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THE SCIENCE OF EXPERTISE

Behavioral, Neural, and Genetic Approaches to Complex Skill

Edited by David Z. Hambrick, Guillermo Campitelli, and Brooke N. Macnamara

With a foreword by Robert Plomin

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9

THE DELIBERATE PRACTICE VIEW

An Evaluation of Definitions, Claims, and Empirical Evidence

Brooke N. Macnamara, David Z. Hambrick, David J. Frank, Michael J. King, Alexander P. Burgoyne, and Elizabeth J. Meinz

Introduction

The question of how people acquire high levels of skill in complex domains such as music, games, sports, and science has long been of interest to psychologists. Nearly 25 years ago, in their classic article, Ericsson, Krampe, and Tesch-Römer (1993) introduced the highly influential *deliberate practice view* in an attempt to answer this question. This view proposes that individual differences in expertise are largely accounted for by differential amounts of "deliberate practice"—effortful training activities specially designed to improve performance.

To test this view, Ericsson *et al.* (1993) asked violin students to retrospectively estimate their lifetime hours of *practice alone*—the time they spent practicing music on their own to improve their skills. Ericsson *et al.* found that the average number of accumulated hours of practice alone was higher for the "best" violinists than for the "good" violinists. Furthermore, the combined average of these two groups was higher than the average for the least accomplished "music teachers." In a second study, Ericsson *et al.* found that "expert" pianists had accumulated thousands of hours more practice alone than "amateur" pianists.

Ericsson *et al.* (1993) concluded that "individual differences in ultimate performance can largely be accounted for by differential amounts of past and current levels of practice," (p. 392) and that "[i]ndividual differences, even among elite performers, are closely related to assessed amounts of deliberate practice" (p. 363). They further argued, "Our theoretical framework can also provide a *sufficient account* of the major facts about the nature and scarcity of exceptional performance. Our account does not depend on scarcity of innate ability (talent)" (p. 392, emphasis added). Making exceptions only for height and body size, they added, "[W]e reject any important role for innate ability" (p. 399).

The deliberate practice view has had tremendous impact on both scientific and popular views on expertise. Cited more than 6,600 times (source: Google Scholar as of December 19, 2016) since its publication, the Ericsson *et al.* (1993) article is one of the most referenced articles in the psychological literature. Moreover, numerous popular books have been inspired by the deliberate practice view, including Geoff Colvin's (2008) *Talent Is Overrated* and Malcolm Gladwell's (2008) *Outliers*, where Gladwell describes his "10,000-hour rule"—the idea that it takes 10,000 hours of practice to become an expert. No one has had a greater impact on scientific and popular views of expertise than Ericsson.

Why is the deliberate practice view so popular? Even though the view is not so simplistic, a likely reason is that it reinforces the idea that through hard work and determination, anyone can accomplish anything they set their mind to—an idea many people embrace. This was the case with professional photographer Dan McLaughlin, who after reading Colvin's and Gladwell's books quit his job to complete 10,000 hours of deliberate practice in golf (see thedanplan.com). With consultation from Anders Ericsson, McLaughlin's goal was to make it to the PGA Tour—the highest level of competitive golf. In a report on the first half of the project, he wrote, "It would be a lot easier to just . . . say it takes 'natural talent' to make it, but we here at The Plan don't believe in that attitude. Anything is possible with enough determination, hard work and proper guidance" (McLaughlin, 2014, p. 913). McLaughlin recalls Ericsson telling him, "I think you're the right astronaut for this mission" (see http://www.thedanplan.com/theplan.php).

Deliberate practice is clearly an important factor in becoming an expert. Obviously, no one can become an expert in a field like music, science, golf, or chess without extensive training. That is, people are not born with the sort of specialized knowledge that underpins success in these domains. Additionally, there is also no reason to doubt that virtually any healthy person will benefit from deliberate practice. Dan McLaughlin is a case in point: After nearly 6,000 hours of deliberate practice his handicap (an index of golf skill) was about 4, putting him in the top 5 percent of amateur golfers (see Figure 9.1). Regardless of whether he reaches the PGA Tour, this is a level of performance that few golfers ever achieve. Furthermore, some forms of training have a greater impact on performance than others. For example, as psychologists have long known, immediate feedback is generally beneficial for learning (McGehee, 1958; McKeachie, 1961).

