# Giftedness Viewed From the Expert-Performance Perspective

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*Traditional conceptions of giftedness assume that only talented individuals possess the necessary gifts required to reach the highest levels of performance. This article describes an alternative view that expert performance results from acquired cognitive and physiological adaptations due to extended deliberate practice. A review of evidence, such as historical increases in performance, the requirement of years of daily deliberate practice, and structural changes in the mediating mechanisms, questions the existence of individual differences that impose innate limits on performance attainable with deliberate practice. The proposed framework describes how the processes mediating normal development of ability and everyday skill acquisition differ from the extended acquisition of reproducibly superior (expert) performance and how perceived "giftedness" gives children access to superior training resources, resulting in developmental advantages.*

## Introduction

Only a minute fraction of adults achieve expert performance. Very few people can flawlessly execute a highly complex violin concerto, match a powerful supercomputer at chess, or run a mile in less than 4 minutes. For a long time, many people considered it obvious that individuals with such skills must be inherently different from the rest of us. They must possess unique talents that cannot be developed by experience or training, because, with no immutable inborn limits, why wouldn't every motivated individual reach the highest level?

This article challenges the innate talent assumption and proposes an alternative, the expert-performance approach (Ericsson & Smith, 1991), which focuses on objective measures of representative performance and experimental analysis of reproducible superior achievement in a given domain. This approach focuses on the vast individual differences between experts and novices and con-

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*Journal for the Education of the Gifted*. Vol. 28, No. 3/4, 2005, pp. 287–311.

trasts those with the smaller differences in performance between individuals on everyday skills. The necessary first step of the expert-performance approach is to specify how we can reliably measure the superior performance in a given domain of expertise. Unless superior performance is measurable and reproducible, it does not qualify as scientific evidence of expertise.

Experts and eminent individuals are often revered and, thus, assumed to be dramatically superior to other less accomplished individuals. However, when scientists attempt to measure experts' performance, they frequently find little evidence for a superior level of achievement for the most relevant tasks in their domain of expertise. For example, the length of training and the amount of professional experience of clinical psychologists do not appear related to their success in treating patients (Dawes, 1994). Furthermore, wine experts have claimed to be able to detect the year and the vineyards based on taste. However, when wine experts were required to detect, describe, and discriminate characteristics of wines without seeing the label on the bottle, their performance was only slightly better than that of regular wine drinkers (Gawel, 1997; Valentin, Pichon, de Boishebert, & Abdi, 2000). Similarly, research has demonstrated that judges show surprisingly low agreements among each other when they try to distinguish highly technically proficient students from professional musicians based only on the sound of their music performance. Rather, judges appear to be influenced by irrelevant factors, such as gender, physical attractiveness, and the reputation of the performer (Gabrielsson, 1999). In these cases, the confident evaluations of experts appear to be linked to their knowledge of the reputations of particular wines and of specific musicians, rather than their ability to make perceptual discriminations. Finally, the accuracy of decision making involved in medical diagnoses for common diseases and of investment in the stock market does not dramatically improve with further professional experience or social status (Ericsson & Lehmann, 1996).

On the other hand, expert performers in other domains can reliably reproduce their superior performance in virtually all situations. For example, elite runners finish the mile in less than 4 minutes at different track competitions. Sports have a long history of designing standardized situations to directly compare different athletes' performances. This is also true of competitions in music, dance, architecture, billiards, and chess. In these domains, elite individuals reliably outperform less accomplished individuals.

Drawing on the experts' control over their performances, Ericsson and Smith (1991) described how it is possible to design representative tasks that capture the essence of expertise, where experts can repeatedly reproduce their superior performance under controlled laboratory conditions. For example, expert chess players are able to select the best move when presented with unfamiliar chess positions; this ability is highly correlated with chess tournament ratings. In this way, one can present experts with a representative situation from their domain and measure their performance (Ericsson, 1996, 2002). We believe this representative, reproducible superior performance is the objective data that theories of human ability and giftedness must explain, as opposed to the informal impressions of ability and talent observed under uncontrolled conditions in everyday life.

## Galton's Traditional Account of Giftedness and Natural Ability

The origins of the traditional account of giftedness are traced back to Galton's (1869/1979) seminal book, *Hereditary Genius* (Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Römer, 1993; Simonton, 1999a). In this famous book, Galton presented an argument for the importance of natural ability in attaining eminent achievement in a domain. Galton argued that such attributes as height are stable over time and are determined by hereditary factors passed on from parents. Analogously, Galton proposed that mental capacities of adults are related to the size of an individual's brain and the physiological differences of nerve fibers:

> Now, if this be the case with stature, then it will be true too as regards every other physical feature—as circumference of head, size of brain, weight of grey matter, number of brain fibres, &c.[*sic*]; and thence, a step on which no physiologist will hesitate, as regards *mental capacity*. (Galton, pp. 31–32, italics added)

Galton (1869/1979) clearly acknowledged the need for training to reach high levels of performance in any domain. However, he argued that improvements are rapid only in the *beginning* of training and that subsequent gains become increasingly smaller until "maximal performance becomes a rigidly determinate quantity" (p. 15). After sufficient practice, an immutable limit on performance is reached, "where he cannot by any education or exertion overpass" (p. 15). These immutable characteristics that constrain further improvements in performance cannot, by definition, be changed by training and experience and must, therefore, by determined by innate factors.

