BEHAVIORAL AND BRAIN SCIENCES (1998) **21,** 399–442
Printed in the United States of America

Innate talents: Reality or myth?

Michael J. A. Howe
Department of Psychology, University of Exeter, Exeter EX4 4QG, England
Electronic mail: *m.j.a.howe@exeter.ac.uk*

Jane W. Davidson
Department of Music, University of Sheffield, Sheffield S10 2TN, England
Electronic mail: *j.w.davidson@sheffield.ac.uk*

John A. Sloboda
Department of Psychology, Keele University, Keele, Staffordshire ST5 5BG, England
Electronic mail: *j.a.sloboda@keele.ac.uk*

Abstract: Talents that selectively facilitate the acquisition of high levels of skill are said to be present in some children but not others. The evidence for this includes biological correlates of specific abilities, certain rare abilities in autistic savants, and the seemingly spontaneous emergence of exceptional abilities in young children, but there is also contrary evidence indicating an absence of early precursors of high skill levels. An analysis of positive and negative evidence and arguments suggests that differences in early experiences, preferences, opportunities, habits, training, and practice are the real determinants of excellence.

Keywords: exceptional ability; expertise; gift; innate capacity; music; potential; prodigy; specific ability; talent

1. Introduction

In many areas of expertise, ranging from music, dance, art, and literature to sports, chess, mathematics, science, and foreign-language acquisition, there is abundant evidence that young people differ from one another in their attainments and in the apparent ease with which they achieve them. Even within a family there may be marked differences: for example, a child who struggles at a musical instrument without much success may be overtaken by a younger sibling.

It is widely believed that the likelihood of becoming exceptionally competent in certain fields depends on the presence or absence of inborn attributes variously labelled "talents" or "gifts" or, less often, "natural aptitudes." According to an informal British survey, more than three-quarters of music educators who decide which young people are to receive instruction believe that children cannot do well unless they have special innate gifts (Davis 1994). The judgement that someone is talented is believed to help explain (as distinct from merely describing) that person's success. It is also widely assumed that the innate talent that makes it possible for an individual to excel can be detected in early childhood. We will refer to the view that exceptional accomplishments depend on a special biological potential that can be identified in some young children but not others as "the talent account." The purpose of this target article is to examine the evidence and arguments for and against this account.

The talent account has important social implications. A consequence of the belief that innate gifts are a precondition for high achievement is that young people who are not identified as having innate talents in a particular domain are likely to be denied the help and encouragement they would need to attain high levels of competence. Children's progress can be affected negatively as well as positively by adults' expectations (Brophy & Good 1973).

1.1. Agreeing on a definition of innate talent. Before considering evidence for and against the talent account, we should be as clear as possible about what is meant by "talent." People are rarely precise about what they mean by this term: users do not specify what form an innate talent takes or how it might exert its influence.

Certain pitfalls have to be avoided in settling on a definition of talent. A very restrictive definition could make it impossible for any conceivable evidence to demonstrate talent. For example, some people believe that talent is based on an inborn ability that makes it certain that its possessor will excel. This criterion is too strong. At the other extreme, it would be possible to make the definition of talent so vague that its existence is trivially ensured; talent might imply no more than that those who reach high levels of achievement differ biologically from others in some undefined way. No matter how talent is defined, those who believe that innate talent exists also assume that early signs of it can be used to predict future success.

For the purposes of this target article we will assign five properties to talent: (1) It originates in genetically transmitted structures and hence is at least partly innate. (2) Its full effects may not be evident at an early stage, but there will be some advance indications, allowing trained people to identify the presence of talent before exceptional levels of mature performance have been demonstrated. (3) These early indications of talent provide a basis for predicting who is likely to excel. (4) Only a minority are talented, for if all children were, there would be no way to predict or explain differential success. Finally, (5) talents are relatively domain-specific.

In principle, it is desirable to define precisely the indicators of talent, but in practice some imprecision is unavoidable, as in the phrase "relatively domain-specific" in (5). We would have preferred to be able to specify the boundaries between domains, but this is not currently possible. Nor can one specify just how much a trait should facilitate the acquisition of special abilities to qualify as a talent: the available empirical evidence is too coarse. We allow the possibility that an innate talent can take different forms. For example, saying that each of two children has "a talent for music" need not imply that both are advantaged in precisely the same way. A domain may draw on many different skills, and individuals' competence levels in them may not be highly intercorrelated (Sloboda 1985; 1991).

1.2. The talent concept in researchers' explanations. Our five properties are meant to provide a working definition that is acceptable to researchers and captures the intuitions of the lay public. Like laypersons, researchers typically believe that when they introduce the term "talent" they are predicting or explaining someone's performance, not just describing it. For example, Feldman (1988), writing about child prodigies, remarks that "it is not obvious what their talents will lead to" (p. 281): He insists that "the child must possess talent, and it must be very powerful" (p. 280). For Feldman, talents cannot be acquired; they must be "possessed" innately by prodigies. He believes that prodigies demonstrate "exceptional pretuning to an already existing body of knowledge, one that countless others had spent time and energy developing and refining" (p. 278). Similarly, Gardner (1993a) equates talent with early potential, noting that "a poignant state of affairs results when an individual of high talent and promise ends up failing to achieve that potential" (p. 176). For Gardner, talent is defined as a sign of precocious biopsychological potential in a particular domain (Gardner 1984; 1993b). The possession of "a strong gift in a specific domain, be it dance, chess or mathematics" is recognised by Gardner when there is a coincidence of factors, the first of which is "native talent" (1993b, p. 51). According to him, individuals who accomplish a great deal are people who were "at promise" in relevant areas from early in life.

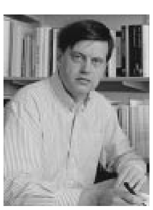
For Heller (1993, p. 139) "scientific giftedness . . . can be defined as scientific thinking potential or as a special talent to excel in [natural sciences]." Detterman (1993, p. 234) likewise suggests that "innate ability is what you are talking about when you are talking about talent." Eysenck and Barrett (1993) claim that a strong genetic basis underlies all the variables associated with giftedness. Eysenck (1995) insists on the existence of genetically transmitted talents, which he regards as necessary but not sufficient for the emergence of genius. Benbow and Lubinski (1993) agree that talent is explicitly biological: they claim that "people are born into this world with some biological predispositions" (p. 65). Based on a survey of the use of terms such as "aptitude," "giftedness," and "talent" by experts and laypersons, Gagné (1993) concludes that a special ability must have a genetic basis to be defined as a gift or aptitude. Winner (1996) and Winner and Martino (1993) regard talents as unlearned domain-specific traits that may develop or "come to fruition" in favourable circumstances but cannot be manufactured. Talents are likely to be identified by parents or teachers or they may be discovered fortuitously (Winner & Martino 1993, p. 259), but many gifted children go unrecognised.

The above quotations make it clear that researchers and experts make extensive use of the concept of talent to predict exceptional abilities and to explain their causes. Because researchers as well as educators rely on the talent account, it is important to examine its validity.