In more technical terms, deliberate practice very clearly contributes to *intra*-individual variability in skill level—that is, an individual's improvement in a domain. However, in recent years, expertise researchers have questioned Ericsson and colleagues' central claim that deliberate practice largely accounts for *inter*-individual variability in performance—that is, performance differences across individuals (e.g., Gobet & Campitelli, 2007; Hambrick, Macnamara, Campitelli, Ullén, & Mosing, 2016). The fact that training is necessary for an

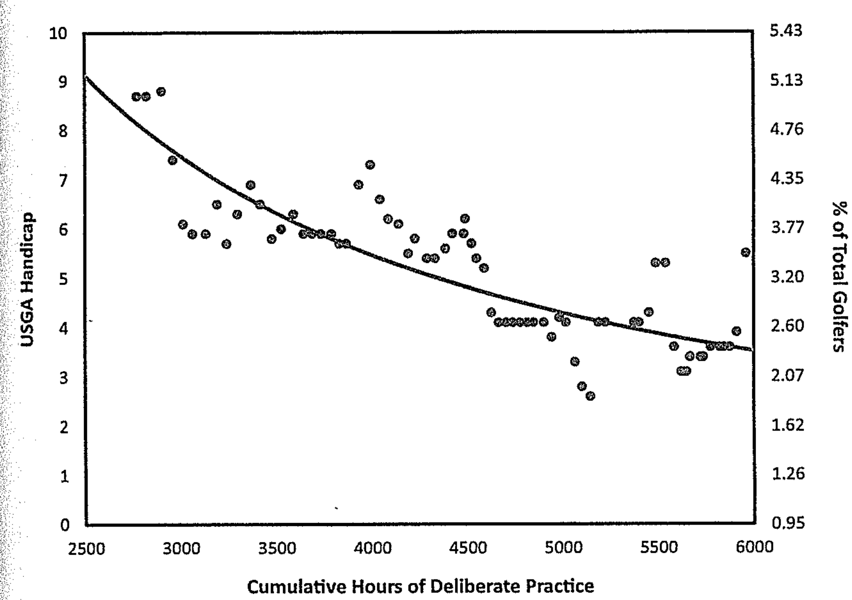

FIGURE 9.1 Illustration of intra-individual variability in skill; relationship between accumulated deliberate practice and golf skill in Dan McLaughlin (data obtained from http://www.thedanplan.com).

individual to acquire skill does not imply that individuals acquire skills at the same rate (or have the same starting points or asymptotes in their performance). That is, the necessity of training for individual improvement does not mean that training must also largely account for skill differences *between individuals*. In fact, evidence from recent meta-analyses (Macnamara, Hambrick, & Oswald, 2014; Macnamara, Moreau, & Hambrick, 2016) reveals that deliberate practice leaves the majority of the inter-individual variability in performance unexplained and potentially explainable by other factors. The view that has emerged from this evidence is that deliberate practice is an important piece of the expertise puzzle—but not the only piece.

In this chapter, focusing on our own research but highlighting findings from others' research, we briefly review empirical tests of the deliberate practice view. We then discuss Ericsson's response to these challenges, focusing on discrepancies between claims and empirical evidence, and inconsistent definitions of theoretical terms. We then discuss how these discrepancies and inconsistencies limit progress in scientific research on expertise.

Empirical Tests of the Deliberate Practice View

Does deliberate practice *largely* explain individual differences in expertise as Ericsson and colleagues have claimed? It does not appear so. Searching more than 9,300 documents, Macnamara, Hambrick, and Oswald (2014) conducted the most extensive systematic review of deliberate practice to date—a meta-analysis across all major domains in which deliberate practice had been investigated. On average, deliberate practice accounted for 12 percent of the variance in performance across individuals. The average contribution of deliberate practice varied considerably by domain—26 percent for games, 21 percent for music, 18 percent for sports, 4 percent for education, and less than 1 percent in other professions. However, across all domains, the evidence indicated that deliberate practice leaves a large amount of variance in performance unexplained, even after correcting for measurement error (see also Hambrick, Oswald, *et al.*, 2014).