Galton's (1869/1979) argument for the importance of innate factors in elite performance is highly compelling and has had a lasting impact on researchers. In a recent review of Galton's work, Jensen (2002) discussed the importance of general heritable intelligence and found that "Overall, Galton's paradigm, with its roots in evolutionary theory, genetics, and physiology, has proved essentially sound" (p. 167). Galton's influence has persisted into modern theories of exceptional ability. For example, Detterman and Ruthsatz (2001) argued "In situations where practice, instruction, or intervention is applied, the most important determinant of a person's final position in a distribution will be their position in that distribution *before* practice, instruction, or intervention" (p. 135, italics added). Plomin and Thompson (1993) concluded that genetics plays a major role in the story and that their analyses indicate "that high ability is also strongly heritable" (p. 77). Other authors have proposed a revised version of Galton's argument. Drawing on empirical evidence about genius and exceptional talents by Lykken (1998), Simonton (1999a) recently argued against the traditional view that talent results from the additive, static effects of genes. He claimed that "[A]lthough superior performance in games, sports, science, and the arts is often ascribed to talent, the hypothesized phenomenon may not be fully understood unless it is conceived as a multidimensional and multiplicative developmental process" (Simonton, p. 435). The complexity of these processes makes it difficult to make and assess empirical predictions for heritable talent. "Only in the case of monozygotic twins, who inherit identical epigenetic programs, would one ever predict equivalent developmental trajectories in the emergence of a given talent" (Simonton, p. 445). Later in this article, we will review some of the new evidence on the rare development of high levels of achievement in identical and fraternal twins.

However, scientists discussing giftedness in art, science, and other professions have also been influenced by Howard Gardner's (1983, 1993) theory of multiple intelligences, where different abilities and innate talents determine success in different domains. Ericsson and Charness (1994) questioned the evidence for Gardner's theory, which led to a discussion between Howard Gardner and the authors (Ericsson & Charness, 1995; Gardner, 1995), and to a subsequent heated exchange by many contributors in *Behavioral and Brain Sciences* (Howe, Davidson, & Sloboda, 1998). Furthermore, more recent research has started to question the generalizability of domain-general abilities and gifts, such as leadership (Fiedler, 1996) and creativity (Baer, 1998) and has supported the domain-specific, acquired nature of these abilities. Similarly, theoretical analyses have shown that the ability of scientists and artists to produce major innovations is very low (Simonton, 1999b) and producing new and different major innovations at a predictable rate appears essentially impossible. The highest levels of creative performance thus fail to meet the reproducibility criterion for expert performance (Ericsson, 1999). In any case, Gardner's theories, as well as other conceptions of giftedness (Detterman & Ruthsatz, 2001; Jensen, 2002; Lykken, 1998; Plomin & Thompson, 1993; Simonton, 1999a), endorse the fundamental assumption that heritable individual differences in innate talent constrain the level of expert performance that people are capable of attaining.

In the first part of the article, we will review evidence that questions Galton's (1869/1979) assumption that innate talents explain individual differences in attained expert levels of performance and shows that the expert-performance framework provides a better account. The second half of the paper will critically review other types of evidence cited in support of giftedness and also discuss common criticisms of the expert-performance framework.

## Recent Evidence Questioning Galton's Assumptions of Immutable Limits

If practice activities only produce diminishing returns as performance approaches the fixed constraints of a person's basic capacities, individuals with fully developed mental and physical capacities (mature adults) should rapidly reach their limits in a given domain. In the first section, we will review evidence that the development of expert performance is gradual and extends over decades, even after physiological maturity is reached. We will then briefly review the evidence against the fixed upper limit of natural ability by demonstrating massive historical changes in the highest levels of performance in many domains. Then we will discuss the importance of environmental conditions and the key role of appropriate training (deliberate practice), arguing that current evidence points to these factors as necessary for the acquisition of expertise. Finally, we will conclude with a discussion of the far-reaching effects of extended deliberate practice on mental capacities and physiological characteristics, questioning the existence and the importance of performance-relevant mechanisms that cannot be enhanced through training.

