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An Introduction to the Special Issue on the Impact of the Work of K. Anders Ericsson

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Abstract

In this introductory article for the special issue dedicated to the impact of the work of K. Anders Ericsson, we provide an overview of how the special issue was developed, introduce the specific areas from which there were contributions, and briefly expand upon the themes identified within the special issue. These themes include the following: (a) the undeniable importance/impact of Ericsson's work, (b) the discussions regarding the operationalization of key terms, (c) calls to move beyond extreme nurturism or nativism, (d) considerations and implications of discussing "variance accounted for" when studying the most elite performance, and (e) the oversimplification of Ericsson's proposals by the popular press.

Keywords

K. Anders Ericsson, expert performance, expertise, deliberate practice, nature vs nurture, Ericssonian

Introduction

It is a tremendous honor to have been asked to serve as the editors of this special issue of the *Journal of Expertise* dedicated to the impact of the work of K. Anders Ericsson. We wanted the series of articles to provide a realistic reflection of Ericsson's work—an historical account of several of the fields influenced by his work, as well as a snapshot of where the study of expertise stands and is going. Within this issue, while varied, the accounts of Ericsson's impact are by no means exhaustive. Rather, the collection of articles is intended to create dialogue and to serve as a potential guide for future work in expertise research.

We asked the contributing authors to provide a review of the scholarship in their area of expertise research with an emphasis on highlighting Anders' impact, identifying the unresolved issues and remaining questions, and proposing possible future directions. We also asked them to include personal anecdotes of their interactions with Anders. The authors were given much leeway in how they accomplished these requests and did so in an exciting multitude of ways. Our job as editors of the special issue is to provide a framework for presenting the scholarship that is both informative and useful.

Interest in human performance is as old as humanity—becoming the best hunter, the best gatherer, or the best combatant would provide an advantage for our ancestors. One can also presume that identifying and aligning with the best performers was beneficial to those with lesser performance abilities. As the needs of humans changed, so did the areas in which humans excelled and, consequently, were rewarded for high performance. Historical

accounts of early interest in the limits of human performance, such as the writings of Sir Francis Galton and seminal expertise research, have been covered extensively elsewhere (e.g., Eccles, 2020; Ericsson & Charness, 1994; Ericsson & Lehmann, 1996; Hambrick et al., 2018), including this special issue of the *Journal of Expertise*. Ericsson's research related to expertise ("expert performance" became his preferred term) first appeared roughly 40 years ago (Ericsson et al., 1980). His collection of work over the decades would go on to be widely heralded, the focus of intense debates, adopted across the globe, and, as is typically the case for influential work, frequently challenged. We now turn to presenting some of the areas of Ericsson's work highlighted in this special issue.

Overview of How Ericsson's Impact is Reflected in This Special Issue Collection

Approaching 90,000 total citations as listed on Google Scholar, Ericsson had an undeniable impact on many academic and applied fields. For example, when we consider only the two of us as researchers, Ericsson's work has informed our research on skill acquisition and expertise in a diversity of professions including law enforcement (Harris, Eccles, Freeman, & Ward, 2017), sport (e.g., Eccles & Arsal, 2015), medicine (Harris, Eccles, & Shatzer, 2017), nursing (Whyte et al., 2012), and personal finance (Eccles et al., 2013). This thin slice of research shaped by Ericsson's ideas shows how it would be impractical to cover all the areas in which Ericssonian principles have made an impact. However, in this special issue, we do present a selection of articles by authors able to provide an overview into the impact that K. Anders Ericsson had on their specialty area including medicine (McGaghie et al., 2021, this issue) and sport (Young et al., 2021, this issue). Other authors take a broader view by of his impact (Harwell & Southwick, 2021, this issue), discuss his impact on team training (Bisbey et al., 2021, this issue), or the use of Ericsson's general framework to derive training (Harris & Eccles, 2021, this issue). A longtime colleague, Neil Charness, summarizes Ericsson's impact on cognitive psychology in addition to the work on expert performance (Charness, 2021, this issue). These impacts include the development of the concept of long-term working memory (Ericsson & Kintsch, 1995), developing techniques for collecting valid verbal reports (Ericsson & Simon, 1980), and providing a loose methodology for a variety of protocol analysis measures (Ericsson & Simon, 1984). A scholar making any single one of these contributions would be noteworthy. Collectively, the result of this special issue is a compilation of articles that provide insight into the state of the science for the respective domain as related to expertise research, the issues either having recently or historically been under debate, and the issues that are considered to be of greatest import moving forward. Specifically, the articles are from the areas of medicine, teamwork, training development, sport, cognitive science/psychology, and the impact on popular culture. In addition, the request for personal anecdotes and flexibility on what these should be led to fascinating insight into the collaborations and relationships that the authors had with Ericsson.