More recently, Macnamara, Moreau, and Hambrick (2016) investigated the contribution of deliberate practice to sports performance. The effect of deliberate practice was very similar to the overall average (18 percent) for studies that measured solitary practice (22 percent), those that measured performance via objective measures (e.g., race time; 20 percent), and those that measured performance via group membership (e.g., an athlete on a national team vs. a state team; 25 percent). However, the relationship between deliberate practice and expertise varied by skill level: Deliberate practice explained 19 percent of the variance in performance among sub-elite athletes (e.g., recreational athletes, athletes competing at the state level), but explained only 1 percent of the variance in performance among elite athletes (e.g., athletes competing in the NCAA championship, international competitors, Olympians). This finding suggests that deliberate practice may lose its predictive power at a high level of skill, contrary to Ericsson *et al.*'s (1993) claim that "[i]ndividual differences, even among elite performers, are closely related to assessed amounts of deliberate practice" (p. 363). That is, factors other than deliberate practice may differentiate who merely reaches a high level of skill and who becomes a top-ranked athlete in a sport.

Overall, these results indicate that people require very different amounts of deliberate practice to acquire complex skills. For example, in Ericsson *et al.*'s (1993) study of violinists, the 95 percent confidence interval around the mean of accumulated deliberate practice at age 18 for the 'best' violinists ranged from 2,894 hours to 11,926 hours (Ericsson, 2014c). Similarly, Sloboda, Davidson, Howe, and Moore (1996) studied the practice habits of music students across different skill levels and found there were some students who attained each skill level by practicing less than 20 percent of the mean amount for that group. As another example, in Gobet and Campitelli's (2007) study of chess players, the amount of deliberate practice (including both individual and group activities) to reach "master" status ranged from 3,016 hours to 23,608 hours—a difference of nearly a factor of 8.

Results of a training study provide an additional illustration to this point. Sakakibara (2014) enrolled children from a music school in a training program

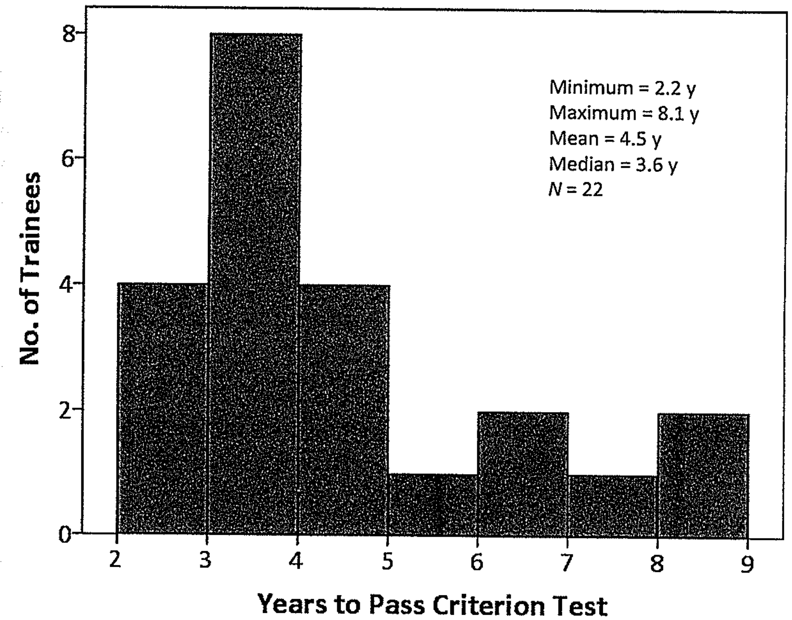

FIGURE 9.2 Frequency distribution for time to reach criterion for AP in Sakakibara's (2014) pitch training study (data obtained from Sakakibara's Table 2; $N = 22$).

designed to train absolute pitch (AP). Colloquially known as "perfect pitch," AP is the ability to name the pitch of a tone without hearing another tone for reference. With a trainer playing a piano, the children learned to identify chords. Then, the children were tested on their ability to identify the pitches of individual notes until they reached a criterion level of proficiency. Nearly all of the children (22 of 24) completed the training and reached the criterion. However, there was a large amount of variability in the amount of time it took them to reach criterion—from around 2 years to 8 years (see Figure 9.2). Based on this finding, Sakakibara concluded that "the possibility of a genetic predisposition in AP cannot be denied" (p. 101).

In short, there is now a large amount of evidence to indicate that deliberate practice does not *largely* account for individual differences in expertise. Based on this evidence, we have argued that deliberate practice is one, but not the only, important factor contributing to inter-individual variability in expertise. More to the point, we have argued that deliberate practice is an important predictor of individual differences (i.e., *inter*-individual variability) in expertise—just not as important as Ericsson *et al.* (1993) originally argued it is.