Some previous challenges to the talent account have concentrated on the field of music. Sloboda et al. (1994a; 1994b) raised objections to the view that musical expertise arises from talent. They noted, for example, that in some non-Western cultures musical achievements are considerably more widespread than in our own (see sect. 3.3), that there are often no early signs of unusual excellence in outstanding adult instrumentalists (Sosniak 1985), and that very early experiences may be the real cause of what is interpreted as talent (Hepper 1991; Parncutt 1993). Others have challenged this analysis, arguing that the evidence of strong cultural influences on musicality can be reconciled

Michael Howe is a Professor of Psychology at the University of Exeter. Previously he taught at Tufts University and the University of Alberta. His research is on human memory, learning, and the acquisition of expertise. He is the author of a number of books about human capabilities, including *Fragments of Genius: The Strange Feats of Idiots Savants* (Routledge 1989), *The Origins of Exceptional Abilities* (Blackwell 1990), and *IQ in Question: The Truth About Intelligence* (Sage 1997). He has recently completed a book about the psychology of genius.

Jane Davidson is a Lecturer in Music at the University of Sheffield. Topics of research include the acquisition of musical skills, social interaction in music performance, production, and perception of musical expression. Editor of the journal *Psychology of Music*, she also performs as a vocal soloist and has appeared at the Queen Elizabeth Hall, St. Paul's Cathedral, and the London International Opera Festival.



John Sloboda is Professor of Psychology and Director of the Unit for the Study of Musical Skill and Development at the University of Keele, England. He has written more than 100 publications mainly in the area of music psychology, including *The Musical Mind: The Cognitive Psychology of Music* (Oxford University Press 1985). From 1994–1997 he was President of the European Society for the Cognitive Sciences of Music.

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

with the existence of innate talent (Davies 1994; see also Hargreaves 1994; Radford 1994; Torff & Winner 1994).

Criticisms of the talent account in other domains have been raised by Ericsson and Charness (1994; 1995), who provide substantial evidence that the effects of extended, deliberate practice are more decisive than is commonly believed. They argue that although children undoubtedly differ in the ease with which they perform various skills (a fact to which Gardner [1995] has drawn attention in challenging their conclusions), no early predictors of adult performance have been found.

2. Evidence in support of the talent account

Several findings appear to favour the talent account. (1) There are many reports of children acquiring impressive skills very early in life, in the apparent absence of opportunities for the kinds of learning experiences that would normally be considered necessary. (2) Certain relatively rare capacities that could have an innate basis (e.g., "perfect" pitch perception) appear to emerge spontaneously in a few children and may increase the likelihood of their excelling in music. (3) Biological correlates of certain skills and abilities have been reported. (4) Case histories of autistic, mentally handicapped people classified as "idiot savants" have yielded reports that appear to indicate impressive skills arising in the absence of learning opportunities.

2.1. Evidence of skills emerging unusually early. The literature on child prodigies (e.g., see Feldman 1980; Feldman & Goldsmith 1986; Fowler 1981; Freeman 1990; Goldsmith 1990; Gross 1993a; 1993b; Hollingworth 1942; Howe 1982; 1990a; 1993; 1995; Radford 1990) abounds with accounts of extraordinarily precocious development in the earliest years. Very early language skills are described by Fowler (1981) in a boy who was said to have begun speaking at 5 months of age, with a 50-word vocabulary 1 month later, and a speaking knowledge of 5 languages before the age of 3. Feldman and Goldsmith (1986) describe a boy whose parents said he began to speak in sentences at 3 months, to engage in conversations at 6 months, and to read simple books by his first birthday. Hollingworth (1942) writes that Francis Galton was reputed to be reading in his third year.

However, in none of these cases was the very early explosion of language skills observed directly by the investigator, and all the early studies were retrospective and anecdotal. Even the more recent studies have some of these limitations. For example, the boy described by Feldman and Goldsmith (1986) was not actually encountered by Feldman himself until he had reached the age of 3. Although the boy's parents claimed to be surprised by his swift progress, Feldman was astounded by their absolute dedication and "unending quest for stimulating and supportive environments" (Feldman & Goldsmith 1986, p. 36).

Fowler (1981) notes that the professed passivity of some parents is belied by their very detailed accounts. One pair of parents insisted that their daughter learned to read entirely unaided and claimed that they only realized this on discovering her reading *Heidi*. It turned out, however, that they had kept elaborate records of the child's accomplishments. Parents who keep such accounts cannot avoid becoming actively involved in the child's early learning.

Accounts of the early lives of musicians provide further anecdotes of the apparently spontaneous flowering of impressive abilities at remarkably early ages (Hargreaves 1986; Radford 1990; Shuter-Dyson & Gabriel 1981; Sloboda 1985; Winner & Martino 1993). A number of prominent composers were regarded as prodigies when they were young, and in some cases there are reports of unusual musical competence in their earliest years. Mozart's early feats are widely known. It is reported that the Hungarian music prodigy Erwin Nyiregyhazi was able to reproduce simple songs at the age of 2 and play tunes on a mouth organ at age 4 (Revesz 1925). Again, however, most of the reports are based on anecdotes reported many years after the early childhood events in question. Some of the accounts are autobiographical, such as Stravinsky's description of having amazed his parents by imitating local singers as a 2-year-old (Gardner 1984) or Arthur Rubenstein's claim to have mastered the piano before he could speak. The accuracy of such autobiographical reports is questionable considering that childhood memories of the first three years are not at all reliable (e.g., see Usher & Neisser 1993). The early biographies of prominent composers have revealed that they all received intensive and regular supervised practice sessions over a period of several years (Lehmann 1997). The emergence of unusual skills typically followed rather than preceded a period during which unusual opportunities were provided, often combined with a strong expectation that the child would do well.

There are also some descriptions of precocious ability in the visual arts, and Winner (1996) has collected a number of drawings by 2- and 3-year-olds that are considerably more realistic than those of average children. Among major artists, however, few are known to have produced drawings or paintings that display exceptional promise prior to the age of 8 or so (Winner & Martino 1993).

2.2. Evidence of special capacities that facilitate acquisition of specific abilities. Some individuals acquire ability more smoothly and effortlessly than others, but that fact does not confirm the talent account. Differences between people in the ease with which a particular skill is acquired may be caused by any of a number of contributing factors. These include various motivational and personality influences as well as previous learning experiences that equip a person with knowledge, attitudes, skills, and self-confidence. Facility is often the outcome rather than the cause of unusual capabilities (Perkins 1981).

Perhaps the clearest indication of a special capacity that is displayed by a minority early in life in the apparent absence of deliberate efforts to acquire it, making further advances likely, is encountered in the field of music. A number of young children have "perfect" or "absolute" pitch perception. A child thus endowed can both name and sing specified pitches without being given a reference pitch (Takeuchi & Hulse 1993). Structural differences in brain morphology related to absolute pitch have been observed. Musicians who have absolute pitch show stronger leftward planum temporale asymmetry than nonmusicians and musicians without perfect pitch (Schlaug et al. 1995). It is not clear, however, whether these differences are the cause of absolute pitch or the outcome of differences in learning or experience.