### *The Gradual Development of Expert Performance*

Recent reviews (Ericsson, 1996; Ericsson & Lehmann, 1996) show that extended engagement in domain-related activities is necessary to attain expert performance. Longitudinal assessments reveal that performance improves gradually, as illustrated in Figure 1; there is no objective evidence either for a high initial level of performance without any relevant experience or for an abrupt improvement of reproducible performance when it is regularly tested. Even the child prodigies in music and chess, whose performance is vastly superior to that of their peers, show gradual, steady improvement over time. Moreover, if the functional capacity of the body and brain limits the achievement of expertise, one would expect performance to peak around the age of physical maturation—the late teens in industrialized countries. However, an expert's best performance is often attained many years, and even decades, later, as illustrated in Figure 1. The age at which performers typically reach their highest level of performance in many vigorous sports is the mid to late 20s; for the arts and sciences, it is a decade later, in the 30s and 40s (see Lehman, 1953, and Simonton, 1997, for reviews). The continued development of expertise past physical maturity shows that experts require vast experience to improve.

The most compelling evidence for the role of extended practice in expertise acquisition is that even the most "talented" need around 10 years of intense involvement before they reach an international level; for most individuals, it takes considerably longer. Simon and Chase (1973) originally proposed the 10-year rule, showing that no modern chess master had reached the international level in less than approximately 10 years of playing. This includes some of the most "gifted" chess prodigies, such as Bobby Fischer, who took just under a decade to reach grandmaster level. Subsequent reviews show that the 10-year rule extends to music composition, as well as to sports, sciences, and arts (Ericsson, Krampe, & Tesch-Römer, 1993). Most important, given that very few individuals sustain a serious commitment to the necessary practice for more than a few months, much less years, most individuals will never know the upper limit of their performance.

### *Historical Improvements in Performance*

The best single source of evidence rejecting the idea that performance is limited by fixed capacities comes from recent historical comparisons (Ericsson, Krampe, & Tesch-Römer, 1993; Lehmann & Ericsson, 1998). The gradual changes in a population's genetic

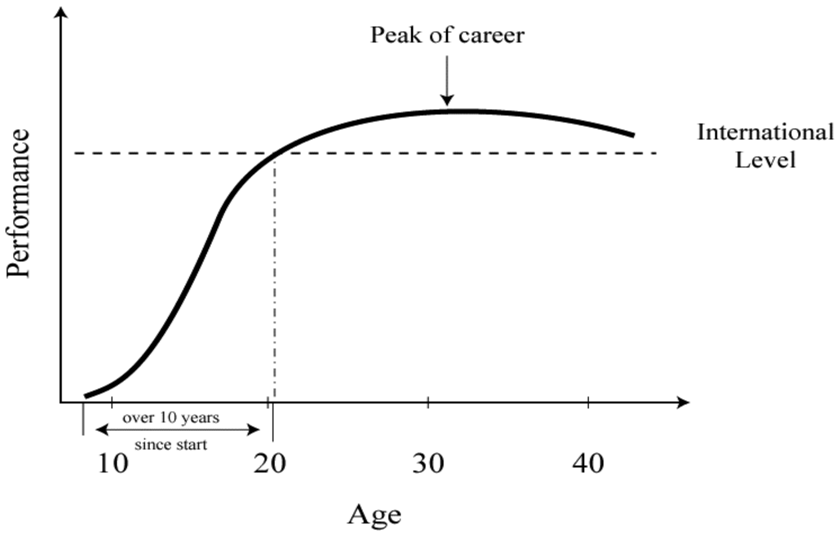


*Figure 1. Expert performance increases as a function of age. An illustration of the gradual increases in expert performance as a function of age in such domains as chess. The international level, which is attained after more than 10 years of involvement in the domain, is indicated by the horizontal dashed line (Ericsson & Lehmann, 1999).*

makeup take thousands of years, yet critical increases in the upper limits of performance have emerged over the last century. The most dramatic improvements in the level of historical performance are found in sports (Schulz & Curnow, 1988). In some events, such as the marathon and swimming events, many serious amateurs of today could easily beat the gold medal winners of the early Olympics. For example, after the IVth Olympic Games in 1908, officials almost prohibited the double somersault in dives, because they believed that those dives were too dangerous and that no human would ever be able to control them. Today's divers consider double somersaults a basic skill to master. Similarly, some music compositions deemed impossible to play in the 19th century have become part of the standard repertoire today (Lehmann & Ericsson, 1998). In general, if the upper limits of performance are fixed by immutable innate capacities, then how has performance increased beyond those limits over a historically short period of time when the gene pool has not changed?

*Training Environments and Practice Activities That Improve Experts' Performance*

The striking difference between elite and average performance results not only from the duration of individuals' training-related activities, but also from the particular types of domain-related activities and environments in which they engage. From retrospective interviews of international-level performers in many domains, Bloom (1985) showed that elite performers are typically introduced to their future domain in a playful manner. As soon as they enjoy the activity and show promise, they are encouraged to seek out a teacher and initiate regular practice. Based on his interviews, Bloom argued that access to the best training resources was necessary to reach the highest levels. In many situations, the parents of the future elite performers spend large sums of money for teachers and equipment and devote considerable time escorting their child to training and to weekend competitions. In some cases, the performer and his or her family even relocate to be closer to the teacher and to the training facilities.