Ericsson's Response

In response, Ericsson has mounted a vigorous defense of the deliberate practice view. However, as we have noted elsewhere (Hambrick, Altmann, *et al.*, 2014; Macnamara, Moreau, & Hambrick, 2016), this defense is undermined by contradictions and inconsistencies in Ericsson's arguments. Here, we highlight some of these contradictions and inconsistencies, focusing on shifting definitions of the key theoretical terms *deliberate practice* and *expert performance.*

Definitions of Deliberate Practice

Ericsson has argued that many of the studies that we included in our meta-analyses did not measure *actual* deliberate practice. For example, in an unpublished commentary Ericsson (2014a, 2014b) claimed many of the studies we included "used operational definitions of practice that violate our [Ericsson et al.'s, (1993)] original definition of deliberate practice" (2014a, p. 4), even though we used operational definitions of deliberate practice used by Ericsson, including his original operational definition (see Ericsson *et al.*, 1993). In a similar vein, in their recent book *Peak: Secrets from the New Science of Expertise*, Ericsson and Pool (2016) claimed that the "major problem with this meta-analysis [Macnamara *et al.*, 2014] was that few of the studies the researchers examined were actually looking at the effects of the type of practice on performance that we had referred to as deliberate practice" (p. 276).

However, Ericsson and colleagues have multiple definitions of "deliberate practice" that sometimes contradict one another. As one example, Ericsson and colleagues have been inconsistent about whether a teacher (or coach) must design training activities for them to qualify as deliberate practice (see Table 9.1): Krampe and Ericsson (1996) explained that "Ericsson et al. defined *deliberate practice* as a very specific activity designed for an individual by a skilled teacher" (p. 333), but Ericsson (1998) later explained that "Ericsson et al. (1993) proposed the term deliberate practice to refer to those training activities that were designed solely for the purpose of improving individuals' performance by a teacher *or the performers themselves*" (p. 84, emphasis added; see also Keith & Ericsson, 2007). Thus, Ericsson and colleagues have claimed both that involvement of a teacher *is* and *is not* necessary for an activity to qualify as deliberate practice. (In our own meta-analyses, we used the latter definition of deliberate practice, particularly given that we could find no record in any study Ericsson has authored on accumulated deliberate practice where his operational definition limited practice estimates to only teacher-designed activities.) As another example, in the seminal study of deliberate practice, Ericsson *et al.* (1993) operationally defined deliberate practice as estimates of "practice alone," yet in the commentary on the Macnamara *et al.* (2014) meta-analysis, Ericsson stated that at present "it is *not possible* to estimate the proportion of deliberate practice from estimates of practice alone" (Ericsson, 2014a, p. 5, emphasis added).

In the commentary on our meta-analysis, Ericsson (2014a, 2014b) rejected 87 of the 88 studies.[1] He even rejected studies that he has used in the past to argue explicitly for the importance of "deliberate practice," including some of his own

TABLE 9.1 Inconsistent definitions of Deliberate Practice

Deliberate Practice Must Involve a Teacher:

"In distinction from leisurely or normal job-related experience, Ericsson et al. defined *deliberate practice* as a very specific activity designed for an individual by a skilled teacher explicitly to improve performance."

Krampe & Ericsson (1996, p. 333, emphasis original)

"Ericsson et al. (1993) used the term '<u>deliberate practice</u> for the individualized training activities specially designed by a coach or teacher to improve specific aspects of an individual's performance through repetition and successive refinement.' (Ericsson & Lehmann, 1996, pp. 278–279)."

Ericsson (2014a, p. 3, emphasis original)*

Deliberate Practice Usually Involves a Teacher:

"When individuals engage in a practice activity (typically designed by their teachers), with full concentration on improving some aspect of their performance, we call that activity *deliberate practice.*"

Ericsson (2007, p. 14, emphasis original)

"Expert performance can . . . be traced to active engagement in deliberate practice (DP), where training (often designed and arranged by their teachers and coaches) is focused on improving particular tasks."

Ericsson (2008, p. 988)

Deliberate Practice Need Not Involve a Teacher:

"Ericsson et al. (1993) proposed the term deliberate practice to refer to those training activities that were designed solely for the purpose of improving individuals' performance by a teacher or the performers themselves."