One might expect musicians who have absolute pitch to be more successful than those who do not, but this is not

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

always true. Perfect pitch perception has circumscribed utility. For example, it makes no contribution to an individual's interpretative ability. Moreover, there is evidence that it can be learned. It is relatively common in young musicians who are given extensive musical training prior to the age of 5 or 6, perhaps because a young child pays more attention to individual notes before coming to perceive sounds as parts of larger musical structures (Ericsson & Faivre 1988). Contrary to the view that absolute pitch provides clear evidence of a talent, it is sometimes found in individuals who begin their training late (Sergent & Roche 1973), and can even be acquired by adults, although only with considerable effort (Brady 1970; Sloboda 1985; Takeuchi & Hulse 1993).

Eidetic imagery has likewise been taken to be a talent. Like absolute pitch, it is observed in some young children but not others, and it appears in the absence of deliberate learning. Eidetic imagery seems to make young children capable of recalling visual information in some detail, but the phenomenon is somewhat fleeting and hard to verify with certainty, and it conveys few, if any, practical benefits. Although the phenomenon seems genuine as a subjective experience, evidence that eidetic imagery is correlated with above average remembering has proved elusive (Haber 1979; Haber & Haber 1988). Accordingly, there is little justification for believing that eidetic imagery conveys an advantage.

2.3. Evidence of biological involvement in exceptional skills. There is a large body of mainly correlational research on the relationship between various measures of brain structure, function, and activity and behavioural data. Performance has been linked to (1) electrocortical measures such as evoked potentials (Benbow & Lubinski 1993; Hendrikson & Hendrikson 1980) and their components (McCarthy & Donchin 1981), (2) hemispheric laterality (Gazzaniga 1985), (3) brain images (see Eysenck & Barrett 1993), and (4) saccadic eye movements (Charlton et al. 1989).

A number of correlates of high ability have been identified, including left-handedness, immune disorders, myopia (see Benbow & Lubinski 1993), blood flow measures (Horn 1986), neurohistology (Scheibel & Paul 1985), prenatal exposure to high levels of testosterone (Geschwind & Behan 1982), allergy, uric-acid levels, and glucose metabolism rates (see Storfer 1990), and laterality (Eysenck & Barrett 1993).

Gender differences in spatial abilities (Humphreys et al. 1993) appear to contribute to gender differences in mathematical performance and are probably based on biological differences. Information-processing parameters involved in a number of human abilities, such as response speed, are at least moderately heritable (Bouchard et al. 1990). Hereditary factors underlie various other individual differences in competence, such as working memory (Dark & Benbow 1991). Enhanced ability to manipulate information in short-term memory has been observed in young people who are unusually successful in mathematics (Dark & Benbow 1990). Moreover, because there are modest positive correlations between measures of special skills and heritable basic abilities such as general intelligence (Ackerman 1988; Howe 1989b), it is likely that some of the innate influences that contribute to variability in intelligence test scores also contribute to individual differences in special skills.

In general, the correlational evidence linking performance to brain characteristics suggests that innately determined biological differences contribute to the variability of expertise in specific areas of competence. There is a large gulf between identifying neural correlates of behavioural differences and finding a neural predictor of talent, however. The relations between neural and performance measures are too weak to warrant conclusions about talent. Moreover, the correlations diminish as tasks become more complex (Sternberg 1993).

To provide support for the talent account, neural correlates of exceptional skills would have to (1) be accompanied by clarity about the direction of causality, (2) include evidence that the neural measure is innately determined (rather than the outcome of differences in experience), (3) be specific to an ability, and (4) selectively facilitate expertise in a minority of individuals. We are unaware of any neural measures that come close to meeting these criteria. Nor has firm alternative evidence of early physical precursors of specific abilities emerged from studies of either prenatal capacities or postnatal cognition (Hepper 1991; Lecanuet 1995; Papousek 1995; Trehub 1990).

Ericsson (1990) and Ericsson and Crutcher (1988) argue that apparent indicators of structural precursors of ability may need to be interpreted with caution. Ericsson (1990) points out that individual differences in the composition of certain muscles are reliable predictors of differences in athletic performance and that this fact has been widely held to demonstrate genetic determinants of athletic excellence. He notes, however, that differences in the proportion of the slow-twitch muscle fibres that are essential for success in long-distance running are largely the *result* of extended practice in running, rather than the initial *cause* of differential ability. Differences between athletes and others in the proportions of particular kinds of muscle fibres are specific to those muscles that are most fully exercised in athletes' training for a specific specialisation (Howald 1982).

Some individual differences in brain structure and function are the outcome of differences in experiences rather than a primary cause. Experience can lead to changes in various parts of the mammalian brain, including the somatosensory, visual, and auditory systems (Elbert et al. 1995). For example, in violinists and other string players the cortical representation of the digits of the left hand (which is involved in fingering the strings) is larger than in control subjects. The magnitude of the difference is correlated with the age at which string players began instruction. Differences in early musical learning experiences may also account for the atypical brain asymmetries observed in musicians by Schlaug et al. (1995).

Although the evidence of a genetic contribution to human intelligence is consistent with the talent account, there are only weak correlations between general intelligence and various specific abilities (Ceci 1990; Ceci & Liker 1986; Howe 1989c; 1990b; Keating 1984). General intelligence need not limit final levels of achievement (Ackerman 1988), and may have little or no direct influence on specific abilities (Bynnner & Romney 1986; Horn 1986; Howe 1989c). Moreover, there is no evidence of specific gene systems affecting high-level performance of special skills in the predictive and selective manner required by the talent account. Psychological traits are more likely to be influenced indirectly by genes in a probabilistic way (Plomin & Thompson 1993). Even in the case of general intelligence, most of the research addresses the aetiology of individual differences in the normal range of ability. Relatively little is known about the genetic origins of high-level ability.

Knowledge about the genetic basis of specific high-level abilities is particularly limited (Plomin 1988; Thompson & Plomin 1993). In the Minnesota study of twins reared apart, self-ratings of musical talent correlated 0.44 among monozygotic twins reared apart, considerably less than the correlation of 0.69 for monozygotic twins reared together (Lykken, in press), suggesting that family experience makes a substantial contribution to self-ratings of musical ability. Similarly, in a study of musical abilities in twins, Coon and Carey (1989) concluded that among young adults musical ability was influenced more by shared family environment than by shared genes. On a number of measures the correlations between dizygotic twins, which ranged from 0.34 to 0.83, were not much lower than those between monozygotic twins (0.44 to 0.90).