Although we had a general expectation as to what issues might arise from the articles found in this special issue, the final product reflects an accounting of Ericsson's impact that is a result of the collective input of the authors. Several of the themes identified in the sections below were expected. However, because we gave the authors free reign within their categories, we did not predict everything that emerged from this endeavor. Thus, the themes of the special issue, and some of the primary themes described below are a combination of *a priori* expectations of the themes that would arise, and some novel themes that came as pleasant surprises. Moreover, the flexibility allowed the authors led to some exciting, fresh angles on frequently discussed topics. The themes identified and briefly discussed in the sections below, are as follows: (a) the undeniable importance/impact of Ericsson's work, (b) the discussions regarding the operationalization of key terms, (c) calls to move beyond extreme nurturism or nativism, (d) considerations and

implications of discussing "variance accounted for" when studying the most elite performance, (e) the oversimplification of Ericsson's proposals by the popular press, and (f) concluding remarks and proposed future directions to answer remaining questions, and resolve contested points.

Impact of Ericsson's Work

As noted above, the work of K. Anders Ericsson is highly cited in academia, and he made important contributions on multiple, often interrelated fronts. These contributions include a framework for studying expert performance (the Expert Performance Approach; Ericsson & Smith, 1991), the concept of long-term working memory as a mechanism by which high-level performers maintain ready access to information stored in long-term memory (Ericsson & Kintsch, 1995), and codifying the techniques of soliciting verbal reports and protocol analysis with Herbert Simon (Ericsson & Simon, 1984). His work on expert performance entered the popular landscape in a variety of iterations (see Harwell & Southwick, 2021, this issue). Moreover, the debates over the issues proposed by Ericsson are numerous, ongoing, and occasionally contentious.

Given the ongoing debates, it can be easy to forget the change brought about by Ericsson's work on both expertise research in academia and a layperson's view regarding the achievements accomplished by the highest-level performers. Our impression is that the past few decades were paradigm shifting with regard to the amount of effort required to perform at the highest levels (i.e., practice). Possibly dismissed as a "straw man" argument[1], Anders took the approach that an extreme nativist view is that a sufficiently talented individual should be able to demonstrate impressive skill at a task for which they were "naturally" suited without engagement in any activities designed for skill development. One of the first steps that Ericsson took to demonstrate that individual performance capabilities are malleable and could be changed with consistently applied effort was demonstrating that individuals could exceed commonly accepted performance capacity limitations, such as S.F.'s extreme digit recall (Ericsson et al., 1980). He later then demonstrated that differences in practice histories could be demonstrably related to performance differences, such as the now famous study of musicians at a German music academy (Ericsson et al., 1993).

In the decades that followed this seminal work on musicians, momentum built behind the view that prolonged engagement in a specific kind of practice activities was a necessary component of reaching the highest level. While this view has been challenged to varying degrees (e.g., Hambrick et al., 2020; Lombardo & Deaner, 2014), research with results supporting this view began to accumulate (for an overview, see Ericsson et al., 2018; Ward et al., 2019). Two domains in which research on the concept of deliberate practice and related ideas was prevalent were the domains of medicine and sport, both of which are reflected in this special issue. Sport was a natural fit for exploration of the concepts of deliberate practice, given the existing structure of practice, coaching, and similar tenets. Sport researchers/practitioners adopted some of the ideas early on (e.g., Baker & Young, 2014), the evidence accumulated, and the approach gained traction.

Ericsson's work also had a tremendous impact in the medical domain, coinciding with an increased emphasis on simulation models for training (e.g., McGaghie, 2008). The traditional model of "see one, do one, teach one" and relying on limited practice opportunities to provide training often had key limitations, including a lack of quality time on task and opportunities to implement feedback for improvement. In order to address such concerns, the adoption of deliberate practice, and the offshoot concept of mastery learning (e.g., McGaghie et al., 2021, this issue), was intended to provide controlled, safe, and realistic opportunities to allow medical personnel to improve performance. The results suggested that the approach was tremendously successful in improving performance in both simulated scenarios and real-world clinical encounters (e.g., McGaghie et al., 2011). Based on these

successes, the adoption of Ericssonian principles has been deemed a paradigm shift for medical training (see Ericsson, 2004; McGaghie et al., 2021, this issue; Harris, Eccles, Ward, & Whyte IV, 2013 for nursing).