Ericsson (1998, p. 84)

"Ericsson et al. (1993) introduced the term *deliberate practice* to describe focused and effortful practice activities that are pursued with the explicit goal of performance improvement. Deliberate practice implies that well-defined tasks are practiced at an appropriate level of difficulty and that informative feedback is given to monitor improvement. These activities can be designed by external agents, such as teachers or trainers, or by the performers themselves."

Keith & Ericsson (2007, p. 136, emphasis original)

Note. *Ericsson (2014a) misquotes Lehmann and Ericsson's (1996) definition of deliberate practice: ". . .specially designed by a coach or teacher" should be ". . .*especially* designed by a coach or teacher" (emphasis added).

studies (see Table 9.2). For example, he rejected his own study of darts (Duffy, Baluch, & Ericsson, 2004) because the practice was not supervised by a teacher. However, he and his colleagues explicitly referred to the practice activities they measured in their study as "deliberate practice" and concluded that the results of the study supported "one of the main tenets of Ericsson et al.'s (1993) theory whereby expertise is acquired through a vast number of hours spent engaging in activities purely designed to improve performance, i.e., deliberate practice" (Duffy *et al.*, 2004, p. 243). For the same reason, Ericsson rejected his own study of Spelling Bee contestants (Duckworth, Kirby, Tsukayama, Berstein, & Ericsson, 2011) for not actually measuring deliberate practice. However, in criticizing a journalist for his portrayal of the study, Ericsson was emphatic that deliberate practice was, in fact, measured in the study, stating:

> To argue that deliberate practice needs to be augmented, he [Jaffe, 2012] explicitly cites an article, which includes deliberate practice in its title, "Deliberate practice spells success." In that study we (as I was also one of the co-authors) collected data on "deliberate practice." (Ericsson, 2012, pp. 5–6)

We do not believe it is scientifically defensible to claim that a study measured deliberate practice and then to claim, without explanation for the shift, that the *same* study did *not* measure deliberate practice. Shifting definitions allows evidence to be accepted as valid when arguing it supports a view, but rejected as invalid when arguing against others' use of the same evidence.

TABLE 9.2 Illustrations of inconsistent definitions of "Deliberate Practice" from Ericsson's (2014a, 2014b) Commentary on Macnamara *et al.*'s (2014) Meta-Analysis

Study rejected by Ericsson (2014b) because practice activity does not meet criteria for "deliberate practice"	*Previous use of the same study (in the left column) by Ericsson to argue for the importance of "deliberate practice"*
Charness, Tuffiash, Krampe, Reingold, & Vasyukova (2005)[a]	"This paper reports the most compelling and detailed evidence for how designed training (**deliberate practice**) is the crucial factor in developing expert chess performance." Ericsson (2005, p. 237)
deBruin, Rikers, & Schmidt (2007)[a]	"this study showed that the amount of **deliberate practice** was related to the development of performance for all players." Ericsson & Towne (2010, p. 410)*
Duckworth, Kirby, Tsukayama, Berstein, & Ericsson (2011)[a]	"Grittier spellers engaged in deliberate practice more so than their less gritty counterparts, and hours of **deliberate practice** fully mediated the prospective association between grit and spelling performance." Duckworth *et al.* (2011, p. 178)
Duffy, Baluch, & Ericsson (2004)[a]	"In short, the present study revealed that the single major factor contributing to professional level dart playing performance is **deliberate practice.**" Duffy, Baluch, & Ericsson (2004, p. 244)
Helsen, Starkes, & Hodges (1998)[b]	"Several studies and reviews have found a consistent association between the amount and the quality of solitary **deliberate practice** and performance . . . in different types of sports (. . .Helsen, Starkes, & Hodges, 1998. . .)." Ericsson, Nandagopal, & Roring (2005, p. 295)
Hodges, Kerr, Starkes, Weir, & Nananidou (2004)[b]	"Research conducted in several domains such as . . . sports (. . . Hodges, Kerr, Starkes, Weir, & Nananidou, 2004) . . . suggests that the amount of accumulated **deliberate practice** is closely related to an individual's attained level of performance." Keith & Ericsson (2007, p. 136)
Hodges & Starkes (1996)[b]	"Several studies and reviews have since found a consistent relation between performance and amount and quality of **deliberate practice** . . . in sports (. . . Hodges & Starkes, 1996 . . .)." Ericsson (1998, p. 87)
Sonnentag & Kleine (2000)[a]	"In a study of insurance agents Sonnentag and Kleinc [sic] (2000) found that engagement in **deliberate practice** predicted higher performance ratings." Ericsson (2006, p. 695)
Tuffiash, Roring, & Ericsson (2007)[a]	"Several researchers have reported a consistent association between the amount and quality of solitary activities meeting the criteria of **deliberate practice** and performance in different domains of expertise, such as . . . Scrabble (Tuffiash *et al.*, 2007)." Ericsson, Perez, *et al.* (2009, p. 9)
Ward, Hodges, Starkes, & Williams (2007)[b]	"Several researchers have reported a consistent association between the amount and quality of solitary activities meeting the criteria of **deliberate practice** and performance in different domains of expertise, such as . . . sports (Ward, Hodges, Starkes, & Williams, 2007. . .)." Ericsson *et al.* (2009, p. 9)

