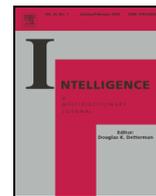


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Intelligence



Nonsense, common sense, and science of expert performance: Talent and individual differences

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ABSTRACT

Controversies surrounding nature and nurture determinants of expert/elite performance have arisen many times since antiquity, and remain sources of concern in the present day. Extreme positions on this controversy are fundamentally silly – *both* nature and nurture are necessary determinants of expert/elite performance, but neither alone represents a sufficient causal factor. The central issues surrounding the so-called “talent myth” and the “deliberate practice theory (also referred to as the “10,000 h rule”) are reviewed. Also provided is a discussion of the science of individual differences related to talent, the fundamental characteristics of talent and the role of talent in predicting individual differences in expert/elite performance. Finally, a review of the critical psychometric and statistical considerations for the prediction of individual differences in the acquisition of expert/elite performance is presented. Conclusions focus on how these various issues fit together, to provide an integrated view of the importance of talent, but also the limitations of talent identification procedures for discovering which individuals will ultimately develop expert/elite levels of performance.

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1. Introduction

Recent discussions in the popular literature and in some scientific circles have generated quite a lot of nonsensical statements, and similar amounts of misinformation about the nature of individual differences in talent and development of expertise across a wide array of domains. So, this paper starts with a review of the extant claims, and then follows with a review of the science that is at odds with such claims.

2. Nonsense

Extreme positions for either nature or nurture represent decisively discredited views throughout the scientific study of intelligence, expertise and elite performance (for succinct overviews of the untenability of either extreme view, see [Anastasi, 1958](#); [Anastasi & Foley, 1948](#)).

2.1. Environmentalism/nurture

The most extreme current exemplar of the environmentalist viewpoint is Ericsson's position regarding deliberate practice and the development of expertise. [Ericsson, Krampe, and Tesch-Römer \(1993\)](#) stated that “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)... We attribute the dramatic differences in performance between experts and amateurs-novices to similarly large differences in the recorded amounts of deliberate practice.” (p. 392). More recently, [Ericsson \(2007\)](#) stated that “... it is possible to account for the development of elite performance among healthy children without recourse to unique talent (genetic endowment) – excepting the innate determinants of body size.” and “Consequently, the development of expert performance will be primarily constrained by individuals' engagement in deliberate practice and the quality of the available training resources” ([Ericsson, 2007, p. 4](#)).

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Generally, it is fair to summarize Ericsson's theory as stating that: Expert performance is attained by lengthy (e.g., 10,000 h), deliberate (structured, coached, etc.), and motivated¹ practice. Conceptually, it would be easy to falsify such a universal statement (e.g., of the quality "All swans are white"), by finding a single exemplar of an individual who had attained expert performance without meeting one or more of these conditions (e.g., Observation of a single black swan renders the universal statement to be factually false). Indeed, observations of a few world-class elite sports figures indicate that the statement, as it stands, is certainly false as a universal truth (e.g., Donald Thomas became world high jump champion after 8 months of training; Helen Glover, "who had no rowing experience whatsoever when she was chosen in 2008, but was a World Championships silver medalist just two years later in 2010;" Crissie Wellington, British Ironman Triathlete didn't even compete professionally until age 30, and then won multiple world championships in short order; and so on. (Source: David Epstein, personal communication, October 13, 2011; see also Epstein, in press).

More insidious, however, is the corollary to the universal statement, namely: If an individual has appeared to have devoted lengthy, deliberate and motivated practice to a task (e.g., sport) and *not* achieved expert performance, one must attribute the failure to one or more of these three factors (i.e., not enough practice, not sufficiently deliberate practice, and/or not sufficiently motivated practice). In this framework, for example, an adequately coached individual who has expended the requisite thousands of hours of deliberate practice, must have failed to become an expert performer because he or she was not sufficiently motivated to achieve expert performance. The theory does not allow for individuals who simply do not have the requisite 'talent' to succeed in becoming an expert performer. With the only stated qualifications of body size and "health" (not more precisely specified), Ericsson only admits a few qualifications, for example "... some specific practice activities appear to change anatomical characteristics in an irreversible manner during certain critical developmental periods. For example, ballet dancers' ability to turn out their feet..." (Ericsson, 2007, p. 19).

However, Ericsson does not make an exception for an individual who does not have the appropriate physiological make-up to become an elite ballerina, other than turnout of the hip, such as "Ligamentous laxity," "Alignment of the leg" and so on (see Hamilton, 1986). As Hamilton noted, "The orthopedic literature suggests that anterversion is genetically predetermined and cannot easily be altered to any great degree. The extent of turnout is probably complete by age 10 or 11. ...a would-be ballet dancer who has poor turnout from the start probably will never be good, and the attempt to force it can create several knee problems." (p. 64). Other primarily genetic factors have been identified as critical to sports expertise – for a review see Tucker and Collins (2012),

and others have suggested that there is a significant role of genetic factors in the speed of acquisition of expertise in cognitive domains (e.g., see Chassy & Gobet, 2010).

While one can certainly admit that extensive practice can and does entail physiological changes in individuals, it is patent nonsense that every healthy child or adult need simply engage in extensive, deliberate and motivated practice to attain expert performance. Ericsson uses examples from his studies of training "expert memory" to illustrate how the theory of deliberate practice works. Ericsson, Roring, and Nandagopal (2007) stated that "moreover Ericsson (2003) was unable to find any reproducible evidence that would limit the ability of motivated and healthy adults to achieve exceptional levels of memory performance given access to instruction and supportive training environments" (p. 5). However, a thorough review has indicated that neither Ericsson nor his colleagues nor anybody else has ever demonstrated these feats with *any* but reasonably highly talented individuals to start with (e.g., university students, who are highly selected on intellectual abilities and prior educational success). A similar statement can be made for any of the other studies of expert performance in chess, Scrabble(r) (Tuffiash, Roring, & Ericsson, 2007), or any other task which has substantial demands on intellectual abilities. There has not been a single study that has demonstrated the attainment of expert memory among severely, moderately, or even borderline intellectually retarded subjects, except for rare case studies of savants (which are *not* about practice effects)!