As is to be expected, the widespread adoption of any approach will necessitate further vetting in order to refine the idea and its conceptualization. During this process, issues arose regarding what is meant by deliberate practice, how it should be identified, how to account for factors other than deliberate practice in explaining performance, and a variety of other considerations (e.g., Hambrick et al., 2018). Such varied interpretations of what constituted deliberate practice, as well as an array of misconceptions and varied interpretations arose both within academia and across the public at large. We will now consider some of these points in the following sections.

Operationalization

Operationalization is one of the actively discussed issues in expertise/expert performance research. This issue is more complex than it might initially appear; for example, the question of how to operationally define an "expert" has been discussed extensively (e.g., Ericsson et al., 1993; Ericsson & Charness, 1994). Related operationalization issues include, (a) what constitutes deliberate practice (the components/process; see Hambrick et al., 2018; Harwell & Southwick, 2021, this issue for discussions on the distinctions), (b) to the related issues of what are the tasks comprising deliberate practice, (c) who has been successfully identified as an expert performer and consequently, who should, and should not, be studied in order to derive training, (d) and the best approach for identifying the activities leading to improvements in performance (e.g., Harris et al., 2014; Harris, 2021, this issue; see also Ward et al., 2013, for a description of the ExPerT model). However, one enduring question of operationalization extending throughout the domain of expertise research is the aforementioned definition of what constitutes (components/process) of deliberate practice (DP), and whether it matters.

Ericsson advocated rigorously for precise definitions of what comprises deliberate practice activities (Ericsson et al., 1993). Recently, Hambrick et al. (2018) made efforts to track the use of the term over time. Other researchers and trainers took a more flexible, pragmatic approach of adapting the application of deliberate practice best to fit the domain or training needs. As such, the academic literature often reflects derivatives of DP such as mastery learning in medicine (e.g., McGaghie, 2008), and guided learning in the teamwork literature (Bisbey et al., 2021, this issue). Similarly, Young et al. (2021, this issue) noted the lack of operational consistency even within the same sport for defining expert performance or what constitutes deliberate practice. Scholars taking a pragmatic approach noted Ericsson's insistence on specific definitions and resistance to modifications to his original conceptualization (although, see Hambrick et al.'s concerns regarding variations in definitions over time). For example, Salas notes that Ericsson changed his mind about coauthoring a paper comparing "guided practice" to "deliberate practice" (Bisbey et al., 2021, this issue), or that ill-defined or inappropriate comparisons would result in situations in which "the baby (theory) would too easily be thrown out with the bathwater (easily disconfirmed quantitative predictions)" (Charness, 2021, p.125, this issue). Other scholars proposed a team deliberate practice model (e.g., Harris et al., 2017b), despite Ericsson's stance that deliberate practice was an individualistic concept.

Debates have turned at times to specific aspects of the approach, such as whether deliberate practice activities are enjoyable (e.g., Helsen et al., 1998), or whether the presence or absence of a teacher negates the particular finding with regard to deliberate practice (e.g., Hambrick et al., 2018). This latter point appeared to be very important for some scholars. For example, Hambrick et al. (2018) found the switch in terms from "deliberate practice" (indicating activities with a teacher/coach) to "purposeful practice" (a more recent designation indicating activities without a teacher/coach) to be problematic. The need to

make a distinction was less important to others, who suggested, for example, that Artificial Intelligence (AI) or related simulated feedback was sufficient (e.g., McGaghie et al., 2021, this issue). While it is understandable to want to consider this specific component, other researchers have been less concerned, for example, as to whether a teacher is present than if performance was measured objectively and feedback was provided based upon such performance measures (e.g., surgical simulations; McGaghie et al., this issue).

In a more general argument, Young et al. (2021, this issue) suggested seeing deliberate practice as a special tool to be explored only with elite performers. However, we argue that the process is adaptable for performers of all levels (e.g., Harris & Eccles, 2021, this issue) and can be applicable as a training tool of great benefit, which is exemplified by the success in medicine of mastery learning training based on deliberate practice (MaGaghie, 2008). We now consider the calls to move beyond a dichotomy of nature versus nurture.