Note. In each quotation, the emphasis on "deliberate practice" is added.

[a] *Study rejected by Ericsson (2014b) because it did not "record a teacher or coach supervising and guiding all or most of the practice." See Ericsson (2014b), Table 2.*

[b] *Study rejected by Ericsson (2014b) because it did not "record assigned individualized practice tasks with immediate feedback and goals for practice." See Ericsson (2014b), Table 3.*

**Ericsson and Towne (2010) cite deBruin, Smits, Rikers, and Schmidt (2008), but the data are the same as in deBruin, Rikers, and Schmidt (2007).*

What are the implications of these inconsistent definitions of deliberate practice for the claim that accumulated deliberate practice largely accounts for variance in performance? If one accepts the definition of deliberate practice requiring a teacher, there is little to no evidence remaining to support the claim that deliberate practice largely accounts for individual differences in expertise. If, on the other hand, one accepts the definition of deliberate practice not requiring a teacher, then the available evidence does not support the claim. Specifically, the available evidence suggests that deliberate practice, as it has been operationally defined and measured by Ericsson and others, is a statistically and practically important predictor of individual differences in expertise but does not *largely* account for individual differences in performance.

Definitions of Expert Performance

Ericsson and colleagues have further criticized studies challenging their view for not capturing *actual* expert performance—in other words, for not including *true* experts. However, as with deliberate practice, it is not clear what qualifies as "expert performance." In particular, Ericsson and colleagues have defined expert performance as "reproducibly superior performance on representative, authentic tasks" (Ericsson, 2006, p. 688, see also Ericsson & Smith, 1991), but the requirements for "superior performance" have been inconsistent.

As one example, Ericsson and Charness (1994) proposed that "if someone is performing at least two standard deviations above the mean level in the population, that individual can be said to be performing at an expert level" (p. 731), whereas Ericsson (2014c) suggested that the expert performance framework applies to "less than [a] handful [of] individuals" (p. 100). By the former standard, it would be reasonable to consider, say, any golfer who has qualified for the PGA Tour or LPGA Tour or any chess player at the rank of "master" or higher an expert. By the latter standard, very few professional golfers or chess masters would qualify as experts. As another example, when arguing against the results of two behavioral genetic studies that included amateurs (Hambrick & Tucker-Drob, 2015; Mosing, Madison, Pedersen, Kuja-Halkola, & Ullén, 2014), Ericsson (2016) claimed the results "cannot be generalized to expert[s]" (p. 352) and that "[e]xperts have acquired skills and mechanisms . . . that allow them to perform tasks that amateurs are unable to perform successfully" (p. 352). Yet he classified *amateur* music students in Ericsson *et al.*'s (1993) study of violinists and *amateur* collegiate bowlers in Harris's (2012) study of bowlers as "experts" (see Ericsson, 2006; Ericsson, 2016; Ericsson *et al.*, 1993). These inconsistencies allow favorable evidence to be accepted under some definitions, and unfavorable evidence to be rejected under other definitions.

Furthermore, an inherent problem with defining expert performance as "superior" performance is that what qualifies as superior will depend on the number of performers in a domain. For example, there are tens of millions of golfers in the world, but perhaps only a few thousand digit memorizers. Thus, superior performance in golf probably reflects a higher level of skill than superior performance in digit memorizing. Moreover, as the preceding discussion illustrates, any judgment about what qualifies as "superior" is ultimately arbitrary. One could, for example, define a "superior" baseball player as a member of a major league team, a member of a major league All-Star team, or a top-10 player in history—and all of these definitions would seem reasonable. In short, "superior" is not a discrete, naturally occurring category—it is an artificial label. In light of these problems, our view is that expertise (or skill) should be treated as the continuous variable that it is in research.