By studying only subjects who have survived successive cuts of ability/talent, and motivation, extreme environmentalists are guilty of presuming that because the only subjects they examine are not markedly different in ability/talent, then ability/talent does *not* importantly limit the probability or possibility of achieving expert performance. Such an approach is tantamount to saying that because all of the individuals who are studied have two functioning eyes, that vision is *not* important to locomotion in the real world. The proposition here is that a universal approach to expert performance in sport or intellectual domains that excludes those who either never attempt the sport or intellectual domain, or who drop out very early in learning, is nonsense.

Much has been made about Watson's (1924/1930) famous quote: "Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select – doctor, lawyer, artist, merchant-chief, and yes, even beggar man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors." (p. 104). What is less frequently noted is the following sentence in Watson's quote "*I am going beyond my facts and I admit it*, but so have the advocates of the contrary and they have been doing it for many thousands of years. [italics added]. (p. 104). The operative point is not so much the extreme environmentalism espoused by Watson, but the qualification that he was "going beyond [the] facts." At least Watson admitted that the extant data did not support his proposition.

One final point should be made about the extreme environmentalist approach. That is, as Lloyd Humphreys was fond of observing, extreme environmentalists are actually *closet hereditarians*. They believe that with the right combination

¹ Ericsson et al. (1993) repeatedly noted that "motivated" practice is a critical component of "deliberate practice," (e.g., "A premise of our theoretical framework is that deliberate practice is not inherently enjoyable and that individuals are motivated to engage in it by its instrumental value in improving performance," p. 371). To make clear the important ingredients of "deliberate practice" in the current context, the term "motivated" is included.

of S–R (stimuli and responses), that the individual can reach his/her genetically-limited maximal level of performance. Thus, if everyone is given the optimal (training) environment, then individual differences in performance *must* be entirely accounted for by genetic limitations.

2.2. Extreme hereditarian views

The extreme hereditarian position (that all differences between individual performers can be attributed to differences in their genetic endowment) is equally nonsensical, but it is how Ericsson portrays any approach that identifies ‘talent’ – which he repeatedly asserts is only considered as ‘innate.’ Ericsson’s argument about the extreme hereditarian position mis-states the fundamental underlying rationale. He stated (Ericsson, 2003) “I also reject Galton’s hypothesis that performance after practice has removed all trainable aspects, and thus becomes rigidly constrained by fixed innate capacities” (p. 100). However, the underlying premise of the hereditarian view (e.g., see Thorndike, 1908) as noted above, is that providing *identical* environments for all participants reduces environmental variation to zero, and thus all differences between individuals must be genetic in origin, through a scientific process of elimination. In Thorndike’s studies, for example, this was simplified to mean practicing a mental task until asymptotic performance was reached. The underlying point, however, is that it has been repeatedly shown that providing equal practice to groups of individuals does not yield zero differences in performance. For relatively simple tasks with consistent information processing components, interindividual variance in performance tends to decrease with practice. But in a study of “feeble-minded teenagers,” Woodrow (1917) found that such practice actually did *not* lead to a decrease in interindividual variance, even though in a parallel examination of normal teenagers, there was a 27% reduction in interindividual differences variance. Such results support the proposition that the role of intellectual abilities does not *necessarily* decrease with practice (for an extensive review of the effects of task practice on interindividual differences variance, see Ackerman, 1987).

Numerous examples of extreme deprivation during childhood leading to impairments in adolescence and adulthood, that *cannot* be fully remediated, show that ability/talent is not like water under pressure, that is, removing the deprivation does not bring forth talent like water from a hose when the blockage is removed. Early critical periods for development of intelligence have been found (e.g., Hebb, 1942, 1949, 1978), as they have for numerous other skills in humans and animals, such as binocular vision, song learning in birds, absolute pitch in humans (by the age of 7), word acquisition, second-language learning, and so on (see Hernandez & Li, 2007 for an extensive review of ‘age of acquisition’). These findings do not indicate that it is impossible for individuals to benefit from practice on unlearned tasks in adolescence and adulthood, but they clearly indicate that such capabilities are not merely *innate* to the extent that they appear spontaneously at any age. Of course, these studies do *not* indicate that such capabilities have *no* genetic component – for example, intelligence is generally believed to have a significant genetic component in the normal population; but rather that genes do not account for all (or sometimes even a large portion) of the variance, when environments substantially differ across individuals.

Finally, an additional general point needs to be made about interpreting the heritability of particular capabilities. As Buss (1984) noted, “Population approaches are limited in that the methods of quantitative genetics will not discover species-typical traits. Leggedness, for example, would have a heritability of near zero because variations from two-leggedness are due mostly to environmental sources (e.g., accidents), rather than to genetic sources... (p. 1137).” In this context, it should be pointed out that in many sports, having two legs can be a necessary condition for expert/elite performance. By studying only those individuals who have been self-selected (through extensive prior experience) or institutionally selected (such as with talent identification programs), Ericsson and his colleagues create sub-populations that are restricted to species-typical traits. Those individuals who lack such traits, whether they be physical or psychological limitations, are eliminated from consideration, and thus the contribution of such traits to the development of expertise is obscured from evaluation. Nonetheless, neglecting such issues and then concluding that genetics makes no contribution to individual differences in expert performance throughout the population are tantamount to closing one’s eyes to avoid seeing information that is inconsistent with one’s prior beliefs.

2.3. Common sense

Although there are surely notable counter-examples in science, one would be well-advised to employ common sense (i.e., critical thinking) when considering various claims of universal statements in the domain of expert and elite performance. As noted earlier, statements that *either* genetic endowment or deliberate practice account for all variance in expert performance each violate a common sense interpretation of the vast array of data encountered in popular and scientific publications. Even acknowledging the limitations of the kinds of studies reported by Ericsson and his colleagues over the past 20 years (e.g., Ericsson & Charness, 1994; Ericsson & Lehmann, 1996; Ericsson et al., 1993), and other studies of expert performance, such as the body of literature from Simonton (e.g., Simonton, 1988, 1994, 2011), it is easy to stipulate the following:

1. Practice is an essential component of expert/elite performance.

Going further is less well established. Thus, it is not controversial to state that: Some significant amount of practice is *necessary*, but not *sufficient* for expert/elite performance. Beyond this stipulation, however, additional conditions are less well demonstrated. Certainly, having exemplary coaching and structured practice can indeed play an important role in developing expertise, and for many individuals, having such coaching is essential. Motivation, although it is not precisely defined in the theories discussed to this point, is almost certainly an important ingredient to the development of expert/elite performance.