The Need to Move Beyond Extreme Nurturism or Nativism

One of the most explicit debates regarding deliberate practice and the more general Expert Performance Approach (Ericsson & Smith, 1991; see also Harwell & Southwick, 2021, this issue, on how the overall framework has been overlooked) has been the proposition that deliberate practice is an approach of extreme nurturism (e.g., Ackerman, 2014; Hambrick et al., 2018). This characterization has been addressed extensively elsewhere (e.g., Ericsson & Harwell, 2019; Macnamara et al., 2014) and specifics of the ongoing debate can be found there. For present considerations, we argue that this debate seemed, at times, much like a debate within the current zeitgeist of modern politics. The conversations often had the vibe, real or imagined, of an emotionally tinged exchange. For example, Ackerman's (2014) take on extreme stances on the nature versus nurture debate uses terms such as "silly," and a section header of "Nonsense" (p. 6). Ackerman continues to discuss the perils of taking an extreme stance of the role of either nature or nurture (which he describes as attributing 100% responsibility to either). He goes on to suggest the "common sense" interpretations that, (a) practice is necessary to reach elite performance levels, (b) factors other than practice that can limit performance attainment (e.g., physical limitations and missing critical windows), and (c) amount of practice does not explain performance differences among elite performers (cf. Young et al., 2021; Harwell & Southwick, 2021; both this issue). Ackerman then goes on to propose that "ultimately, the science of expert/elite performers must be a science of *individual differences*" (p. 10; emphasis his).

We mostly agree with Ackerman (2014) on the first two positions: that practice is necessary to reach elite performance levels, and that there are factors other than practice that limit performance attainment. The third point, that the amount of practice does not explain performance differences among elite performers, is currently being investigated (e.g., Tucker & Collins, 2012; Young et al., 2021, this issue; Harwell & Southwick, 2021, this issue). Despite Ackerman's claims that the study of elite performance "must" be framed within the lens of an individual differences approach, the issue is still being resolved. Using a basic analogy, gasoline, steering wheels and tires are all important for automobile performance; to argue for an inclusive approach, considering the role of all of these components, and then go on to state that the study of automobile performance must be limited to only one of the considerations (e.g., steering wheels) seems counterproductive.

To be clear, Ackerman (2014) is critical of extreme views on both approaches of the nature versus nurture argument. The distinction of inter-individual (responsible for performance differences between individuals) versus intra-individual differences (responsible for improving performance of an individual with a given base rate) leads Ackerman to call the study of expertise a science of individual differences. However, we propose that deliberate practice can enact great influence over both – improving intra-individual skills and

allowing/causing inter-individual separation (two perfectly inter-individually matched performers will distinguish themselves with sufficiently different types or amounts of deliberate practice).

The crossover popularity of the expert performance approach and deliberate practice seems to have led to the sense of urgency and purpose among those advocating for one approach or another. Arguably, in the arguments proposed to date, scholars have rarely proposed 100% influence of either nature or nurture, but they were often attempting to clarify or state their findings or viewpoint (though see Ericsson et al., 2017 for an argument related to giftedness).

Indeed, there have been calls to move on from either "extreme" approach by a variety of authors or to move beyond the nature versus nurture debate altogether (Ackerman, 2014; Hambrick et al., 2018; Ward et al., 2017; Young et al., 2021, this issue). It is noteworthy that this call comes from a cross-section of viewpoints in relation to expertise. Thus, it appears that the greatest consensus exists with regard to the move beyond a simplistic view of nature versus nurture. Moreover, the proposed means by which to move beyond this debate are quite varied. The proposals range from labelling the act of advocating for either extreme as "silly" (Ackerman), to continuing to seek evidence to support one or the other (e.g., Young et al., 2021, this issue), to dropping the silos and communicating with the goal of more integrative approach (Ward et al., 2017). We argue for a more integrative approach akin to the call by Ward et al. (2017). Such an approach will require a spirit of cooperation and a willingness to go where the data takes us, an approach that might be easier said than done. There is no way to be completely unbiased in relation to the approach one advocates, but an inter-subdisciplinary path forward, in which a collaborative approach among expertise researchers is welcomed, will be needed (see Fiore & Salas, 2008 for the distinction between a multidisciplinary versus interdisciplinary effort).