The importance of general processing constraints diminishes as levels of expertise increase (Ackerman 1988; Krampe & Ericsson 1996); and some differences in basic skills are predictive of unskilled performance but less so of skilled performance (Ericsson et al. 1993b). In Coon and Carey's study all 8 relevant estimates of the heritability of musical ability were lower for participants who had taken some music lessons than for those who took no lessons at all; the average was less than 0.20 in the former group. Genetic differences that are initially relevant to expertise may be less important when large amounts of training and practice have been provided.

2.4. Evidence of unusual capacities in autistic savants. In most case histories of idiot savants it is apparent that the emergence of special skills is accompanied by obsessive interest and very high degrees of practice (e.g., see Howe 1989a; 1989b; Howe & Smith 1988; Sloboda et al. 1985; Treffert 1989). However, there a few reports of mentally handicapped children who display remarkable specific skills that seem to have been acquired without deliberate training or instruction. Among the well-documented cases are those of two child artists and a young musician; all three were described as being autistic.

From the age of 4, one of the artists, a girl named Nadia, was unusually slow, clumsy, and unresponsive, and spoke hardly at all, but drew many remarkable pictures, usually of horses, birds, and other animals. These pictures used advanced techniques to represent perspective, proportion, foreshortening, and the illusion of movement; they also showed impressive manual dexterity (Selfe 1977). The drawing skills of the other child artist, Stephen Wiltshire, are equally impressive (O'Connor & Hermelin 1987; Sacks 1995).

A 5-year-old autistic boy was described in Miller's (1989) study of musical abilities in the mentally handicapped. Like the artist Nadia, this boy was largely unresponsive to his physical environment and severely retarded in language development, with practically no speech. When confronted with a piano keyboard, however, he could not only reproduce a heard melody but also transform the piece by transposing it to a different key. He could improvise in ways that conformed to the conventions of musical composition. The abilities Miller observed seem to be based on a capacity to encode the fundamental units quickly and efficiently and to represent musical items in a complex knowledge system that incorporated sensitivity to harmonic relationships, scale or key constraints, melodic structure, and stylistic norms.

The remarkable capacities of autistic musicians and artists may seem to call for something close to the talent account. At least in the cases of Nadia and the 5-year-old boy described by Miller, their observed level of performance was beyond anything encountered in nonautistic children of comparable ages. Exactly why these children could do things that others could not remains largely a matter for speculation, although it is noteworthy that in many documented cases the autistic individuals spent many hours each day concentrating on their special interests. There is no direct evidence that the causes are innate, and if they do have an innate component, its main direct effect may be to augment the individuals' obsession rather than their specific skills as such.

3. Evidence appearing to contradict the talent account

Section 2 examined various kinds of evidence that appears to be consistent with the talent account. This section cites a variety of findings in the opposite direction. Other reasons for questioning the innate talent viewpoint are also introduced.

3.1. Lack of early signs. As noted in section 2.1, much of the evidence pointing to very early indications of unusual abilities is either retrospective or based on records supplied by parents whose claims to have played no active role in stimulating their children's progress are belied by other information. Except in the case of a small number of autistic children mentioned in section 2.4, there is no firm evidence of exceptional early progress without above-average degrees of parental support and encouragement. This is not to say that parental support or special opportunities and training account for all instances of excellence.

Innate influences might operate in ways that do not produce early signs, but to predict progress early evidence of talent is necessary. Unidentifiable early influences cannot be regarded as instances of talent, for the reasons given in section 1.1.

We will first consider some studies of whether children identified as unusually able by mid-childhood or later had displayed any early signs of special qualities other than those induced by early parental training or special encouragement.

It is important to keep in mind that early ability is not evidence of talent unless it emerges in the absence of special opportunities to learn. For example, it was once thought that the ability of infants in certain parts of Africa to sit and walk appreciably earlier than European children must have a genetic basis, but Super (1976) showed that this inference was wrong. Studying infants in a Kenyan tribe, he confirmed that they did indeed display motor capacities such as walking, standing, and sitting without support a month or so earlier than children in other continents, but he also discovered that the only skills these infants acquired earlier than others were those that their mothers deliberately taught them. When genetically similar infants from the same tribe were brought up in an urban environment in which parents did not provide the special training given in traditional villages, the infants displayed no motor precocity. Super reported a correlation of −0.9 between the age at which a baby began to crawl and a measure of the extent to which parents encouraged crawling. These findings do not rule out the possibility that some early differences have biological bases (Rosser & Randolph 1989), but they do show that this cannot be automatically assumed.

Retrospective interview studies of the early progress of individuals who eventually excel have provided little evidence of early signs of promise. Sosniak (1985; 1990) interviewed at length 21 outstanding American pianists in their mid-thirties, who were on the brink of careers as concert pianists. She also talked to their parents. There were few indications of the musicians displaying signs of future excellence while they were still very young. In most cases, unusually fast progress followed rather than preceded a combination of good opportunities and vigorous encouragement. Even by the time the young pianists had received approximately six years of relatively intensive training, it would have been possible to make confident predictions about their eventual success in only a minority of the cases. Similarly, a biographical study of 165 professional musicians in Poland produced very few reports of any preschool behaviour predictive of unusual musicality (Manturzewska 1986). A longitudinal study of elite German tennis players likewise found no early capacities that predicted tennis performance in early adulthood (Schneider 1993; see also Monsaas 1985). Interview studies of the childhood progress of accomplished artists (Sloane & Sosniak 1985), swimmers (Kalinowski 1985), and mathematicians (Gustin 1985) reported very few early signs of exceptional promise prior to deliberate parental encouragement.

Howe et al. (1995) studied the form and frequency of early signs of musical ability in 257 children, only some of whom made superior progress as performing musicians. The investigators asked the parents to indicate whether specific indicators of musical promise had occurred, and if so, when. The parents were asked when their children first sang, moved to music, showed a liking for music, were attentive to music, or sought involvement in a musical activity. Only with the first of these behaviours, early singing, did those who were eventually most successful display (slightly) earlier onset than the other children. In most of these cases a parent regularly sang to the infant well before any singing by the infant was observed (see also Howe & Sloboda 1991a; 1991b; 1991c; Sloboda & Howe 1991).

Some authors have suggested that early interest and delight in musical sounds may indicate innate musical potential (Miller 1989; Winner & Martino 1993), but a questionnaire found that these indicators failed as predictors of later musical competence (Howe et al. 1995). In any case, the assumption that even very early preferences must be innate rather than learned is questionable. Small differences in the amount of attention infants give (for any of a number of reasons) to different kinds of stimuli may elicit increasingly different actions and responses, which eventually produce marked preferences and contribute to differences between young children in their patterns of abilities (Renninger & Wosniak 1985; see also Slater 1995).

3.2. Evidence pointing to an absence of differences in ease of learning between "talented" individuals and others. Differences in rate or ease of acquisition of a capacity could reflect a specific talent, but only if other influences are ruled out. This is not easy to do. Confounding variables such as the degree of familiarity with task items may influence performance even in simple memory tasks based on highly familiar numbers (Chi & Ceci 1987; Miller & Gelman 1983).