However, the evidence presented to date appears to also indicate the following general propositions:

2. Not everybody gets to be an elite performer in every (or perhaps any) domain, and it isn’t just lack of deliberate

practice that explains this fact. Obvious factors that constrain the development of expert/elite performance include:

- (a) Physical limitations (in addition to height, other aspects of the individual's morphology restrict the person from reaching an expert/elite level of performance [such as in ballet]);
- (b) Injuries (whether directly related to a sport, or from other sources). Countless numbers of promising players have shortened careers through injuries that are simply not reversible by additional training or through current medical/surgical techniques. (It should be noted, however, that some injuries might have an interactive effect with practice, to the degree that the injury impairs the ability of the individual to engage in practice.)
- (c) Early experiences and critical periods. As noted earlier, the absence of exposure to learning/skill-building opportunities at young ages may irreversibly impair an individual to the degree that it is impossible to reach expert/elite performance levels within the individual's likely lifespan. While this has been well demonstrated for music components of pitch discrimination, it is also unrealistic to think that a 50-year old adult who has never played a musical instrument, could reach an elite level of piano or violin expertise within his or her lifespan, even if the individual chucked his/her day job and spent all waking hours at deliberate practice.
- (d) Aging. A corollary to (c) above is that in many fields of expertise, adult aging ultimately takes a significant toll on performance, even if the individual was able to engage in continued deliberate practice. Numerous changes in sensory, perceptual, motor, and intellectual capabilities take place with increasing age during adulthood – few of them in a positive direction. Seventy-year old 'elite performers' don't play competitively (in terms of occasionally winning) against 20-year old 'elite performers' on any field of play – be it baseball, football, track and field, chess (e.g., see Roring & Charness, 2007) and so on. In sports, world records are not broken by 'seniors,' except in comparison to their own age group.

When performance requires speed of intellectual processing, increasing age in adulthood is typically associated with reduced performance, even when the individuals perform the task daily. The "Power law of practice" (Newell & Rosenbloom, 1981), which states that speed of completing a task is a log-linear function of number of task trials, ultimately fails to take account of this fact. Several decades of scientific examination conclusively show that there are declines in performance, on average, for such tasks too. Of course, some individuals are more resilient in the face of aging than others – but anyone who believes that at age 90 (when he retired from performing heart surgeries), the pioneering heart surgeon Michael DeBakey had the same steady hands that he had at age 40, is deluding themselves (e.g., see Carmeli, Patish, & Coleman, 2003 for discussion of aging effects on motor performance). Rather than a power law of practice, a more accurate

representation across a lifetime of practice and performance is the common engineering representation for the lifespan of mechanical systems, called a 'bathtub curve' which in this analog accounts for *both* burn-in (that is acquisition of expertise) *and* wear out (loss of functions with age) components from a life-span perspective.

Substantial evidence exists that older adults engage in "selective optimization and compensation" (e.g., see Marsiska, Lang, Baltes, & Baltes, 1995) as a strategy change to maintain or preserve the expression of their skills. But, this strategy is typically not as effective as the original performance – it just delays the inevitable decline that comes with age-related body and mind changes (Salthouse, 1996).

3. Amount of practice does not explain a substantial amount of individual differences variance *among* expert/elite performers.

If 'deliberate practice' (with all that entails – namely amount of practice, structure of practice, and motivation) is the key ingredient that is associated with expert/elite performance, why is it that there is extensive evidence that among those individuals who have attained a critical level of deliberate practice (e.g., 10,000 h), there remain substantial and relatively consistent variations in observed performance levels (e.g., see Campitelli & Gobet, 2011). That is, some individuals may have accumulated 15,000, 20,000 h or more of deliberate practice, yet remain also-rans on the leader board, or never achieve medal status in national or international competitions. Other factors must clearly play a role in the demonstration of expert performance (*viz.*, see the golf performance slump of Tiger Woods after a series of highly publicized personal problems).

3. Science

The main problem with both the extreme nature and nurture approaches to expert/elite performance is the identification of "talent" as innate or fixed. Although genes are surely important in accounting for the range of individual differences in a variety of important characteristics (including intelligence), talent and other psychological constructs are *developed qualities*. In the context of intelligence and learning, Ferguson (1954, 1956), summarized this point by stating essentially that "With the possible exception of some learning which takes place very early in life, all learning occurs within the context of experience. We bring to bear on the learning of any task a mass of prior experience which may either facilitate or inhibit the learning of that task." (Ferguson, 1954, p. 100). That is, humans are born with a relatively small set of inherited fixed action patterns (or reflexes). After that, new learning builds on what has been acquired before. And, what is acquired during infancy and early childhood is an entire range of likes and dislikes (motivation, interests), along with knowledge and skill sets that are the building blocks for future learning. Learning and transfer occur at an extremely high rate in early infancy and childhood, such that by the time a child enters school, he or she has a vast repertoire of knowledge, skills, and dispositions (traits), in comparison to the newborn infant.

Although estimates of intellectual abilities in infants and young children are notoriously unstable from one occasion to the next, by the time a child enters first grade, his/her *relative* standing with respect to his/her age cohort is well established, such that Age 6 IQ measures are highly correlated with Age 18 IQ measures (e.g., Anastasi, 1954; Honzik, MacFarlane, & Allen, 1948; similar stabilities over even longer periods have been shown in other studies; for a review see Deary, Whalley, Lemmon, Crawford, & Starr, 2000). Nonetheless, it is important to note that six-year olds are *not* as intelligent as 18-year olds. What IQ estimates point to is rank-ordering within an age cohort, not absolute depth and breadth of intellectual knowledge and skills. Moreover, even with a reasonably high correlation of IQ measures from Age 6 to Age 18, *some* individuals in the population show marked developmental changes in their relative standing; changes that can be attributed to environmental deprivations or advantages, but also to personality and interest traits (e.g., see Bayley, 1968).