Skepticism and healthy debate are cornerstones of good science, and this is not a suggestion to cease working toward the underlying answers. To the contrary, we propose that greater openness to dialogue, and considering the complexity of a potentially competing finding, interpretation, or viewpoint. For example, to build upon Ackerman's (2014) point mentioned above and proposed by a multitude of scholars seeking to move beyond the nature versus nurture debate, the science of expertise/expert performance must be a continued exploration of *both* individual differences *and* environmental factors, including extended deliberate practice. Suggesting that one has the "truth" or "final answer" with regard to any concept makes for great pontification, but unfortunately does little to help sort through the nuances, which is required to get at the ultimate answers. Unexplored, unresolved, or debated/contested issues do not render one viewpoint or the other without merit; such issues are just pieces of the puzzle that we are all attempting to solve.

For example, in a demonstration of the falsifiability of the need for long-term engagement in deliberate practice activities (historically thought to have been 10,000 hours), Ackerman (2014) provides examples of athletes having reached world-class status in extremely short spans of time (e.g., 8-24 months). Such examples, indeed, might be indicative of the role of inter-individual differences in attaining world-class status so quickly. However, the examples also might reflect the impact of engagement in other athletic/physical activities with transferable advantages. Similarly, from the individual-differences perspective, the failure to identify a distinct difference between a future world champion or eventual league Most Valuable Player at various ages throughout their development, including professional selection (low ranking prospects), would not be indicative of a final verdict on the role of individual differences (see also Ackerman, 2014). Ackerman makes the explicit claim that such early identification/selection of eventual world class performers is difficult, and doing it accurately is nearly impossible. We expand on this below.

Oversimplification by the Popular Press

The numerous popular press books (e.g., Gladwell, 2008) and references attributed to, or with origins in, Ericsson's work have also complicated the discussion. Harwell and Southwick (2021, this issue) address some of the misconceptions and attempt to correct them. Perhaps the most widespread misconception is that 10,000 hours of practice will always equal expert performance. The academic arguments are discussed extensively elsewhere (e.g., Ericsson, 2016; Macnamara et al., 2016), but we want to acknowledge that academic viewpoints reaching the masses will often take on a life of their own. Anecdotally we have observed multiple instances in which Malcolm Gladwell was credited with proposing the concept of deliberate practice, along with a belief in the previously mentioned view that putting in 10,000 hours of practice will equal expert performance.

An obvious issue is the near impossibility of correcting the record once an idea has become so widespread and the simplified version repeated so frequently. Both researchers and laypersons levied the critique that 10,000 hours of practice, without consideration given to the content, will not always lead to elite performance. Questions have also arisen as to the actual requisite number of hours needed to reach elite performance levels (e.g., Hambrick et al., 2014). What should constitute practice and how that should be identified is certainly an ongoing discussion, including in the present manuscript. Moreover, the idea of 10,000 hours being a required threshold for reaching expert performance levels need not be debated; rather, the focus should be on identifying domain-specific averages needed to reach performance benchmarks (e.g., national level) when identifying the typical length of engagement is of greater interest. We are of the view that the number of specific hours engaged in deliberate practice is of potentially less importance (other than reflecting extended engagement) than identifying the effective deliberate practice activities in which the performers engaged and identifying key benchmarks indicating an individual has reached sought after performance goals.

The present subsection on the popular and/or common misconceptions is the focus of an article in this special issue (Harwell & Southwick, 2021) and the discussion could be extended into a full-length book. We would like to conclude this subsection with a couple of points about academic concepts having reached the public arena. As mentioned above, a concept often takes on a life of its own once it becomes popular enough to penetrate the vernacular of the general public. While helpful on getting the word out to the masses, the resulting discussion can have only a passing resemblance to the original idea. Consider the example in which a successful small-group class exercise in building small scale replicas of Spanish missions in California led to the expansion of the project to include a greater number of students. As the program grew, stores in the area began selling pre-made models for students to purchase, and the effectiveness of the activity for learning was greatly diminished (Yeager & Walton, 2011). This example highlights that the mass production obviously missed the point that the reason that the mission model building activity was so successful in the original form was because of the *process* in which the student engaged: background research, exploring the construction, and figuring out how to make it work. The mass production of the mission models, without recognition of parents and educators as to the reason for the original underlying benefit, is surprising. However, our experience has been that upon widespread adoption of a psychological science concept, it is not uncommon for the essence of the proposed concept to be lost in interpretation.