Investigations of long-term practice effects provide some relevant evidence. Sloboda et al. (1996; see also Sloboda 1996) found no significant differences between highly successful young musicians and other children in the amount of practice time they required to make a given amount of progress between successive grades in the British musical board examinations. Group differences in average progress were no greater than would have been expected from the differences in the amount of time spent practising. Consistent with these results, Hayes (1981) and Simonton (1991) found that all major composers required long periods of training (see also Ericsson & Lehmann 1996; Howe 1996a; 1996b; 1997). Hayes (1981) concludes that at least 10 years of preparation are necessary. Simonton (1991) considers this an underestimate of the amount of time required. He estimates that, on average, prominent composers produced the first of their compositions to gain a secure place in the classical repertoire between the ages of 26 and 31, having begun music lessons around the age of 9 and started composing at around age 17. Chess players likewise need at least 10 years of sustained preparation to reach international levels of competitiveness (Simon & Chase 1973) and those who begin in early childhood take even longer (Krogius 1976). Comparable periods of preparation and training are essential in various other areas, including mathematics (Gustin 1985), X-ray and medical diagnosis (Patel & Groen 1991), and sports (Kalinowski 1985; Monsaas 1985; see also Ericsson et al. 1993b).

3.3. Exceptional levels of performance in "untalented" people. A body of findings hard to reconcile with the talent account comes from experiments on ordinary adults who are given large amounts of training at skills that make heavy demands on memory (Ceci et al. 1988; Chase & Ericsson 1981) or perception (Ericsson & Faivre 1988). In some instances, the trained subjects achieved performance levels far higher than what most people (including experts in the psychology of learning and memory) had believed possible. Uninformed observers assumed that the participants must have had a special innate aptitude. There have been similar findings in studies of job-related skills in waiters (Ericsson & Polson 1988) and bar staff (Bennett 1983). The cocktail waitresses in Bennett's study could regularly remember as many as 20 drink orders at a time: their performance was considerably better than that of a control group made up of university students. It is conceivable that people who are employed as waiters and bar staff gravitate to such jobs because of an inborn memory skill, but the Chase and Ericsson findings make it far more likely that employees excel in recalling orders because of on-the-job practice.

Accomplishments that are rare in one culture but relatively common in another also implicate learning rather than innate aptitude. In certain cultures very high levels of skill (by Western standards) have been observed in children

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

swimming and canoeing (Mead 1975), in land navigation over apparently featureless terrains (Lewis 1976) and maritime navigation across open water. Certain musical accomplishments are also considerably more widespread in some non-Western cultures than in our own (Blacking 1973; Feld 1984; Marshall 1982; Merriam 1967; Messenger 1958; Sloboda et al. 1994a; 1994b), and Australian desert aboriginal children perform better than white subjects on certain visual memory tasks (Kearins 1981). The fact that such precocious development of some skills in infants disappears when parents do not apply traditional training customs (Super 1976, see sect. 3.1) suggests that cultural variability in performance is caused by differences in opportunities to learn.

3.4. Conceptual difficulties with the notion of talent. There are certain conceptual and logical problems with the idea that talent contributes to exceptional human abilities. In everyday discourse reasoning about talent is often circular, for example: "She plays so well because she has a talent. How do I know she has a talent? That's obvious, she plays so well!"

Even among researchers who use the concept of talent for explanatory purposes, the supporting evidence is based on its alleged *effects*. Like many scientific constructs, talent is not observed directly but is inferred. There is nothing wrong with this, but one must be certain that the findings cannot be accounted for more plausibly without introducing the talent concept (Howe 1988a; 1988b; 1990b; 1990c, 1996b; Sloboda et al. 1994a; 1994b).

4. Alternative influences contributing to the phenomena attributed to the effects of talent

The causes of exceptional abilities may not be qualitatively different from those of less exceptional abilities in ordinary people. The links between high abilities and experiences that promote learning have been extensively discussed elsewhere (e.g., Berry 1990; Howe 1990a). Here we will consider the contribution of training and practice to various kinds of expertise.

Many dimensions of human variability may influence an individual's learning experiences and that person's eventual patterns of ability. These include: 1. relevant prior knowledge and skills; 2. attentiveness, concentration, and distractibility; 3. interests and acquired preferences; 4. motivation and competitiveness; 5. self-confidence and optimism; 6. other aspects of temperament and personality; 7. enthusiasm and energy level; 8. fatigue and anxiety.

Variations in opportunities and experiences, and in the appropriateness of training and the effectiveness of learning, practice, and testing procedures are also influential.

4.1. Evidence from studies of practising. Dramatic effects of training and practice on ordinary people were discussed in section 3.3. Even those who are believed to be exceptionally talented, whether in music, mathematics, chess, or sports, require lengthy periods of instruction and practice (Charness et al. 1996; Ericsson & Charness 1994; Ericsson et al. 1993; Starkes et al. 1996). Music is an area of competence thought to be especially dependent on talent (Davis 1994; O'Neill 1994); hence practice effects in other areas of competence are likely to be at least as strong as in music.

Ericsson and his coworkers (Ericsson et al. 1990; 1993a) have found strong correlations between the level of performance of student violinists in their 20s and the number of hours that they practiced. By the age of 21 the best students in the performance class of a conservatory had accumulated approximately 10,000 hours of practice, compared with less than half that amount for students in the same institution who were training to be violin teachers. Differences of similar magnitude were found in a study comparing expert and amateur pianists (Krampe 1994). Measures of the accumulated number of practice hours since instrumental lessons began were good predictors of within-group as well as between-group differences in performance. Studies of expert musicians by Manturzewska (1990), Sloboda and Howe (1991), and Sosniak (1985) provide further evidence that regular practice is essential for acquiring and maintaining high levels of ability. Furthermore, considerable help and encouragement is required by all young players, even those thought by their teachers and parents to be highly talented, if they are to maintain the levels of practice necessary to achieve expertise (Sloboda & Howe 1991; see also sect. 4.2).

Sloboda et al. (1996) supplemented retrospective data on practice with concurrent diary-based information. They confirmed the strong positive correlation between practice and achievement, which was largest for the more formal and deliberate kinds of practice activities, such as scales and exercises. Achieving the highest level (Grade 8) of the British Associate Board examinations in performing music required an average of approximately 3,300 hours of practice irrespective of the ability group to which the young people in the study were assigned. This suggests that practice is a direct cause of achievement level rather than merely a correlate of it.

Correlations between measures of performance and amounts of practice by music students range from approximately $+0.3$ to above $+0.6$ (Lehmann 1995). It is likely that these figures substantially underestimate the real magnitude of the relationship between performance and practice, for the following reasons: (1) The performance measures provided by grade levels are inexact indicators of attainment; and (2) global measures of practice time take into account neither the effectiveness of the particular practice strategies nor the role of other potentially influential factors such as the student's level of alertness, enthusiasm, and determination to do well. Kliegl et al. (1989) have confirmed that the intensity and quality of practice are as important as the sheer amount of it. Of course, the finding that practice is a major determinant of success does not rule out inherited influences; some traits that affect practising, such as the capacity to persist, may have innate components, but such components would not constitute "talents," as required by the talent account.