3.1. Science of individual differences

Ultimately, the science of expert/elite performers must be a science of *individual differences*. There are two main categories of individual differences that need to be accounted for in such a science, they are: Inter-individual differences (i.e., differences *between* individuals) and two types of intra-individual differences (i.e., differences *within* individuals). The first type of intraindividual differences represent developmental differences, or differences within an individual that occur because of maturation, aging, or in response to some intervention (e.g., practice, coaching). The second type of intraindividual differences refers to differences between different traits within an individual (such as the individual performing better on math tasks, compared to spatial or verbal tasks, but could also refer to the differences between the individual's baseball skills and his/her soccer skills). This second type of intraindividual differences can be indexed by an individual's knowledge/skill *profile* – that is, the individual's relative strengths and weaknesses. A final type of individual differences of interest is known as interindividual differences in intraindividual change. These differences index which individuals benefit more or less during maturation or as a response to practice and training. An individual who rapidly learns a new skill (a steep learning curve) is different from an individual who slowly learns the same skill or does not learn at all (a shallow or flat learning curve).

3.1.1. Dimensions of interindividual differences

If individual differences in developed traits are related to the development and expression of expertise, one may reasonably wonder *which* traits and when they are relevant. However, trait theory is extensive and list of candidate trait measures is large indeed. Below, I provide a brief review of this domain.

Several major attempts to taxonomize individual differences have been put forth over the last couple of millennia (e.g., see Arikha, 2007). Modern differential psychology has taken a much more detailed approach, dependent to a large degree on analysis of patterns of correlations among variables, to describing the dimensions of interindividual differences. Guilford (1959) noted that individuals may differ on seven major categories ranging

from physical to psychological, namely: (1) Physiology, (2) Morphology, (3) Aptitudes, (4) Needs, (5) Temperament (personality), (6) Attitudes, and (7) Needs.

Each of these categories of interindividual differences may be further subdivided into many separable, but sometimes overlapping factors. For example, “aptitudes” are typically represented as a hierarchy of abilities, with the most general abilities at the top of the hierarchy, and more narrow abilities at the lower part of the hierarchy (e.g., see Carroll, 1993). General intelligence can be decomposed into abilities such as fluid intelligence, crystallized intelligence, spatial/visualization abilities, perceptual speed abilities, psychomotor abilities, and so on. Each of these abilities can be further subdivided into narrower factors, for example, psychomotor abilities can be decomposed into abilities of fine motor coordination, steadiness, gross motor skills, balance, and so on. There are literally hundreds of previously identified ability traits and personality traits along which individuals differ.

3.1.2. Traits and situations

Behavior in general, and responses to stimuli in particular, can be described as partly a function of differences between individuals along these dimensions, and partly as a function of the environmental press of the situation. Some traits characterize limitations on the individual's behavioral repertoire, such as aptitudes, physiology, and morphology. That is, these traits are usually identified with what the individual can do, when there is *maximal* motivation for performance. An individual with low IQ may not be capable of solving complex physics problems, for example, just as an individual who is of short stature may not be able to dunk a basketball, even when the rewards for such behaviors are substantial. The other traits (e.g., temperament/personality) usually describe the individual's *typical* behaviors, that is, the kinds of behaviors the individual typically expresses, when there is a weak environmental press. An extrovert will typically prefer the company of other people, when given an opportunity to do so, whereas an introvert will typically avoid the company of other people, *ceteris paribus* (i.e., when everything else is equal), see Ackerman (1994) and Cronbach (1949) for discussions of this issue.

Less well studied than the issues described above, is the range of behavioral repertoires that go along with individual differences in personality and interest traits (Ackerman, 1997). For example, an individual may have a preference for a certain kind of environment, such as the person high or low on introversion/extroversion. But, some individuals are more resilient or more flexible in their abilities and skills in competently behaving in an environment outside their most-highly preferred environment (e.g., such as speaking before a large audience, or engaging in solitary study over an extended period of time).

Interests represent a domain of interindividual differences that appear to be especially important in the scientific study of the development of expert/elite performance. Current theories of interest development (e.g., Holland, 1959, 1997) state that an individual's interests develop as a function of early (in childhood) experiences of success and failure, which in turn, affect the development of self-concept and self-estimates of abilities. As children develop a differentiated sense of their self-concept, their interests become crystallized, such that by

the time they reach early adulthood, their interests are highly stable throughout their adult life-span (Strong, 1952).

4. “Investment” theories

A framework that has been proposed to account for development of individual differences in abilities and knowledge over the lifespan, that can be generalized to a wide variety of domains of expert/elite performance is known as the “investment hypothesis.” The initial framework was developed by Cattell (1971/1987). It was built on earlier investigations and theories, namely by McDougall (1933), who noted the interplay of ability and motivational traits in the development of individual differences in knowledge, and Hayes (1962), who proposed that both inherited and developed motivational drives lead individuals toward or away from different learning experiences, that in turn, lead to developmentally different trajectories for abilities and knowledge between individuals. To the degree that there is substantial neural plasticity in children, these differences in motivational patterns early in a child’s life will lead to differences in competencies over the course of development.

Cattell’s investment theory incorporated the ideas of McDougall and Hayes. Cattell specified that the amount of time and effort expended in the investment of fluid intelligence is partly determined by the individual’s interests, personality traits, and motivation toward or away from activities that relate to acquisition of knowledge and skills (see also Ackerman, 1996). In addition, through examination of the relations among ability traits, personality traits, and interests (Ackerman & Heggestad, 1997), the concept of “trait complexes” was introduced, to account for combinations of traits that appear to be facilitative or impeding factors in the development of particular domains of knowledge and skills. Individuals who are high in intellectual/cultural trait complexes (e.g., those who have high levels of verbal abilities, high levels of intellectual engagement personality traits, and artistic/investigative interests, tend to orient toward development of domain knowledge and skills in academic subjects (e.g., literature, music, art). Individuals who are high in social trait complexes (e.g., social interests, extroverted personality traits) tend to avoid acquiring academic domain knowledge, but instead invest their cognitive resources in developing social skills.