It also bears noting that Ericsson and colleagues have made contradictory claims about the existence of evidence for expert performance as measured by representative laboratory tasks. As a case in point, Ericsson, Roring, and Nandagopal (2007) claimed that "representative tasks have been found to capture expertise in . . . simultaneous translations of languages" (p. 10), and as evidence for this claim cited a review of the literature on expertise in language interpreting authored by Ericsson (2000/2001). However, in that review, Ericsson actually concluded that *no* representative laboratory tasks have successfully captured expertise in the interpreting domain, stating that "in the domain of interpreting researchers have not identified such demonstrations of consistently superior performance" (p. 211) and that "[o]nly future research will tell whether the application of the expert-performance approach to interpreting will advance our understanding of language comprehension and production, translation, and interpreting." (p. 216). When a person with authority in a field makes contradictory claims, it can lead to confusion in the literature, making it difficult to draw conclusions and to identify unanswered questions for future research.

Other Claims of the Deliberate Practice View

In addition to the claim that deliberate practice largely explains individual differences in expertise—where depending on one's definition of deliberate practice the evidence is either lacking or does not support this claim—other key claims of the deliberate practice view are problematic. Here, we mention three.

The 10-Year Rule

The first is the claim that at least 10 years of deliberate practice are required to reach an elite level in a domain. Ericsson and colleagues have endorsed this idea numerous times in the literature. For example, Ericsson *et al.* (1993) concluded that "expert performance is not reached with less than 10 years of deliberate practice" (p. 372). Similarly, Ericsson and Lehmann (1996) argued, "The highest levels of human performance in different domains can only be attained after around ten years of extended, daily amounts of deliberate practice activities" (p. 273). As another example, Ericsson, Prietula, and Cokely (2007) claimed that "our research shows that even the most gifted performers need a minimum of ten years (or 10,000 hours) of intense training before they win international competitions (p. 119), and Ericsson (2008) stated, "To reach a level where one can win international competitions, it is estimated that over 10,000 hours of DP [deliberate practice] have been generated for several domains" (p. 992). As a final example, Ericsson, Prietula, and Cokely (2007) declared, "It will take you *at least* a decade to achieve expertise, and you will need to invest that time wisely, by engaging in 'deliberate' practice—practice that focuses on tasks beyond your current level of competence and comfort" (p. 116, emphasis added). Later, however, Ericsson (2013) stated:

> In direct violation of the alleged necessity of 10,000 h in 10 years for becoming an expert, our original study [Ericsson *et al.*, 1993] estimated that one of our four groups of expert violinists had only *averaged* around 5,000 h of solitary practice (the activity most closely matching the criteria for deliberate practice) at age 20—as a consequence more than half of them had actually accumulated less than 5,000 h. (p. 534).

It is difficult to discern from these statements what, exactly, Ericsson and colleagues' position actually is on the necessity of at least 10 years (or 10,000 hours) of practice for achieving expertise.

Ericsson and colleagues' position aside, what does the available evidence indicate about the 10-year rule and the 10,000-hour rule? In short, it indicates that they are unfounded. For example, a number of chess players have obtained the grandmaster level in fewer than 10 years, including Magnus Carlsen who achieved the title after around 5 years of serious study while others have accumulated more than 25,000 hours of deliberate practice over many years and have not reached master status (Gobet & Campitelli, 2007). As another example, Lombardo and Deaner (2014) used archival records to document the 20 fastest American male sprinters in history, and found that eight of the 12 sprinters for whom data were available were found to reach world-class status in fewer than 10 years ($M = 8.7$, SD = 3.8). The 10-year rule may serve as a reminder to laypeople that expertise is acquired only after extensive training, but as a scientific proposition, it appears to be false.