The second point is that the view of individual differences explanation for performance has been prevalent for centuries (e.g., someone is a "natural"). A view emphasizing the role of prolonged practice is comparatively recent and was surprisingly successful in moving the needle of the perspective held by the public at large. While advocates of increased screening (an individual differences approach; Moreau et al., 2019) suggest selection of the most promising

individuals via screening will best direct/open up resources, there is also the risk of moving the pendulum forcefully back in the other direction. Such a pendulum swing would risk losing the deliberate practice discussion completely as a consideration; that is, a return to the traditional view. Moreover, Ackerman (2014) argues that screening does not work well, and it is difficult to separate future high performers from others at a young age. Curiously, Moreau et al. (2019) make the argument that failure is more likely to lead to stigmatization when the emphasis is on environmental interventions or approaches; for example, growth mindset or deliberate practice. This argument is antithetical to such approaches (failure is to be expected) and stigmatization should only occur due to misunderstandings of the concepts or poor implementation (the mission model exercises mentioned above).

Variance Accounted For/Sufficiency of Deliberate Practice

As evidence mounted in support of the concept of deliberate practice, a collective of researchers was interested in determining both the necessity and sufficiency of deliberate practice for elite performance, and the variance accounted for by deliberate practice. A key determination from this line of scholarship was that deliberate practice is necessary but not sufficient for reaching elite performance levels (e.g., Campitelli & Gobet, 2011). Along the same vein, meta-analyses (e.g., Macnamara et al., 2014) suggested that deliberate practice accounted for much less of the variance in performance than proposed by advocates of deliberate practice, though this debate is ongoing (Ericsson & Harwell, 2019; see also Harwell & Southwick, 2021, this issue). Moreover, much of the debate concerned how procedural changes of what is considered deliberate practice could impact the final outcome regarding variance accounted for (Ericsson & Harwell). For example, the inclusion criteria of whether or not a teacher was involved could lead to inclusion in one meta-analysis and exclusion from another. We would like to address a few points with regard to this discussion.

The first point is to reiterate the consensus that deliberate practice is necessary for one to reach elite performance levels. The conversation will continue with regard to the distinction of intra-individual changes, which are responsible for improving performance of an individual with a given base rate, versus inter-individual changes, which are responsible for performance differences between individuals (e.g., Ackerman, 2014). We reiterate the argument that a pragmatic strategy would be to have an aspiring individual engage in deliberate practice activities until performance is no longer improving as anticipated (Harris et al., 2020). Conceptually, this is the same argument that continuously and incrementally increasing the amount of weight an individual lifts should allow continuously higher weights to be lifted. Such an approach is particularly relevant given the difficulty of predictive selection of the best performers across domains and developmental stages, from youth to professional leagues as noted by Ackerman (2014).

Additional factors beyond deliberate practice have been proposed to account for elite performance. For example, within the domain of chess, the proposed factors are season of birth, handedness, and the beginning of domain involvement during a sensitive period (Campitelli & Gobet, 2011). In a similar vein, the following factors were proposed to be responsible for high levels of physical performance: biological sex, height, VO_2max, and performance capabilities of skeletal muscle (Tucker & Collins, 2012). However, deliberate practice is the only factor reported that is under the control of the individual. While resources and other factors can still result in disparate opportunities, factors such as handedness or season of birth are certainly beyond the control of the individual. Whether or not one chooses to pursue the arduous path of reaching the highest performance levels, with no guarantees of being successful, is up to the individual. For example, Andre Agassi's father required him to hit 2,500 balls per day, an amount equal to about 1 million per year (Agassi, 2010; such an approach is relevant to the investment theory discussed below).

The third consideration here is the possibility that early involvement can provide a long-term competitive advantage given the potential importance of critical windows, even if the young performer is sampling a variety of activities. The relevance for the present subsection is that a young child awaiting identification could miss that critical window and the opportunity to gain experience in the domain. The young child's subsequent performance potentially could suffer suggesting that the child was lacking natural ability when, in fact, the child missed an opportunity to develop their skills. Such involvement would be important for enhancing any preexisting advantage, such as hand-eye coordination or working memory capacity, that the child already had and to allow the beginning of the process of accumulating the advantages of engagement of deliberate practice activities (or early play). Such *foundational windows* are important because they refer to windows of early engagement in which the influence of pre-existing natural abilities and developmental activities are difficult to separate. We now consider the theme of physical adaptations as a purported consequence of engagement in deliberate practice activities.

