback

Given that appropriate feedback, goal setting and monitoring have been proposed as key characteristics of effective practice (see Ericsson et al., 1993; Singer, Murphey & Tennant, 1993, for a review based on studies in sports), providing goals and feedback also would be expected to be beneficial in the music classroom. However, these methods are far more difficult to implement for a group situation than in one-on-one instruction, where an individual performer's specific goal can be related to a specific outcome. For example, although the band director may verbally provide a goal for the group and then give a summary feedback, verbal instructions and feedback may not be given concerning those aspects to which a particular student was actually attending. Instead, students should be involved in the process of goal setting and monitoring and internalize this process. Some teachers have their students evaluate each others' performance. In addition to the disciplinary benefit of this "keep everybody busy" method, it might also serve an important function in allowing the students to improve their abilities to internalize goal setting and to monitor outcomes. Also, many method books provide checklists to be used for setting the right goals or more generally for monitoring progress during practice. Any pedagogical and technical device that supports more specific goal setting and subsequent monitoring will improve the quality of practice in accordance with the deliberate practice concept.

Multiple Training Activities

Deliberate practice in music typically refer to individuals' solitary efforts to improve a particular aspect of their performance. However, the concept of deliberate practice includes any training activity for which goals have been defined and feedback is available. Each learning activity in turn promotes the acquisition of an associated skill; all these skills together lead to a structure which supports a particular performance. To become creative improvisers, jazz musicians imitate models, listen to recordings, and try to understand the style of a given performer. Chess experts spend large amounts of time studying published chess games by masters, predicting the next move and then comparing their predicted move to what the master actually did. Discrepancies between a chosen chess move and the master's move then are analyzed. Assuming that the master's move was indeed the best choice, this activity combines goal setting and instant feedback.

From the chess and jazz example it becomes clear that training activities of experts are closely matched to task demands of the domain, and students should use those same or adapted activities to start developing similar skill and associated underlying representations. For example, expert wind players may work out the peculiarities of their instrument (e.g., natural pitch tendencies), and all students should be taught to work on these performance aspects. Generally, only the careful study of experts' training activities will allow us to translate and adapt some of them to group settings which often include novices and more advanced music students.

Awareness of Mental Representations

Performance is primarily constrained by the requirements of the task and environmental expectations. For example, since work and play do not typically require individuals to exhibit their maximal performance, professionals are often able to increase their performance through training when given external incentives to do so (see Ericsson et al., 1993). Also, plateaus in improvement of performance are mostly due to insufficient motivation and rewards to keep expending the time and effort to improve; but in some cases progress is arrested due to strategies that cannot be extended easily to higher levels of performance. Therefore, music educators should carefully determine the ultimate performance goal for each student and design an educational plan to teach the mental representations that will be necessary to reach that goal.

The ability to perform a specific piece of music can be attained by many different methods. Some methods provide short cuts to minimize effort, while others help to develop and refine complex mental representations. For example, rote memorization is an efficient process for memorizing short easy pieces, but this type of memorization may prove ineffective for longer pieces with a more complex structure or when the memorized material needs to be manipulated during performance. For improvement to continue, strategies that have been useful in the early stages of skill acquisition, such as rote memorization, may need to be replaced later by more effective ones. For example, professional actors have developed strategies for understanding the fictional character they portray on stage so that they can reproduce their lines and actions to virtually eliminate the need for rote memorization (Noice & Noice, 1997). Musicians also show complex memorization strategies (Chaffin & Imreh, 1997; Hallam, 1997; Lehmann & Ericsson, 1998b). Thus, encouraging young musicians to memorize their music by rote might in fact be counterproductive because it may prevent—or at least discourage—the use of higher level musical representations. A similar argument could be made for rote imitation, which may well be an excellent behavior in acquiring musical interpretations at lower levels of performance with sometimes astonishing results; but it is unlikely to suffice when the student attempts to develop into a mature artist. Anecdotal evidence suggest that the ability to imitate by rote versus a more complex artistic skill distinguishes prodigies who eventually fail from those who succeed (e.g., Cortot, 1935).[4]

It should be stressed that many of the above thoughts and suggestions are not new and most of them can be found in teaching methods and treatises. However, while our theoretical framework allows us to explicate why these things work, most master teachers use them intuitively without reflecting on the corresponding learning mechanisms.

Conclusion and Discussion

Skills can be fostered and developed, and training and practice play a crucial part in this process. As the discussion of practice and acquired mental representations has conveyed, there are, however, often qualitative differences in the underlying mechanisms that mediate seemingly similar levels of performance. This may be especially true at lower levels of performance. Mere repetition and experience lead to more fluent performance, but by themselves do not lead to the mental representations that experts employ (e.g., the difference between rote memorization and more complex internal representations of a piece of music that allow experts to adapt to different performance problems). The close association between extended training and performance with the associated specific physiological, psychomotor, and cognitive adaptations provides strong evidence for the acquired nature of skills. Thus, explaining high level performance solely in terms of innate talent might mislead parents and teachers to settle for short-term successes rather than to support and foster the covert and (admittedly) slow emergence of superior skills and representations.

The most effective activities for improving performance are effortful and involve conscious decisions with trade-offs and life-long consequences. They draw heavily upon a person's motivational resources, but not for mindless perserverance to repeat a section 1,000 times, but for motivation to concentrate and deliberately build an integrated skill. Simply playing the same problem section correctly several times or slowing down the tempo may eliminate an immediate performance problem, but it may be far less useful in the long run than carefully studying the cause of the problem (and finding the solution). This procedure would remedy a particular deficiency (as well as similar future problems) by building appropriate mental representations. Even for a student not aspiring to be a virtuoso, the realization of this interplay of final goal and often short-term effort would be of motivational and educational value.

Would it be possible for educators to identify the types of representations a student would most benefit from at a given level of performance? Could educators then design instruction that would enable development of the cognitive and psychomotor skills necessary for expert performance? We believe that further advances in our understanding of music performance learning will depend greatly on future studies of the mental representations that experts are able to develop in relatively optimal learning environments. Not until we understand how these representations can be acquired reliably under optimal conditions can we seriously discuss potential implications for public music education. Regardless, we believe that increased insights into the general processes and cognitive mechanisms of effective deliberate learning will help both teachers and students to reach their immediate performance goals in a manner that is consistent with their long-term goals as musicians. Accordingly, the often-encountered emphasis on short-term performance goals without regard for the mental processes that mediate the attained performance may well be short sighted and might indirectly limit many children's ultimate level of music achievement.

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Author note

Parts of this paper were presented by the first author as an invited paper at the 1997 SUNCOAST Music Education Forum in Tampa, Florida. We also wish to thank R. Woody, L. Hill, and two anonymous reviewers for their comments on earlier versions of this paper.

Footnotes

[1] For example, the height of the tallest 4-year-olds (those in the 95th percentile) is comparable to that of the average 5-year-olds (those in the 50th percentile, Malina & Bouchard, 1991, p. 50). Thus, especially at younger ages, height differences are considerable among children who are almost 12 months apart.

[2] This is anecdotal musical evidence and includes young W. A. Mozart's alleged transcription of a piece after a "single" hearing (MGG, 1961, vol. 9, 701; see Stafford, 1991, for a more moderate version of the same anecdote), and the ability of conductors (e.g., George Szell and Arturo Toscanini) to perform even long operas without a score.

[3] Thus far the only exception to this general rule is height, for which current research shows a strong genetic determination (Ericsson & Lehmann, 1996).

[4] Alfred Cortot is one of the most famous piano teachers of the 20th century.