To summarise, there may be little or no basis for innate giftedness for the following reasons: (1) the lack of convincing positive evidence (sect. 2); (2) the substantial amount of negative evidence (sect. 3); (3) the finding that even crude retrospective measures of practice are predictive of levels of performance (sect. 4.1); (4) the observation by both Hayes (1981) and Simonton (1991) that "talented" individuals do not reach high levels of expertise without substantial amounts of training (sect. 3.2); (5) the evidence of Ericsson and others (Ericsson & Faivre 1988) that people who are

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

assumed to possess no talent are capable of very high levels of performance when given sufficient opportunities for training (sect. 3.3); and (6) the apparent absence of differences in the amount of practice time required by the most and least successful young musicians to make an equivalent amount of progress (sects. 3.2 and 4.1). The conclusion is reinforced when some of the other measurable factors known to contribute to variability in performance are taken into account: opportunities, preparatory experiences, encouragement, support, motivation, self-confidence, perseverance, and single-minded concentration (Howe 1975; 1980). To these influences must also be added differences in quality of instruction, effectiveness of practice strategy, and degree of enthusiasm.

4.2. Criticisms and counterarguments. There has been considerable opposition to the suggestion that the influence usually attributed to talent can be accounted for by the many known determinants of performance levels (including hereditary ones) that fall outside the definition of talent (Davidson et al. 1996; Ericsson et al. 1993a; Sloboda & Howe 1991; 1992; Sloboda et al. 1994a; 1996). A first objection is that the evidence linking practice to progress is largely correlational. Most of the findings take the form of data showing that the more a person trains and practices, the higher that individual's level of performance. These correlations could merely indicate that individuals who are successful in and committed to a field of expertise are likely to spend more time practising than those who are less successful.

One counterargument is that the findings closely parallel those obtained in training studies in which amounts of practice have been deliberately manipulated (Ericsson et al. 1990). Also relevant is the finding by Sloboda et al. (1996) that the rate of progress of young musicians in a given year is most highly correlated with the amount of practice and teacher input in that same year, whereas if the correlation simply reflected differing lifestyles of more and less successful performers, the amount of progress in one year would be more highly correlated with the amount of practice in the following year.

It is conceivable that some children practice more than others because they have some kind of innate potential that encourages them to do so. However, as Sloboda & Howe (1991) and Howe and Sloboda (1991b) discovered, even among highly successful young musicians, the majority freely admit that without strong parental encouragement to practice they would never have done the amounts of regular practising needed to make good progress. Strong and sustained parental encouragement to practice was evident in virtually all successful young musicians (Davidson et al. 1996). It is conceivable that the parents who gave the most support did so because they detected signs of special potential, but that seems unlikely in view of the failure to find early signs of excellence in those children who later excelled (sect. 3).

Of course, a parent's beliefs about a child's putative talents can affect parental behaviours; hence such beliefs may indirectly affect a child's performance (e.g., Brophy & Good 1973). As noted in section 1, it is also true that self-beliefs can predict future performance (Dweck 1986; Sloboda et al. 1994a; Vispoel & Austin 1993). However, the question at issue is whether talent as such, as distinct from an individuals' beliefs about its presence, influences a child's attainments.

A second objection is that although differences in training, practice, and other aspects of an individual's experiences can go a long way toward accounting for differences in technical skills, they fail to account for those differences in less tangible traits, such as expressivity or creativity, that separate the most exceptional performers from others. This objection represents a certain shifting of the goalposts when it is introduced as an argument for the existence of talent. Nevertheless, it needs to be considered. Expressivity in music has been discussed by Sloboda (1996), who argues that although *technical* skills must be acquired *ab initio* by extensive instrument-specific practice, some *expressive* accomplishments may occur rather early through an application of existing knowledge (such as emotional signals, gestures, and other bodily movements) to the domain of music. People might differ in musical expressivity in the absence of any differences in music-specific practice for a variety of reasons, one being that people differ in their levels of nonmusical expressivity. Expressive ability may thus appear to arise in the absence of overt evidence of practice or teaching, but this does not mean it is innate.

A third possible objection is that although practice, training, and other known influences may jointly account for performance differences in the majority of people, there could be a small number of individuals to whom this does not apply. Evidence to support this objection is lacking, however.

The fourth criticism is that, although comparisons between more and less successful groups of people may not have revealed differences in the amount of practice needed to achieve a given amount of progress (Sloboda et al. 1996), this does not demonstrate that such differences do not exist at an individual level, and there is some evidence that they do (Charness et al. 1996). In future research on practising it would be desirable to pay more attention to individual differences. However, as reported in section 3.2, no case has been encountered of anyone reaching the highest levels of achievement in chess-playing, mathematics, music, or sports without devoting thousands of hours to serious training.

5. Summary and conclusion

We began this target article by describing the widespread belief that to reach high levels of ability a person must possess an innate potential called talent. Because the belief in talent has important social and educational consequences that affect selection procedures and training policies, it is important to establish whether it is correct. Belief in talent may also act as a barrier to further exploration of the causes of excellence in specific domains of ability.

To ensure that our use of the term coincided with that of scientific researchers as well as teachers and practitioners, we suggested that: (1) A talent has its origin in genetically transmitted structures; (2) there are early indicators of talent; (3) talent provides a basis for estimating the probability of excelling; (4) only a minority of individuals have special talents; and (5) the effects of a talent will be relatively specific.

In examining the evidence and the arguments for and against the talent account, we began in section 2 by considering positive findings. We examined evidence that certain

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

young children excel without special encouragement and that some children are born with special capacities that facilitate the acquisition of particular abilities. There proved to be little evidence of early accomplishments that could not be explained by other known determinants of early progress. We also found no evidence of innate attributes operating in the predictable and specific manner implied by the talent account, apart from autistic savants whose exceptional skills appear to stem from an involuntary specialization of their mental activities.

Section 3 surveyed evidence contrary to the talent account. The absence of early signs of special ability was discussed. Where early precocity is encountered, it is invariably preceded by ample opportunities and encouragement. In addition, when prior differences in knowledge, skills, motivation, and other factors known to affect performance are controlled for, there is little evidence of individual differences in ease of learning. High levels of accomplishment invariably require lengthy and intensive training, and even people who are not believed to have any special talent can, purely as a result of training, reach levels of achievement previously thought to be attainable only by innately gifted individuals (sect. 3.3). There are also logical and conceptual arguments against the notion that talent is explanatory (sect. 3.4).

Section 4 examined alternatives to the talent account. Large amounts of regular practice were found to be essential for excelling. Studies of long-term practice and training suggest that individual differences in learning-related experiences are a major source of the variance in achievement.