5. Motivational traits and states

As aptly noted by Starkes (2007), discussion of the role of motivation in the context of the nature/nurture debate is “... akin to the elephant in the room.” (p. 94). In Ericsson’s deliberate practice framework, motivated/deliberate practice is a requisite condition for achieving expert/elite performance. Indeed, in any theory of performance, whether it be performing well on a test of intelligence (e.g., see Binet & Simon, 1905; for a review, see Ackerman, 1996), studying for a course final exam, writing a novel, or even getting a child to take out the household trash, motivation is one of two essential ingredients of performance (the other being capability to perform the behavior). Motivation theorists traditionally consider motivation expressed as the *direction* of effort, the *intensity* of effort, and the *duration* or *persistence* of effort expenditures (Kanfer, 1990). However, as Kanfer noted, “Motivation is not directly

observable. What we *observe* is a multidimensional stream of behavior and the products of those behaviors Motivational processes can be inferred only from analysis of this continuing stream of behavior that is determined by environment and heredity and is observed through their effects on personality, beliefs, knowledge, abilities and skills.” (Kanfer, 1990, p. 78).

Hayes (1962), in an argument for the genetic determination of motivational trait differences, provided several illustrations of different motivational patterns between different strains of guinea pigs, rats, mice, and dogs. He extended these illustrations to a larger theory of the development of intelligence (and by implication, expertise), in humans, where motivational traits determine the direction and intensity of a child’s pattern of behavior, leading to individual differences in the level of different intellectual abilities. However, as with any of the other traits discussed in this paper, it is reasonable to assert that environmental rewards and punishments for motivated behaviors will also affect (to a degree) the individual’s orientation toward or away from different activities, over both short and long-term horizons. Holland, for example, proposed that interests are composed of two major components: (1) types (which are motivational, in terms of direction of effort), and (2) occupational level (which concerns the level of challenge or complexity that the individual aspires to, such as achievement or attainment aspirations, and thus relates to intensity and persistence of motivated effort). An individual’s placement along the various types of interests and level of interests depends, at least in part, according to Holland, on the individual’s patterns of successes and failures in childhood, on the broader family environment (e.g., socio-economic status), that together interact to influence the child’s self-concept for particular domains – self-concept roughly translates to the individual’s confidence in his/her abilities. Development of self-concept, interests, and abilities/skills occurs through feedback resulting from the child’s success and failure experiences, in either a positive or negative fashion, respectively, increasing the child’s interests with success feedback or decreasing the child’s interests with failure feedback. It is important to note that, once acquired, an individual’s self-concept may be high or low, but also may be accurate or inaccurate.

It is not unusual to find adolescents or adults with inaccurate self-concepts, but it is more typical to find individuals who have a pretty-good sense of their abilities and skills (e.g., see Ackerman & Wolman, 2007). In fact, some individuals attempt to motivate their continued efforts to master tasks by engaging in a bit of self-delusion, known as “defensive pessimism” (Norem & Cantor, 1986). Such individuals tell themselves that they will fail without extensive time and effort spent practicing and studying, and thus use the fear of failure as a motivational spur to action. Other individuals can be characterized as having a “rage to master” (Winner, 1996); something that is often found among prodigies in a variety of domains. These individuals persist to a much greater degree in engaging a task than others, because of a keen motivational interest in mastering a task – perhaps to an obsessive degree. Such motivations are typically narrow – they pertain to a specific domain, rather than to learning in general.

By the time individuals reach adulthood, they have stable patterns of general motivational traits that include three major factors: desire to learn/mastery, competitiveness/other-oriented goals, and worry/emotionality in achievement contexts (Kanfer

& Heggstad, 1997). The first two factors are 'appetitive' — that is, they concern an individual's motivation *towards* success; the third factor is related to 'aversion,' or motivation away from failure. The difference between the first two factors generally relates to an individual's *intrinsic motivation* (internally derived motivation) and the individual's *extrinsic motivation* (an orientation toward external rewards and excelling in competition). However, these traits are not specific to an individual activity, but to achievement activities in general. Indications from cross-sectional studies of adults (e.g., Kanfer & Ackerman, 2004) appear to point to changes in these motivational traits as adults age from late adolescence to middle age and beyond. For example, extrinsic motivations of money may diminish, once the individual has achieved his/her goals for financial security.

In addition to motivational traits that operate on a general or more distal level, there are motivational states that operate on a specific or more proximal level. An individual may be more or less motivated to perform a task well (or even to practice on any given day) when a parent or coach is present, or the extrinsic rewards for performance are very high or very low. Thus, from a motivational perspective, the level of effort devoted to a task for any specific sample of behavior, will only partly be attributable to the individual's motivational traits, and partly attributable to the specific level of environmental press that is currently imposing on the individual.

In the context of attaining expert/elite performance, the sheer amount of practice an individual completes is only an indirect indicator of motivation, and the conditions of external rewards/punishments must be considered as contributing factors (not to mention the costs and benefits of practicing a task measured against alternative actions [for a child or adolescent, this would include alternatives to practice such as engaging in play, studying, or doing chores]). Examination of the individual's goals is often a useful method to understanding the individual's commitment and level of motivation for task practice, but these have rarely been examined in the context of the study of expert/elite performance development, at least during the long intermediate stages of skill acquisition.

In the final analysis, an adequate understanding of the role of motivational traits and states in development and expression of expert/elite performance can only be accomplished by taking account of the early development of interests and self-concept, but also goals and aspirations, along with family environmental influences (e.g., parent involvement, presence or absence of siblings, socioeconomic status) on motivation toward or away from the target skill.

6. Investment theories and expert/elite performance

What are the implications of investment theories for development of expert/elite performance, especially in sports? There are three main implications, as follows:

1. "Talent" in this framework, is the individual's current standing on various dimensions of individual differences (e.g., cognitive, affective, conative). These traits arise through a complex interaction of genetics and environment, but once developed, are relatively stable and important determinants of future behaviors and skill development.