Additionally, a century of laboratory research has revealed that learning is most effective when it includes focused goals, such as improving a specific aspect of performance, feedback that compares the actual to the desired performance, and opportunities for repetition to achieve the desired level of proficiency. Based on interviews with expert violinists at the music academy in Berlin, Ericsson, Krampe, and Tesch-Römer (1993) traced the duration of music students' engagement in specific activities during the period prior to entering the music academy. They were particularly interested in activities that had been specifically designed to improve performance, which they called deliberate practice. A prime example of deliberate practice is the music students' solitary practice in which they work to master specific goals determined by their music teacher at weekly lessons. The authors compared the use of time among several groups of differentially skilled musicians, obtained from daily diaries and retrospective estimates. Even among these expert groups, they found that the most accomplished musicians had spent more time in activities classified as deliberate practice during their development and that those differences were reliably observable before their admittance to the academy at around age 18. By the age of 20, the best musicians had spent more than 10,000 hours practicing, which is 2,500 to 5,000 hours more than the two less accomplished groups of expert musicians, respectively, and 8,000 hours more than amateur pianists of the same age (Krampe & Ericsson, 1996).

Several studies and reviews have found a consistent association between the amount and the quality of solitary deliberate practice and performance in chess (Charness, Krampe, & Mayr, 1996), in music (Krampe & Ericsson, 1996; Lehmann & Ericsson, 1996; Sloboda, 1996), and in different types of sports (Ericsson, 2003a, 2003b; Helsen, Starkes, & Hodges, 1998; Starkes, Deakin, Allard, Hodges, & Hayes, 1996; Ward, Hodges, Williams, & Starkes, 2004). The concept of deliberate practice also accounts for many earlier findings in other domains, such as medicine, software design, bridge, snooker, typing, and exceptional memory performance (Ericsson & Lehmann, 1996), as well as for the results of the rare longitudinal study of elite athletic performers (Schneider, 1993).

### *Going Beyond Mere Experience: The Transforming Effects of Extended Deliberate Practice*

The fundamental claim that most adults reach a stable performance asymptote within a limited time period may hold for everyday activities, such as casual golf, driving a car, balancing a checkbook, using new computer software, or other common skills. However, the same claim does not extend to expert performers, who continue improving their performance for years and decades.

When children and adults are first introduced to an activity, their primary goal is to reach an acceptable level of mastery. According to the traditional theory of skill acquisition (Fitts & Posner, 1967), people initially need to concentrate on what they are going to do in order to reduce gross mistakes, as illustrated in the lower arm of Figure 2. With more experience, salient mistakes become increasingly rare, and their performance eventually reaches an acceptable standard where the need for effortful concentration is minimized. As the performance becomes adapted to the situational demands and becomes increasingly automated, individuals stop making specific intentional adjustments. In direct contrast, expert performance continues to improve as a function of more deliberate practice, as shown by the top arm of Figure 2. The challenge for aspiring expert performers is to avoid the arrested development associated with automaticity and to acquire new cognitive skills through their continued learning and improvement.

Furthermore, successful development of elite performance requires more than the extended engagement in the typical domain-related activities. Elite performers transform the cognitive and physiological mechanisms mediating their performance by engaging in deliberate practice, as shown in Figure 2. Moreover,