The evidence we have surveyed in this target article does not support the talent account, according to which excelling is a consequence of possessing innate gifts. This conclusion has practical implications, because categorising some children as innately talented is discriminatory. The evidence suggests that such categorisation is unfair and wasteful, preventing young people from pursuing a goal because of the unjustified conviction of teachers or parents that certain children would not benefit from the superior opportunities given to those who are deemed to be talented.

We do not claim to have a full or precise answer to the question: "If talents do not exist, how can one explain the phenomena attributed to them?" However, we have listed a number of possible influences, and evidence of their effects.

Innate talents are inferred rather than observed directly. One reason for assuming that they exist at all has been to explain individual differences, but these can be accounted for adequately by experiential ones such as training and practice, as well as biological influences that lack the specificity and predictable consequences associated with the notion of talent.

It could be argued that the talent account is not totally wrong, but simply exaggerated and oversimplified. In our list of the five defining attributes of innate talents (sect. 1.1), two are relatively unproblematic: (1) Individual differences in some special abilities may indeed have partly genetic origins, and (4) there do exist some attributes that are possessed by only a minority of individuals. In this very restricted sense, talent may be said to exist.

One might argue for retaining the concept of talent even though the other three criteria are not met. If the underlying issues were exclusively academic this would be reasonable. "Talent" would be the place-holder for the as yet unmapped influence of biology on special expertise. In practice, however, the other three attributes – (2) being identifiable before the emergence of high ability, (3) providing a basis for predicting excellence, and (5) being domain-specific – are crucial, because it is precisely these attributes that are the ones regarded by practitioners as justifying selectivity and discrimination.

Open Peer Commentary

Commentary submitted by the qualified professional readership of this journal will be considered for publication in a later issue as Continuing Commentary on this article. Integrative overviews and syntheses are especially encouraged.

Testing the limits of the ontogenetic sources of talent and excellence

Paul B. Baltes
Max Planck Institute for Human Development, Berlin, Germany;
sekbaltes@mpib-berlin.mpg.de

Abstract: Experiential factors such as long-term deliberate practice are powerful and necessary conditions for outstanding achievement. Nevertheless, to be able to reject the role of biology based individual differences (including genetic ones) in the manifestation of talent requires designs that expose heterogeneous samples to so-called testing-the-limits conditions, allowing asymptotic levels of performance to be analyzed comparatively. When such research has been conducted, as in the field of lifespan cognition, individual differences, including biology based ones, come to the fore and demonstrate that the orchestration of excellence requires joint attention to genetic–biological and experiential factors.

Rarely is the scientific evidence sufficient to allow unequivocal conclusions to be drawn when it comes to the issue of disentangling genetic and experiential factors in human development (Baltes et al. 1988), yet scholars are tempted to take extreme positions. This applies also to Howe et al. Their abstract, for example, carries a single message: "Analysis . . . suggests that differences in early experiences, preferences, opportunities, habits, training and practice are the real determinants of excellence."

I agree that the factors listed are powerful ones, and that the ontogenetic collaboration produces manifestations that we may call "excellent" (Baltes 1997; Baltes et al. 1997). What I object to, however, is that the summarizing sentence and the general tone of the target article suggest that biology based, "innate" individual differences are not part of the ensemble. Here, my interpretation of the evidence presented, and of other evidence, is different. To make my point, I shall refer to one of my primary research interests, the study of lifespan cognitive development (Baltes 1993; 1997; Baltes et al., in press), to present contradictory evidence and to illustrate the kind of research needed to exclude the contribution of individual differences involving biology based genetic factors.

In the field of lifespan cognitive development, one of the perennial problems has been to determine whether individual differences associated with age set limits to what experience and individual commitment can accomplish. Not unlike most of the research summarized by Howe et al. on the question of talent, much of the evidence was based on designs that are limited in inferential power by definition: criterion-group comparisons, post hoc life-history analyses, quasiexperimental designs, and the like.

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

Unsurprisingly, the evidence was mixed. Depending on the researcher's starting viewpoint, different conclusions were possible. Using strict scientific logic, what was studied, and how it was studied could not answer the question.

An important advance was the introduction of a new research paradigm: testing-the-limits (Baltes 1987; Kliegl & Baltes 1987; Lindenberger & Baltes 1995), the search for maximum performance potential, for example, through cognitive–motivational engineering and extensive practice. With this paradigm, extreme conditions of both experiential (e.g., practice) and individual-difference factors (e.g., young versus old subjects) can be studied, thereby providing a joint view on both.

A two-pronged conclusion resulted: Yes, the orchestration of experiential and practice factors produces outstanding levels of performance in all age groups and for many individuals, yet, if maximum levels or limits of performance (in the sense of asymptotic levels of potential) are studied by means of testing-the-limits procedures, older adults did not reach the same asymptotes as younger ones did. Moreover, as subjects reached higher and higher levels of performance, individual differences were maintained or even increased. Let me summarize one research program to make the need for testing the limits of "talent-relevant resources" more concrete.

Our focus was on exceptional memory performance, a domain that is often used as a candidate for exceptional talent (Baltes & Kliegl 1992; Kliegl et al. 1990). When people participated in 36 sessions of intensive and organized training in a memory technique (the method of loci) that can be used to reach exceptionally high levels of memory performance, all of them benefitted from this intervention. If continued beyond 36 sessions (Kliegl et al. 1987), people reached levels approaching those of memory experts. This finding is consistent with those reported in Howe et al.

This testing-the-limits work, however, produced an equally convincing second finding that highlighted the fundamental significance of individual differences. As subjects were pushed toward the limits (asymptotes) of their maximum performance potential, individual differences were magnified (Baltes & Kliegl 1992). The conclusion is clear: the talent for being a memory expert reflects both experiential and individual-differences factors. In this case, because of the age association and extreme robustness of the individual difference finding, the likelihood is high that biology based factors are involved (see Lindenberger & Baltes 1995 for further expositions).

Howe et al. make some use of our work, but their interpretation is one sided (sect. 4.1). They select only one of the two main findings, that is, the finding of major training gains for all. The equally compelling evidence of sizeable individual differences in acquisition curves and maximum performance potential is ignored. Moreover, they ignore that, contrary to their view (sect. 2.3), the correlation between the skill trained in this testing-the-limits experiment and a multivariate measure of intelligence was larger at the end of training (Kliegl et al. 1990).

Howe et al. are likely to argue that research into age-associated individual differences of asymptotes in performance potential is not a direct analogue to the cases of talent and excellence they have pursued. However, they will need to acknowledge that practically none of their studies used research designs that fulfill the minimum requirement of experimentation: the a priori assignment of a random or heterogeneous sample of individuals to different constellations of performance and the analysis of cumulative progress toward asymptotic limits of performance. My hypothesis is clear: if such testing-the-limits studies were conducted, the biological individual-differences factors of talent, and excellence, if they exist, would come to the fore and be part of the ensemble (see also: Fox et al. 1996). I reach this conclusion despite my long-term commitment to highlighting the cultural and experiential in the production of excellence in human development (e.g., Baltes 1997; Baltes et al., in press).