Deliberate Practice vs. Other Forms of Domain-Relevant Experience

The second claim is that deliberate practice is a stronger predictor of individual differences in performance than other forms of domain-specific experience—namely, engaging in activities for external reward ("work") and for pleasure ("play"). As Ericsson (2013) stated, "[I]t is now quite clear that the number of hours of merely engaging in activities, such as playing music, chess and soccer, or engaging in professional work activities has a much lower benefit for improving performance than deliberate practice" (p. 534). However, evidence suggests that this might not be the case. For example, in a study of pianists' accompanying and sight-reading performance, Lehmann and Ericsson (1996) measured actual accompanying experience (i.e., a work activity) as well as accumulated piano practice. They found that accompanying experience was more strongly correlated with all performance measures (rs = .63, .72, .67; all $ps < .01$) than was practice (rs = .32, .42, .36; all *ns*). As another example, in a study of insurance agents, Sonnentag and Kleine (2000) measured the number of cases handled (i.e., work activities) as well as deliberate practice. They found that the number of cases handled was a better predictor of job performance ($r = .37$, $p = .01$) than was cumulative deliberate practice ($r = .13$, *ns*). In short, there is evidence to suggest that (1) deliberate practice is not the only form of domain-relevant experience that is an important predictor of expertise, and (2) other types of experience may be more important predictors of expertise than deliberate practice in some domains.

The Role of Genetic Factors in Expert Performance

Evoking Watson's (1930) famous guarantee that he could take a "dozen healthy infants" and take "any one at random and train him to become any type of specialist I might select . . . regardless of his talents" (p. 104), the third—and boldest—claim of the deliberate practice view is that "the distinctive characteristics of elite performers are adaptations to extended and intense practice activities that selectively activate dormant genes that *all healthy children's DNA contain*" (Ericsson, 2007, p. 4, emphasis added). To argue for this view, Ericsson, Roring, and Nandagopal (2007) cited the results of a study by Carson, Nettleton, and Reecy (2001), claiming that "when humans engage in intense physical activity, several hundred genes are activated from their dormant state in the DNA (Carson *et al.*, 2001)" (p. 22). It should be noted, however, that the Carson *et al.* study made no mention of human expertise at all, nor of extended practice; it examined initial changes to microRNA over three days of physical work overload in rats. We can find no empirical evidence that can reasonably be interpreted as support for Ericsson and colleagues' idea that extended practice activities "selectively activate dormant genes that *all healthy children's DNA contain*" (Ericsson, 2007, p. 4, emphasis added). This claim would seem to be highly speculative.

Summary and Conclusions

Some people are better—*much* better—at complex tasks than other people. The question of why they are has been a topic of scientific inquiry for as long as psychology has been a field. The pendulum has swung on the question between "nature"—the view that experts are "born"—and "nurture"—the view that experts are "made." The latter view has been dominant in the scientific literature since the early 1970s (Chase & Simon, 1973), and particularly since Ericsson and colleagues proposed the deliberate practice view (Ericsson *et al.*, 1993).

Ericsson and colleagues' efforts to identify optimal conditions for complex learning are highly commendable. Their work has highlighted the importance of environmental factors in acquiring expertise and brought worldwide attention to the study of expertise, including to the public. Described in numerous pop psychology and self-help books, the deliberate practice view affects people's decisions from child rearing and personal development—including career changes—to how to allocate personal, institutional, and organizational resources. However, inconsistent definitions and contradictory interpretations of evidence are problematic for the viability of a scientific theory. That is, conclusions concerning a theory are susceptible to bias if conflicting definitions of a variable can be used interchangeably so as to use the same evidence to either support or reject a theory. Accordingly, we think it is critical for proponents of the deliberate practice view to clearly and consistently define key variables in their framework.

Most importantly, the central claim that individual differences in expertise can largely be accounted for by deliberate practice is not supported by the available evidence. Under some definitions of deliberate practice (see e.g., Krampe & Ericsson, 1996; Ericsson, 2014a, 2014b), there is little to no evidence to support this claim. Under other definitions of deliberate practice (see e.g., Keith & Ericsson, 2007; Ericsson, 1998), the available evidence indicates that deliberate practice is important but does not largely account for individual differences in performance (e.g., Macnamara *et al.*, 2014).

In sum, it seems clear that deliberate practice is one important predictor of expertise. However, it seems equally clear that other experiential factors, genetic factors, task factors, and their interactions must also be considered, lest we commit the single cause fallacy. We believe the challenge now for researchers interested in advancing the science of expertise is to develop consistently testable hypotheses and models that take into account multiple relevant factors. By putting the nature–nurture debate to rest, scientific research on the origins of expertise can move forward.

Note

1 Moreover, the one study Ericsson (2014a, 2014b) did not reject—Ericsson *et al.* (1993) Study 2—also appears to violate the criteria he set forth because can we can find no record that participants were asked to restrict their practice estimates *only* to teacher-designed activities. See instructions to participants in Appendix A, Krampe (1994).

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PART II

Neural Approach