- a. Different skills place different demands on various traits (e.g., intellectual ability, physiology, morphology). The relative stability of many traits, even allowing for extreme environments encountered after childhood, means that some individuals will have an extremely low likelihood of developing particular kinds of expert/elite performance, because they lack the requisite developed traits.
 - b. Having adequate levels of key traits is necessary, but not sufficient for talent development. Investment of cognitive, affective, and conative resources is needed to reach expert/elite performance.
2. By the time an individual reaches school age, he/she already has a reasonably well developed set of personality-linked likes and dislikes, interests, and array of aptitudes. Substantial interindividual differences exist in these traits, that appear to be instrumental in even getting the individual to engage in a particular skill-building environment (whether it be in music, art, various sports, science, math, and so on). The implication is that there are substantial individual differences in the interest and desire for either particular activities, but also in the motivations for persisting in such activities, especially in the face of failure or inadequate learning progressions (e.g., plateaus in performance). Individual coaches and tutors may be able to help an otherwise interested or motivated individual over performance plateaus, but individual differences in initial interests and motivation will intensify or attenuate the influence of a coach or tutor.
 3. Beyond infancy, new learning and skill acquisition importantly depend on prior learning (namely transfer of knowledge/skills, Ferguson, 1956). As the child matures into adolescence and beyond, there is a substantial decline in mental (and physical) plasticity. With the exception of some tasks that require physical maturation for expression, acquisition of skills beyond these critical periods will require greater amounts of time and effort, and eventually, the individual will no longer be capable of developing expert/elite levels of performance, regardless of available time and effort for deliberate practice. Transfer of training is especially important in the acquisition of new skills/expertise. An individual who has acquired skills that have overlapping components with another skill, will be expected to have a much steeper acquisition function for the new skill (i.e., learn the task faster than a novice who has no prior expertise in either domain).

In general, the degree of transfer is dependent on the overlap and the compatibility of the two different skills (Osgood, 1953; see Adams, 1987 for a review). Transfer situations with reasonably positive overlap include, for example, driving in an F1 competition and driving in NASCAR. Transfer situations with both negative and positive overlap, for example, include gymnastics and ballet, where the individual must 'unlearn' some incompatible techniques and response patterns in order to acquire the new skill. In such cases, transfer may be an overall neutral, positive or negative phenomenon, depending on the level of initial learning (where early learning is more general, later learning is more task specific) and the incompatibility of specific skilled movements across the two activities. In more intellectual areas, such as the science

professions, transfer of expertise typically occurs between areas that have the same or similar foundational knowledge (e.g., from biology to biochemistry), there have been several cases of individuals who have made substantial scientific contributions in more than one domain (e.g., see [Simonton, 1988](#)).

7. Talent identification

One of the recurrent themes in the literature purporting to support the extreme nature/deliberate practice approach is the absence of demonstrated correlations between measures of interindividual differences traits (e.g., intelligence, personality, motivation) and differences among expert/elite performers, or even between expert/elite performers and individuals who have undertaken extensive practice, but yet not achieved comparatively high levels of performance. The inference that is made from these ‘findings’ is that “talent” (which Ericsson calls “genetic endowment”; [Ericsson, 2007, p. 4](#))) does not importantly figure in either the development of expert/elite performance or in individual differences in performance at high levels of expertise. First of all, it is important to note, as I have done several times in this paper, that it is erroneous to refer to “talent” as “genetic endowment” – genetic endowment may be necessary for development and expression of talent, but genetic endowment is by no means a sufficient cause for expression of talented behavior. It takes both environmental support and an interaction between genes and environment to give rise to talent, that is, individual differences in the capabilities to perform any complex behavior.

A review of the literature and consideration of statistics provide straightforward explanations for the lack of demonstrated validity in predicting individual differences in expert/elite performance. In nearly every case where individual differences measures have been administered to expert/elite and non-expert elite performers (e.g., see [Ericsson, 2006](#); [Tuffiash et al., 2007](#)), the studies have been flawed by: (1) small samples, (2) restriction in range, (3) either poor or otherwise limited measures of traits, and (4) a misinterpretation of the literature on abilities and individual differences. A brief overview of these issues is provided here.

1. Statistical power to detect a significant relationship between two variables (e.g., a trait measure and a performance measure) is directly related to the size of the sample of individuals being tested. For example, if we assume that the trait of intelligence accounts for 10% of the variation in performance among elite chess players, in order to have a high degree of statistical power, such as .80 (that is, the probability of detecting the effect if indeed it exists), a minimum sample of size of 76 subjects is required (source: *G*Power*, [Faul, Erdfelder, Lang, & Buchner, 2007](#)). However, statistical power of an experiment is diminished, when the sample is restricted in range of talent (e.g., either intelligence and/or performance), or when the measures have inadequate reliability and/or validity.
2. Restriction of range of talent. When sampling from the population at large, one can expect no restriction of range of talent. However, when a sample is chosen from a population that is already restricted on measures, especially those variables that are correlated with one of the variables being

assessed, observed correlations are much closer to zero than they are in the population at large (see [Ghiselli, Campbell, & Zedeck, 1981](#)). There are statistical procedures for estimating the population correlations when such conditions are encountered (e.g., see [Thorndike, 1949](#)), but these have never been reported in the deliberate practice literature, even when ‘intellectual abilities’ are assessed in samples of highly-selected elite university students as experimental subjects. A related problem is typically found with measures of the performance criteria, especially when speed of responding to a complex stimulus in a skill-learning task is the criterion. That is, the magnitude of individual differences – that is, the spread of individual performances on the criterion – is much larger at initial stages of practice than it is at well-practiced performance (see [Ackerman, 1987](#)). It is not unusual to find post-practice interindividual differences to have as little as 1/3 the overall variance in performance, when compared to pre-practice performance. The restriction in range on the performance measures means that there is less variance that *can* be explained by any predictor variable post-practice than at pre-practice stages of skill acquisition.

As mentioned earlier, examining only those individuals who have passed successive hurdles in earlier task engagement (e.g., access to the task, time available for practice, availability of coaches or other instruction), means that the full range of talent in the population is not represented in a study, and so may lead to the erroneous assertion that there is no influence of particular variables on performance, even though those variables are absolutely essential ingredients for expert/elite performance, or even for average or good levels of performance. To adapt [Buss’s \(1984\)](#) example, the correlation between leggedness and swimming or skiing performance among individuals who have practiced for thousands of hours on these respective tasks, is essentially zero, simply because there is no variance in leggedness among most likely samples of individuals who would fit the inclusion criterion of high levels of practice. This is an extreme example, but it is also true that there is a relatively small correlation between intelligence and grades among graduate students in elite universities, and there is most likely a negligible correlation between those individuals who receive Nobel prizes for science or medicine, and those who are nominated, but do not receive the award.