Physical Adaptations

One of the themes proposed by Ericsson that has generated the greatest skepticism is that of physical adaptations because of prolonged engagement in deliberate practice activities (e.g., Ericsson & Lehmann, 1996). Ackerman (2014) labelled as "nonsense" the view of such physical adaptations resulting from prolonged deliberate practice, and Young et al. (2021, this issue) considered the claim "curious."

There is some evidence to support Ericsson's view. For example, skillful violin playing requires a very specific range of motion in which joint freezing allows adjacent limb segments to operate as a single unit. Importantly, this ability to restrict degrees of freedom appropriately is acquired over time via practice, such that, "only violinists with more than 700 practice hr achieved sagittal shoulder range of motion comparable to experts" (Konczak et al., 2009, p. 243). Similar adaptations in range of motion, based on anatomical changes, have been reported in a variety of other sports such as baseball pitching and dancing (see Ericsson & Lehmann [1996] for a review).

Since physical adaptations seem to be too great a leap for some researchers, we now further discuss the claims. For example, Ackerman (2014) describes the concept of investment theories and their implications for expert performance, proposing an interplay between the environment and individual capacities for creating stable characteristics; that is, both nature and nurture have a role. More specifically, early investment in the individual leads to changes, which in turn, serve to result in additional investment or a redirection of resources. An individual having received a great deal of investment and experiences, particularly early on, should develop a set of interests and aptitudes that allow the individual to continue to develop. Critically, an individual missing the early investments will find themselves incapable of benefitting to the same degree as those having received large investments, or at all. Within this framework, it seems reasonable that early, consistent actions result in adaptations that result in the individual's stable characteristics such as the range of motion changes described above. Moreover, these stable characteristics are candidates to be labelled as "natural abilities" in observing a 9-year-old whose family has invested heavily in tennis lessons for the past few years.

Additionally, there is evidence that expert performers have developed cognitive advantages (e.g., long-term working memory) that allow for performance advantages (Sohn & Doane, 2004: Ward et al., 2011). While controversial, physical adaptations would be the next consideration. As implied above, it is possible that very early engagement in deliberate practice activities leads to the observed differences that are typically labelled individual differences at 9 years of age (the foundational window mentioned above). Sufficiently early engagement could begin an adaptation process at an early enough age that

the changes are indistinguishable from preexisting physical characteristics; examples include pitchers' arm movement (see Ericsson & Lehmann, 1996 for additional examples), or the aforementioned violinist (Konzak et al., 2009).

While proposals of physical adaptations are viewed as a stretch (Ackerman, 2014; Young et al., 2021, this issue), there is also evidence suggesting that changes in brain functioning can be enacted well into adulthood. For example, Maguire et al. (2000) found that the posterior hippocampi (involved in memory functioning) of licensed London taxi drivers were larger than non-drivers; the longer the driver has been driving a taxi, the greater the hippocampal volume. On a similar note, researchers found that the cerebellum of world-class mountain climbers is larger than the cerebellum of non-climbers (Di Paola et al., 2012). Skeptics of the view of physical adaptations would make the counterargument that such differences are preexisting and that individuals self-select accordingly; for example, an individual with appropriate motion capabilities will become a pitcher. However, there is evidence that anatomical changes are possible, even in short time spans. For example, Draganski et al. (2004) was able to demonstrate changes in brain anatomy (increased gray matter) when individuals with no juggling experience were trained to juggle for a period of 3 months. No changes were observed in a control group who did not engage in the training[2].

Perhaps of greater importance, researchers observed that brain-based anatomical and activation changes that occur when individuals learn to read, typically in childhood, are absent in illiterate adults but are present in adults who have learned to read as an adult (Dehaene et al., 2011). This evidence is compelling as we have yet to encounter anyone capable of reading without having to learn to do so. Reading is also an area in which early engagement (the foundational window) can provide a tremendous advantage (e.g., Nisbett et al., 2012). However, we realize that evidence of changes in brain anatomy and organization is a somewhat different argument than some of the other physical adaptations that have been proposed (e.g., Ericsson & Lehmann, 1996).