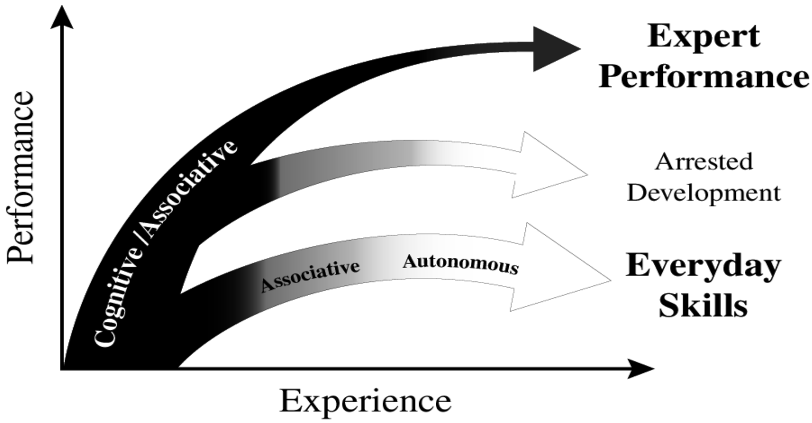


*Figure 2. The course of improvement of expert performance versus everyday activities. An illustration of the qualitative difference between the course of improvement of expert performance and of everyday activities. The goal for everyday activities is to reach as rapidly as possible a satisfactory level that is stable and "autonomous." After individuals pass through the "cognitive" and "associative" phases, they can generate their performance virtually automatically with a minimal amount of effort (see the gray/white plateau at the bottom of the graph). In contrast, expert performers counteract automaticity by developing increasingly complex mental representations to attain higher levels of control of their performance and will, therefore, remain within the "cognitive" and "associative" phases. Some experts will, at some point in their careers, give up their commitment to seeking excellence and, thus, terminate regular engagement in deliberate practice to further improve performance that results in premature automation of their performance. (Adapted from "The Scientific Study of Expert Levels of Performance: General Implications for Optimal Learning and Creativity," Ericsson, 1998b, p. 90.)*

this modification of complex cognitive mechanisms requires problem solving and full concentration (Ericsson, 1996, 2002). In a similar manner, shaping physiological mechanisms results from the effortful challenging of the associated biological systems. In fact, research on aerobic fitness shows that to merely *maintain* one's fitness level athletes have to consistently engage in the same high-intensity exercise they used to develop their bodies' current physiological adaptations. However, once an adaptation is attained, it is possible to reduce the duration of the weekly training time from the level originally required. But the key challenge of deliberate practice is to *maintain improvement efforts* for as long as the individual wishes to move beyond his or her current level. With such an approach, the individuals' level of performance rises, and the demand for further effort is not reduced—if anything, the demand for effort is *increased*.

As a result of deliberate practice, many biological characteristics, such as width of bones, flexibility of joints, size of heart, metabolic characteristics of muscle fibers, and so forth, can be changed after years of intense and carefully designed training. Biochemical processes that preserve equilibrium during intense training influence these anatomical changes (Ericsson, 2003c). For example, when subjects run, the mechanical impact of feet hitting the ground can deform the cell walls of bone cells, separating the molecules. These molecules can then set in motion a cascade of biochemical processes by activating genes to stimulate growth of bones' diameter, but not length. Further, this proposed mechanism for bone adaptation explains why there are a few exceptional characteristics that cannot be increased through practice, namely height. The kind of external strain and forces that would have to be induced on long bones in the body to increase their length is virtually physically impossible, which explains why height is currently the only confirmed instance of innate talent that both influences expert performance and cannot be modified by training. Height is associated with superior performance in many sports, especially those involving strength and speed, and smaller body size is associated with superior performance in gymnastics and horseback riding.

Deliberate practice can also lead to the acquisition of qualitatively different mental representations that allow the expert performer to bypass the information-processing constraints imposed by basic capacities. For example, the increased capacity of the experts' working memory for planning and reasoning reflects acquired domain-specific memory skills for efficient storage in long-term memory (Ericsson & Kintsch, 1995). Similarly, the superior speed of elite athletes in representative situations, such as the return of a tennis ball, does not reflect superior perceptual acuity or faster cognitive speed, as reflected by simple reaction time, but, rather, skilled anticipation of events by identification of early predictive cues. Overall, after long periods of sustained effort, performers transform their mental representations to adapt to highly specific tasks. These adaptations do not result from mere experience in a domain and only arise from extensive efforts. The real key to understanding expert and exceptional performance is linked to *the motivational factors* that lead a small number of individuals to maintain effortful pursuit of their best performance throughout their productive career, in contrast to the vast majority of individuals who prematurely settle for a merely acceptable level.

With respect to Galton's (1869/1979) claims, we contend that they could be consistent with the development of many everyday skills, where a stable level of acceptable performance is rapidly attained through experience (Ericsson, 1996, 2002). Once a sufficient level of performance has been reached, additional experience does not alter the structure of the performance, but leads to its automation. However, Galton's claims are inconsistent with the development of high-level and expert performance, where the structure of performance is gradually constructed, transformed, and shaped by deliberate practice. The primary goal of expert performers is to increase the ability to plan, control, and monitor performance by continually improving their mental representations, allowing them to surpass the limits associated with everyday skills. Our reviews have not uncovered any evidence for innate, unmodifiable gifts necessary for the attainment of high levels of performance, with the exception of height and body size (Ericsson, 1996; Ericsson & Lehmann, 1996)—the characteristic that Galton explicitly referred to in his analogy between the heritabilities of physical and mental capacities.

## The Effects of Perceived Talent

Galton's (1869/1979) conception of giftedness appears intuitive from informal observations on how people acquire skills in everyday life. Some people develop certain recreational and everyday skills much faster than others; for example, some children seem to easily acquire athletic abilities and others quickly learn new games. When some individuals learn more rapidly or more readily than their peers, it is tempting to label these individuals as talented. The talent view can also be attractive to some teachers and students, because, when a student fails to make progress, neither the teacher nor the student can be held responsible—the student merely lacks the necessary gifts. However, the expert-performance perspective claims that findings on how people may rapidly attain proficiency in everyday activities cannot be extrapolated to explain the results of the extended period of training and consequent adaptations necessary to reach the highest levels in a domain of expertise. Moreover, we argue that the evidence for effortless acquisition of expertise by talented eminent individuals comes primarily from anecdotes and stories, rather than verified scientific data. In this article, we sometimes use quotation marks around *gifted* and *talented* because individuals are often considered innately talented without any firm objective evidence.