It would, however, be erroneous to assume that on the basis of a lack of a significant correlation between leggedness and swimming performance, or between intelligence and Nobel prizes received, that these key variables have no role in differentiating between expert and non-expert performers. Individuals with fewer than two legs cannot reach expert/elite swimming performance levels, any more than profoundly intellectually retarded individuals could receive a Ph.D. from an elite university and go on to attain a Nobel prize (e.g., generally, estimates of IQ of Physics Ph.D.s have a mean of about 140, which is achieved by fewer than 1% of the population – see [Simonton, 1988](#)). If, for example, an open admissions process were in place at the university graduate school, such that anyone would be admitted, regardless of talent or prior experience, the correlation between intelligence and graduate school success would be high. Indeed, such was the case early in the 1910s and

1920s, prior to the widespread implementation of selection tests, such as the SAT, for selecting students for university admission (see [Toops, 1926](#) for a review).

3. Selection of predictor measures. The number of trait factors across cognitive, affective, and conative domains is very large (in the hundreds), and there are typically numerous instruments designed to measure each of these. Selection of an appropriate set of predictors is often a difficult task that one must undertake prior to conducting a study. In addition, just because a test is named by a developer with a particular trait does not insure that the measure is reliable (i.e., provides consistent rank-orders of individuals), valid (i.e., the instrument measures what it sets out to measure), or suitable for the sample of subjects in the study ([Anastasi & Urbina, 1997](#); [Cronbach, 1990](#)). *Ceteris paribus*, brief tests tend to be less reliable than longer tests, and reliability sets an upper bound on validity, because a measure cannot correlate more highly with another instrument than it does with a repetition of the same test. Conventional psychometrics authorities ([Mulaik, 1972](#)) recommend that any attempt to measure a single trait requires at least three highly reliable and valid measures, that can be aggregated to provide an overall robust estimate of the underlying trait. Assessment of multiple traits in a single study requires that the investigator must select and administer a large number of measures, a requirement that has never been met by the kinds of investigations that seek to determine individual differences determinants of expert/elite performance.
4. Misinterpretation of the literature. Ericsson and his colleagues repeatedly claim that “In general, IQ tends to correlate with performance at very low skill levels, and is not significant for individuals reaching high levels of performance after extended deliberate practice, which supports other findings that IQ has increasingly less, even no reliable, predictive power after many years of experience (see [Hulin, Henry, & Noon, 1990](#))” (p. 38). There are several aspects of such statements that are problematic. First, it implicitly revives the old chestnut that the relationship between intelligence and performance is *not* linear, that is, intelligence correlates with performance for low-performing individuals, but not for high-performing individuals (e.g., see [Hoffman, 1962](#); for evidence to the contrary, see [Coward & Sackett, 1990](#)). Second, it draws on a highly flawed review of the literature ([Hulin et al., 1990](#)), where within-task correlations (that show a ubiquitous simplex-like pattern, regardless of whether the measures are intelligence or weather records, see [Humphreys, 1960](#)) are interpreted as predictive validity studies (for critical reviews, see [Ackerman, 1989](#); [Barrett, Alexander, & Doverspike, 1992](#)). Third, it ignores data that are directly contradictory to their hypothesis, such as when tasks have substantial demands for handling novelty (e.g., air traffic control), where intellectual abilities are highly related to individual differences in both novice and experienced task performers (e.g., see [Ackerman & Kanfer, 1993](#); [Sells, Dailey, & Pickrel, 1984](#)). Forth, the initial premise, that of using IQ as the sole ability predictor of performance after extended practice, is insufficient, mainly because IQ measures were developed to predict educational performance of children and adolescents, and were not developed to predict expert performance in occupations for

adults. The fact that such measures do indeed correlate with non-trivial magnitudes provides evidence that abilities are indeed predictive of individual differences in expert performance – the fact that other, more tailored ability measures do so with even greater degree of validity supports the notion that the IQ is broader than is optimal for prediction of expert performance, even in sport (e.g., see [Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012](#))

8. Base rates, Bayesian statistics, and the prediction of expert/elite performers

Advocates of the dominant role of “nurture” over talent in accounting for expert/elite performance have pointed to Terman's studies of genius ([Terman, 1925](#); e.g., see [Gladwell, 2008](#)). Briefly, Terman recruited over 1000 children who scored above IQ = 140 (putting them in the top 1% of the population) to participate in a longitudinal study, where they were tracked over 70 years (e.g., see [Holahan et al., 1995](#)). Even though Terman's subjects turned out to have higher levels of achievement in myriad activities, compared to the population at-large, it is noted that among the children *not* selected for the study were individuals who went on to obtain Nobel prizes (namely, [Shockley](#) and [Alvarez](#), see [Shurkin, 2008](#)). The implied, but erroneous, conclusion from these observers is that talent (intelligence) is not particularly important in the determination of who will achieve scientific eminence. Aside from the psychometric issues discussed earlier, there is a fundamental problem with prediction outcomes for individuals who are at one or the other tail of a wide distribution of talent. The fundamental problem comes from the influence of *base rates* (i.e., the proportion of individuals in the population who have the criterion attribute) on the capability of any predictor or set of predictors to identify those individuals. The full explication of the underlying Bayesian statistics is beyond the scope of this paper, but the general framework for predicting behavioral outcomes, while also taking account of test validity and base rates has been described in detail by [Meehl and Rosen \(1955\)](#).

A quick, back-of-the-envelope set of calculations illustrates the difficulty in identifying expert/elite performers among an otherwise unselected group of individuals. The key ingredients to the calculation are the base rate of the outcome (in this example, achieving world-class performance levels in some sport), and the efficiency of some prediction measure or measures (e.g., running speed at Age 10, perceptual/motor skills at Age 6, visual acuity at Age 15). By definition, expert/elite performance is only achieved by a very small number of individuals, in comparison to the population at-large. If we assume that expert/elite performance is achieved by only 1 in 100 individuals (which is a very liberal estimate), then the base rate for expert/elite performance = .01. Let us further assume that we have developed a battery of physical and psychological tests that successfully classify 70% of those that will reach the expert/elite level of performance (this is called “hits” within the theory of signal detection). Of course, this means that we will “miss” 30% of the individuals who go on to be expert/elite performers. Let us also assume that we successfully classify an equal rate of individuals who will *not* develop expert performance (70% correct rejections and 30% false alarms – that is, individuals who are identified as reaching expert/elite

performance, but fail to do so). A correlation coefficient calculated from such results would indicate a relationship of r (tetrachoric) of .40, which is a quite respectable predictive validity for predicting a behavior that is at least 10 years in the future from the time of testing.