The Impact of Ericsson's Work on Training

As mentioned above, Ericsson's work has had a great impact on training in multiple domains such as those presented in this special issue, and beyond. Moreover, each of the subsections covered thus far is related to training on some level. Operationalization of the terms used when discussing expertise and expert performance is important because the clarification allows researchers and readers to be aware of the exact stance taken by the scholars. We covered some of these debates in the sections above. In this section, however, we address the adaptability of the techniques for training individuals across a variety of skill levels (Harris & Eccles, 2021, this issue; ExPerT model of Ward et al., 2009). It is important to consider the adaptability of the techniques used to study expertise and expert performers to derive training to benefit all skill levels. In part, this is because of the concern that some expertise researchers had about using novices to derive conclusions regarding expert performance (e.g., Ericsson, 2014), as well as suggestions that deliberate practice be deemed a tool for working only with elite performers (Young et al., 2021, this issue).

We posit that the Expert Performance Approach and deliberate practice allows training to be derived from the most elite performers and can be used to train individuals at all performance levels. This can be accomplished by isolating and identifying critical moments during performance that can be extracted and used to circumvent the natural process of arriving to that point developmentally, such as returning a tennis serve (Williams et al., 2002) or hitting a baseball pitch (Fadde, 2016). Specific examples of how this was accomplished were pinpointing the area of the server on which the most skilled tennis players focused in order to return a serve (Williams, et al.), or identifying via occlusion the critical moment of the pitch providing the advantage to the most-skilled batter (Fadde, 2016). This information then was used to improve the performance of early-stage tennis players by

providing training that specified where to focus on the opponent's body when attempting to return a serve. Similarly, the information identified from the study of the most skilled batters was used to develop training designed to enhance a batter's ability to use that critical moment for identification during the pitch, resulting in the team leading the conference in most metrics.

The technique also can be used to derive training by tracing the developmental path taken by the skilled performer to apply to training, such as an aspiring chess champion studying historic games by identifying the best next and comparing their decision to the actual move of the highest-level player (e.g., Shadrick & Lussier, 2004). This approach also works with performers already performing at a high level such as National Basketball Association (NBA) player Steph Curry adopting another player's successful shooting practice regimen to great success (Davis, 2015; see also Harris et al, 2020), or players in a different sport league adopting the training regimen that led to success for another player.

As a final note, these training processes are adoptable at the local or regional level to derive training based on the best surgeon in a hospital's system or the best regional salesperson. Trainers must take care to operationally define the measures of performance in order to identify representative tasks allowing identification of the best performers, pinpoint extractable training possibilities, and assess training outcomes in order maximize such training development (Harris et al., 2017b, 2020). Accumulating and sharing training techniques derived from such training could accelerate individual growth in the domain. Thus, this approach of extracting training suggests that such techniques can be used for individuals of all skill levels, expanding the usefulness of studying expertise to novices.

Concluding Remarks and The Path Forward

The impact of Ericsson's work extends well beyond academia (as noted by the authors of the articles in this special issue) but many of the issues highlighted in his work, and the work he influenced, remain the subject of ongoing and vigorous debate. Such debate is certainly the hallmark of a healthy scientific approach, and the topic continues to generate a great deal of discussion. As with many topics reaching the mainstream, the interpretation of the research and associated terms ends up taking on a life of their own.

Ericsson and colleagues found themselves transitioning from a wave of popularity related to their work (Ericsson et al., 1993, is currently at almost 12,000 citations per Google Scholar) to seeing it attributed to others or engaging in debates with scholars who challenge the claims made by Ericsson. As noted, scholars in the area of expertise research are now going about the arduous process of refining and clarifying the views being proposed and seeking to move beyond the dichotomy of the nature versus nurture debate. This special issue of the *Journal of Expertise* is one such endeavor toward this end, but it alone will not put any ongoing debate to rest. This issue can serve, however, an important goal of identifying what scholars deem to be remaining questions to be resolved and how to go about finding answers. The final article of this special issue is dedicated to summarizing the suggestions provided by the contributing authors on how to advance the field. We hope that you find this issue helpful in moving the scholarship of expertise forward and that Anders Ericsson would find our effort to summarize his impact to be of an "objectively high performance" standard.

Endnotes

1. Hambrick et al. (2018, p.1) stated, "Today, no scientist takes seriously a strict nature view of expertise—which is to say that no one believes people are literally born experts, innately endowed with skill."
2. These gains in increased grey matter were diminished at a follow-up scan preceded by a time span of 3 months during which the participants did not train.

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