First, we will review the anecdotal evidence for early talent and then identify instances where perceived "talent" is related to success and how early training can lead to acquired mechanisms and physiological adaptations that might be misattributed as innate talent and gifts. In the last section, we will address a common criticism of the expert-performance approach, namely its unwillingness to extrapolate from evidence on the heritability of everyday abilities to that of elite performance.

### *Anecdotal Accounts for Early Talent*

When we apply standard scientific criteria to the empirical evidence for exceptional performance, we find that most anecdotal, often amazing, descriptions of innate talent cannot be adequately verified (Ericsson, 1998b, Lykken, 1998). In his classic book, *Men of Mathematics*, Bell (1937) argued that "In all of the history of mathematics there is nothing approaching the precocity of Gauss as a child (p. 220). As a 3-year-old, Gauss overheard his father calculating the weekly payroll for his workers, and by mentally checking the calculations Gauss pointed out a mistake. Unfortunately, these and other popular childhood anecdotes about Gauss' mathematical genius are based solely on stories told by Gauss himself as an old man. Given that these accounts lack any independent verification, they are not even considered by modern biographers (Bühler, 1981). However, Bell based his complete faith in Gauss's detailed descriptions of events from his early childhood on another controversial claim, namely that Gauss had a photographic memory that never decayed. Subsequent laboratory research has been unable to confirm even a single instance of a photographic memory (Ericsson & Chase, 1982; Haber & Haber, 1988). Throughout his life, if Gauss repeatedly tried to search for evidence of his innate "gifts," his accounts in adulthood may reflect transformed and elaborated memories from childhood. Regardless, unverifiable anecdotes from history, regardless of their content, have no place in a scientific analysis of exceptional and expert achievement.

In a review of the more recent evidence proposed for innate talent, Ericsson and Charness (1994) argued that, because training and practice have great effects on performance, many people have looked for evidence of gifts in early childhood. For example, Scheinfeld (1939) claimed that virtually all the famous musicians have shown clear evidence for music "talent" prior to any training in music. However, a closer examination of the "clear evidence" cited for innate talents reveals it to be "response to violins at concert" (p. 239; e.g., Yehudi Menuhin at 18 months) or producing song-like sounds before speaking (e.g., Arthur Rubinstein at 18 months). These and other related types of musical "talent" have been recently reported among all children, and the age of first appearance or frequency is unrelated to subsequent music performance (Howe, Davidson, Moore, & Sloboda, 1995). Apparently, parents search for signs of talent and when they find "something," they rely on it as a reason to provide training and encourage the development of skill, which we argue are the real causes for the development of high levels of performance. Even talent identification procedures in most educational programs have unclear or ambiguous definitions for "gifts." Feldhusen & Jarwan (1993) pointed out that "much of current practice in identification derives from practicality, judgment of questionable 'experts,' or tradition" (p. 247). These authors agree that "there is a need to be explicit in defining the giftedness construct, the component traits and aptitudes, as a prelude to the use of the [giftedness] label" (p. 247). Without a consensus or a clear definition of giftedness, a scientific evaluation of its causal effects on performance improvements remains tenuous, especially when the evaluation of giftedness is confounded by the effects of training and experience.

### *The Effects of Perceived Talent—the Relative-Age Effect*

Efforts to find objective measures of innate talents that predict adult professional achievement have been disappointing and largely unsuccessful (Ericsson & Lehmann, 1996). In fact, there is now evidence that the most successful selection programs in sports are systematically biased by factors unrelated to innate talents. For example, professional athletes in soccer and ice hockey are born much more frequently (3–6 times) in some months of the year than in others (Boucher & Mutimer, 1994). The factors determining this "birthdate" effect are now widely accepted. When children start participating in sports, they are nearly always grouped together in age cohorts. For example, children born between January 1 and December 31 in a specific year are grouped together to form teams in hockey. Consequently, the oldest children in that cohort will be almost 1 year older than the youngest children in the same age cohort. Children often start to compete when they are very young, such as around 6 years of age. At that young age, one additional year of development will result in considerable differences between children in the same cohort, especially since some 7-year-olds will be competing with 6-year-olds. Coaches who do not know the children's birth dates tend to perceive the oldest and most physically mature children within an age cohort as the most talented. The older children are, thus, more frequently selected into talent-development groups. This selection process allows children access to better training resources that, in turn, accelerate their development. A recent review by Musch and Hay (1999) has more or less conclusively linked the birthdate effect to the relative age of children competing within the same age cohort. The most compelling evidence comes from a recent study (Helsen, Starkes, & van Winckel, 2000) that analyzed a natural experiment where the dates defining the age cohorts were changed. In Belgium, the age cohort for soccer players originally consisted of all children born from August 1 to July 31, resulting in high success for children born in August, September, and October. This age cohort was changed in 1997 to the time frame from January 1 to December 31. Within a single year, children born in January to March immediately became the most highly selected among the young soccer players. However, the early search for talent clearly has powerful effects by selectively identifying, though likely incorrectly, some children as being more "talented."