Taking the .01 base rate (1 in 100) for success into account, the calculations indicate that, on the basis of a positive test score (indicating that the individual *will* attain expert/elite performance), an individual has an actual probability of achieving expert/elite performance of $P = .023$, that is, about 1 chance in 43 of achieving expert/elite performance (even though the test can be considered to be 70% accurate in detecting expert/elite performers)! Put another way, this means that of 100 individuals who “pass” the valid test that predicts expert/elite performance, only 2 will ultimately succeed, and 98 will ultimately fail. However, some would argue that world-class performance is attained by far fewer individuals than 1 in 100. If the base rate were in fact .001 (that is, 1 in 1000 will ultimately achieve world-class performance), then the actual probability of achieving expert/elite performance, given a positive test score, is reduced to $P = .002$. This means that in 1000 individuals identified as having a positive indicator for world-class performance, only 2 will succeed, and the other 998 will fail.

With this as background, it should be easy to see that it is nearly impossible to identify individuals at an early age who will go on to achieve expert/elite performance, *unless* either the base rate is much higher (e.g., 50% of individuals go on to achieve this level of performance), or the test has an extremely high validity (e.g., the correlation between the predictor measure and the criterion of expert/elite performance approaches 1.0). Note that what this analysis indicates, is *not* that the predictor measures are invalid for predicting expert/elite performance, or that the only thing that matters is deliberate practice. In fact, it was assumed that our test had a reasonably high validity index, and that whatever was measured (e.g., talent), was indeed predictive of success. The bottom line is that when base rates are extreme (near zero or near one), tests must have impossibly high validity to make predictions that substantially improve upon the underlying base rate for success. Getting back to Terman's study, and the failure to identify Nobel Laureates, the answer is that one should have expected that an initial base rate around .001 (1 in 1000), it was much more likely that Terman would have missed these individuals than it would be for him to have found them.

9. Successive hurdles approach

As noted by Meehl and Rosen (1955), one approach to mitigate against errors of prediction when base rates are very low, is to employ a successive hurdles approach to assessment, when each additional hurdle represents a more valid prediction, and an increase in the base rate for success. This is, in fact, the exact procedure that is used in most sports-selection situations, whether in the 1980s Romanian gymnastics system (e.g., see Wood, 2010), 2006 Australian skeleton team (Bullock et al., 2009) various other sports in other countries (see Wolstencroft, 2002 for a review) or in the modern NFL football system. These systems are constructed such that children with interest/talent typically self-select to participate in the sports to

begin with, but with increasing age and practice in club sports or school sports, their numbers are successively winnowed-down, so that at each subsequent stage, a smaller number of the most highly talented/experienced/etc. individuals remain. By the time an individual reaches collegiate sports (e.g., college football), they represent only 1 in 100 or 1 in 1000 of the original group of children who start off in the sport. By analyzing the performance of individuals at this stage, prediction of future professional or Olympic success occurs at a much higher rate (though, such selection is still error-prone, as NFL teams can testify when early draft picks turn out to be mediocre players, once they enter the level of professional sports). Again, this approach does not exclude the possibility that individual differences in talent are strongly correlated with expert/elite performance, but rather the influence of talent has to be considered as a predictor at each stage of the funnel starting with childhood performance and ending with collegiate performance. By the time an individual reaches the collegiate level, nearly all of the individuals with low levels of talent (the “false alarms” in the example above) have dropped out or been otherwise selected-out of the pool of potential expert/elite performers.

In the context of those who persist in believing that genetic endowment is the primary source of influence in determining those who attain expert/elite performance, a one-step selection procedure will still largely fail to accurately identify those individuals who will reach their ‘potential,’ unless the validity of the genetic markers is extremely high, in order to move beyond the extreme base rates. This means that should there be many gene markers that together account for individual differences in later expert/elite performance, each one would have to be fully accounted for, or the overall validity would be too small for effective prediction. In the context of those who persist in believing that deliberate practice is the primary source of influence in determining those who attain expert/elite performance, the successive hurdles approach to talent identification is exactly the data they would use to “support” their theory, but such support would be illusory, given the extreme restrictions of range in talent among those individuals who end up at the end of the funnel that eliminates sub-elite performers at each stage.

10. Summary and conclusions

In this paper, I have attempted to provide a critical review the central issues regarding so-called “Talent myth” and the “10,000 h rule” as they are applied to expert/elite performance. The main points put forward in this paper are as follows:

1. When it comes to expert/elite performance, both the extreme nature and the extreme nurture views are silly. (“Silly” is a term that philosophers sometimes use, see Bergmann, 1956.) It is only possible to explain individual differences in elite/expert performance by a combination of genetic and environmental factors, along with their interactions.
2. Although practice (motivated and deliberate) is necessary for expert/elite performance, it is not sufficient.
3. Not everyone gets to be an elite performer in most endeavors, because of physical limitations, mental limitations, and age of acquisition/aging factors.

4. "Talent" is not properly thought of as a genetic or innate endowment, but rather as a developed set of traits that are integral to the further development of expert/elite performance. In some sports, by mid-childhood, and for most sports, by mid-adolescence, a failure to learn and show initial excellence in sport will lead to inadequate 'talent' for ultimately reaching expert/elite performance.
5. Development of expert/elite performance skills is most likely a complex function of cognitive, affective, and conative traits that in turn, determine the direction, intensity duration, and effectiveness of practice/learning.
6. Inadequate study designs will often result in the failure to find significant correlations between trait measures and individual differences in the development of expert/elite performance.
7. Analyzing differences among only those individuals who have engaged in extensive task practice, is unlikely to yield useful information about the importance of trait measures for predicting expert/elite performance, because achieving extensive task practice effectively reduces the range-of-talent in the sample, thus eliminating from consideration those who lack the requisite standing on critical traits.
8. Single-step talent identification, when the sample is largely unselected (e.g., novices) is unlikely to yield a successful classification of individuals who will become expert/elite performers, because the target behavior is highly unusual (base rates of .01, .001 or even lower rates), and tests must have unreasonably high validity to supersede base rate predictions.
9. Multiple hurdle approaches, which largely describes current talent identification procedures in the real world, are most likely to yield successful classifications of future expert/elite performers, given the successive winnowing of the population on the basis of talent and performance indicators.
10. Talent *does* matter in the development of expert/elite performance.

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