### *How Early Training Can Cause Adaptations That Are Perceived as Innate Talents and Gifts*

The talent attribution often causes parents to provide regular instruction and supervised practice, which in turn lead to marked performance improvements. In many domains, such as music and sports, parents arrange for their children to start practice at very young ages, sometimes as young as 3–4 years of age (Ericsson, Krampe, & Tesch-Römer, 1993; Lehmann & Ericsson, 1998). This early start becomes a major advantage for later skill development, and these trained children will be able to perform at substantially higher levels when compared to many of their peers, who may only begin in a domain at around 10–14 years of age. The qualitatively higher performance of the trained children reinforces the perception that they are "gifted," often motivating them to continue effortful improvement activities.

Early training during certain periods of development, such as early childhood, appears to yield especially large adaptive responses. For example, recent research has shown that normal children between 3 and 5 years of age can acquire perfect pitch: the ability to name individual tones presented in isolation. Differences in brain structure are observed in individuals with perfect pitch when compared to that of other musicians (Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995). These differences can be explained by early childhood activities that lead to different patterns of neurological development. Numerous animal studies show that training influences neurological development through the growth of blood supply, the density of synapses, and even by restricting development of certain structures. For musicians who play stringed instruments, the size and elaboration of cortical mapping for the fingers, especially the little finger on the left hand, is correlated with the onset of music training (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). Other performance-related physiological characteristics, such as the metabolic characteristics of muscle fibers, may be more easily influenced during early development than in adolescence and adulthood (Ericsson, 2003a, 2003b, 2003c; Ericsson & Lehmann, 1996).

In our review of the acquisition of very high levels of performance, we showed that the best performers had engaged in substantially more deliberate practice and that this was responsible for large physiological adaptations that distinguish the elite from less accomplished performers. The importance of intense engagement in practice activities has been demonstrated for "gifted" children in the visual arts. According to Hyllegard (2000), parents of children in a gifted program reported that their children spent more time drawing and copying per week than many of the best musicians spent on solitary practice at comparable ages (Ericsson, Krampe, & Tesch-Römer, 1993). In her studies of visually "gifted" children, Winner (1996) found that they differed in their attitude toward their craft. Not surprisingly, one highly typical characteristic of gifted individuals is the "rage to master," where they "exhibit intense (almost obsessive) interest [in a domain] and an ability to focus their attention sharply" (Winner, 2003, p. 372). Such motivational characteristics are fundamental attributes of deliberate practice, which is the cause of continued improvement.

### *Reasons Expert Performance May Not Be Mediated by Heritable Talents*

Reviews of giftedness and genius (Lykken, 1998; Sternberg, 1996) criticize the expert-performance approach for not sufficiently considering the overwhelming evidence for the moderate heritability of many human abilities in everyday life. In fact, Sternberg found it incredible that Ericsson and his colleagues (Ericsson, 1996; Ericsson, Krampe, & Tesch-Römer, 1993) had argued for "the overshadowing role of deliberate practice" for the acquisition of expert performance in light of "the overwhelming evidence for the existence of talent differences" (p. 348). The expert-performance approach (Ericsson, 1996, 1998a, 2002, 2003a; Ericsson & Charness, 1994) does, however, acknowledge that performance on many types of psychological tests is heritable in the sense that genetically related individuals, such as identical twins, are likely to have a more similar performance than fraternal twins and adopted siblings (Plomin, DeFries, McClearn, & McGuffin, 2000). The point of disagreement concerns whether the large body of evidence on heritability of abilities measured in the laboratory and in everyday life can be generalized to the mechanisms that mediate very high levels of performance. Behavior geneticists argue that such an extrapolation from observed heritabilities of everyday abilities to those of expert performance is reasonable (Bouchard & Lykken, 1999), based on a few assumptions.

The first assumption supporting extrapolation to expert performance is that the same basic capacities mediate all types of performance—ranging from the initial performance on unfamiliar tasks to expert performance. There is, however, extensive evidence that shows that during the acquisition of skill, the mediating mechanisms change dramatically (Fitts & Posner, 1967). After the initiation of regular deliberate practice, further changes to the mechanisms mediating expert levels are assumed to be even more dramatic (Ericsson, 2002). When a new task is initially learned, individual differences in tests of cognitive abilities and intelligence are related with performance (Ackerman, 1987; Keil & Cortina, 2001). With further practice, these effects diminish; and after a decade of experience, no reliable differences in performance remain (Hulin, Henry, & Noon, 1990). Consistent with the argument that acquired skills draw on mechanisms that are unrelated to those used in everyday and in unfamiliar tasks, Howe et al. (1998) reported that heritabilities for skilled (not expert) performance were low, much lower than those estimated for psychometric tests of basic capacities. The expert-performance perspective argues that one cannot extrapolate to expert performance from the observed heritabilities for behavior and performance in everyday life or even moderately skilled performance. As shown earlier in this article, expert performance is mediated by acquired complex mechanisms and physiological adaptations (Ericsson, 1998a) that result from the extended periods of daily deliberate practice.

The second assumption for supporting extrapolation to expert performance from average and recreational levels of performance is based on the generalizability of the structure of human abilities. Why wouldn't expert performance be heritable if so many other aspects of human performance are? Interestingly, Bouchard and Lykken (1999) acknowledged that this proposed extrapolation is merely an untested assumption. Ericsson, Krampe, and Tesch-Römer (1993) investigated the rare studies on the heritability of expert performance, and they pointed out that these studies examined Olympic athletes and did not report any reliable heritability of elite performance. More recent research on twins has shown that the same genetic endowment does not determine attained level of expert performance. Not even when identical twins engage in extended practice in the same domain will twins necessarily attain the same, or even similar, levels of performance (Klissouras et al., 2001). More generally, Bouchard and Lykken (1999) reported that twins (fraternal or identical) almost never reach elite levels of performance. This striking underrepresentation of twins and of adopted individuals among the elite will effectively prevent the estimation of heritability for eminent achievement. It will, therefore, be very difficult to empirically test Simonton's (1999a) hypothesis that the correct unique combination of innate talents in a supportive environment will reliably lead to outstanding achievement in a domain.

In sum, as scientists, we do not preclude the possibility that individual differences in genetic endowment, beyond the discussed effects of height, may some day emerge as useful predictors of the attained level of expertise. We simply point out that the current evidence for hypothetical innate capacities that limit people's ability to attain expert performance is essentially nonexistent and does not meet normal scientific standards (Ericsson, Krampe & Heizmann, 1993). Moreover, the expert-performance perspective has always recognized the likely possibility that "individual differences in factors related to individuals' motivation to practice can account for any heritable influences in attained levels of performance" (Ericsson, Krampe, & Tesch-Römer, 1993, p. 399). This perspective makes a clear distinction between the instructional, motivational, and attentional factors, the prerequisites for sustaining daily deliberate practice for extended periods of time, from the innate endowments of capacities, gifts, and talents. We believe that this distinction will be crucial to teachers and educators who are interested in improving the education and training of a new generation of students.

## Conclusions

The traditional view of giftedness emphasizes the role of innate talent and extrapolates the acquisition of proficiency in everyday skills to the acquisition of expert and eminent performance. The expert-performance perspective rejects that extrapolation and proposes instead that the acquisition involves gradual improvements that correspond to changes in how the brain and nervous system control performance and in the degree of adaptation of the body's physiological systems. It also argues that these changes are induced by practice activities designed to modify the current mechanisms to allow incremental performance improvements. Hence, the individual differences in genetically determined capacities and fixed structures required for the development of elite performance appear to be quite limited, perhaps even restricted, to a small number of physical characteristics, such as height and body size. The expert-performance framework attempts to explain the large individual differences in performance in terms of individual differences in sustained deliberate practice.

More generally, the framework also challenges researchers to specify the particular causal mechanisms that explain correlations between perceived characteristics of experts and the level of their performance. There is now compelling evidence that many abilities of the elite performers are not signs of innate talent, but, rather, the result of extended practice, sometimes amplified by an early start of training during childhood. Similarly, it is possible that, when coaches perceive a relation between high levels of motivation and attained performance, the ratings of motivation may really reflect the athletes' willingness to engage in relevant practice with higher quantity and, most important, quality (deliberate practice).

Once we acknowledge that expert performance is mediated by complex integrated systems of representations for the execution, monitoring, planning, and analysis of performance, it becomes clear that the acquisition of expertise requires extended, deliberate efforts. Even the individuals initially considered "gifted" must continue to practice for years and decades. Failure to sustain deliberate practice may partly explain why so many individuals stop improving and, thus, never realize their potential (Winner, 2003). On the other hand, those individuals who continue their efforts demonstrate their remarkable plasticity and suggest the great achievement potential of all healthy children and adults.

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## Authors' Note

This article was prepared in part with support from the FSCW/Conradi Endowment Fund of Florida State University Foundation. The authors want to thank Ed Cokely and Len Hill for their valuable comments on an earlier draft of this paper.