Superiority on the Embedded Figures Test in autism and in normal males: Evidence of an "innate talent"?

Simon Baron-Cohen

Departments of Experimental Psychology and Psychiatry, University of Cambridge, Cambridge, CB2 3EB, England, United Kingdom;
sb205@cus.cam.ac.uk

Abstract: Howe et al. suggest that most talents can be explained in terms of practice and other environmental effects, and only exceptionally by innate factors. This commentary provides an illustration of one such exception: performance on the Embedded Figures Test by people with autism and their relatives.

It is hard to argue with Howe, Davidson & Sloboda's reasonable conclusion that excelling is not necessarily a consequence of innate gifts, in the face of their compelling evidence in support of the alternative theory, namely, that excelling often only occurs after large amounts of regular practice, training, and learning-related experiences. Theirs is not only an eminently balanced position (after all, they do not deny that innate talents may exist), but its implications are altogether far more attractive socially and politically in implying that excellence is in theory accessible to everyone, given the relevant environmental conditions.

In this commentary, I provide an example of a talent that seems strongly heritable, and that fits the *restricted* sense in which Howe et al. allow that innate talents may exist. In their view, innate talents may exist in the sense that: (1) individual differences in a special ability may be partly genetic, and (2) some attributes are only possessed by a minority of individuals (see sect. 5). In my view, a perfect example of this is superiority on the Embedded Figures Test (EFT) by both normal males and people with autism.

The Embedded Figures Test and normal males. In the EFT, the person is shown a simple shape (the target) and asked to find it as quickly and as accurately as possible in a larger complex design in which it is embedded. Two examples of the test are shown in Figure 1 (the first from the children's test, the second from the adult test). In the original reports of this test (Witkin et al. 1962), it

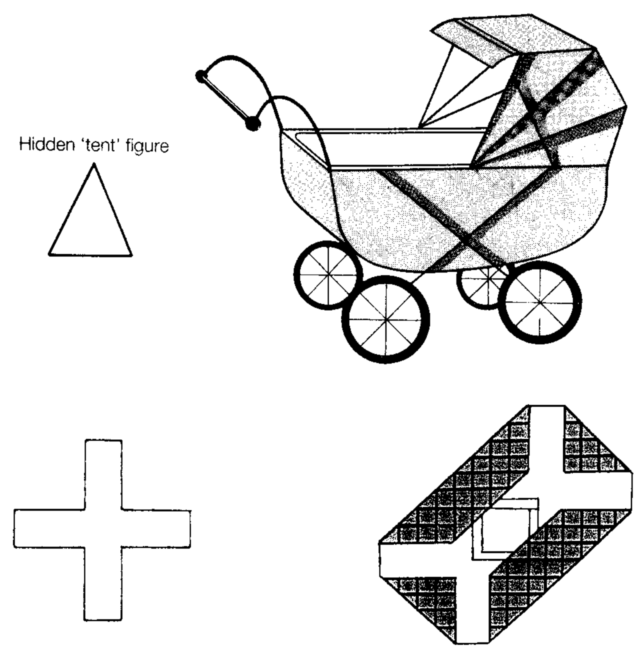


Figure 1 (Baron-Cohen). Two examples from the Embedded Figures Test. (Reproduced with permission.)

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

was found that males are significantly faster than females at finding the embedded target figure. During the last 40 years, this result has been replicated extensively. In our own studies, we have also demonstrated this male superiority effect (Baron-Cohen & Hammer 1997a).

Note that this should not be interpreted in any 'sexist' light, as it is by no means obvious that just because one's perceptual processes can disembed the target more quickly, they are in any sense better. Rather, the author of the test interpreted this sex difference purely in terms of a difference in cognitive "style," with no implication that those who are quicker on the EFT are better or worse than those who are slower. Those who are quick on the EFT are sometimes referred to as being more "field independent" in their cognitive style.

This male superiority on the EFT may well reflect an innate talent in that it is hard to see how males could have had large amounts of practice or training when the sex difference is found on the *first* presentation of the test. One might try to construct an argument in terms of how parents' choice of toys for little boys gives them an implicit opportunity to learn how to disembed, but this is rather post hoc and undemonstrated. On the face of it, there is nothing quite like the EFT in our early environment that could account for the sex differences in terms of exposure, learning, and practice, in which case it could well be owing to genetic factors.

The Embedded Figures Test and autism. So much for fitting Howe et al.'s first criterion (individual differences). What makes performance on the EFT even more likely to reflect an innate talent is that it also fits their second criterion (possessed only by a minority of individuals). Here the relevant data are from people with autism or Asperger's syndrome.[1] Both conditions are likely to be caused by genetic factors, on the evidence from family and twin studies (Bolton et al. 1994; Folstein & Rutter 1977; Gillberg 1991; Le Couteur et al. 1996). Of most relevance to this commentary, children with autism perform above their mental age on the children's version of the EFT (Shah & Frith 1983), and adults with autism are *faster* on the adult version of the EFT (Jolliffe & Baron-Cohen 1997).

What makes EFT performance seem strongly genetic is the finding that parents of children with autism or Asperger syndrome are also *faster* on this test (Baron-Cohen & Hammer 1997a). The EFT results from (1) normal males, (2) people with autism or Asperger syndrome, and the latter's first-degree relatives, in conjunction with other data, have led to the theory that autism is an extreme of the normal male brain (Baron-Cohen & Hammer 1997b).

The example we have provided does not contradict Howe et al.'s general thesis, and is described to illustrate the restricted sense in which innate talents may exist. Of course, even the evidence reviewed here does not *prove* that performance on the EFT is owing to genetic factors. It simply suggests it strongly. A demonstration, if it comes, will require identifying genes that contribute to EFT performance, together with evidence concerning how those genes actually function in relation to this aspect of cognition. Such genes are unlikely to be specific to performance on this kind of task and may instead be secondary to some more basic aspect of cognition.

NOTE

1. Asperger's syndrome is thought to lie on the autistic spectrum. It is diagnosed when an individual shares all of the features of autism (e.g., social abnormalities, communication abnormalities, and limited imagination in early development) but does not show any history of either general cognitive or language delay, which are part of the diagnosis of autism (APA 1994).

Could the answer be talent?

Urie Bronfenbrenner and Stephen J. Ceci

Department of Human Development and Family Studies, Cornell University, Ithaca, NY 14853; **ub11@cornell.edu; sjc@cornell.edu**

Abstract: We present a theoretical model and corresponding research design (Bronfenbrenner & Ceci 1994) that could yield stronger evidence for (or perhaps against) Howe et al.'s conclusions. The model assesses levels of heritability (h^2) under different amounts of training and practice, thus providing estimates of the independent contribution of "innate talent" to the quality of development outcomes. The design can also reveal the extent to which this independent contribution varies systematically as a function of other influential factors identified by Howe et al.

In their thoughtful, judicious, and otherwise remarkably comprehensive review, Howe, Davidson & Sloboda present a detailed and compelling argument. As they note, the results of studies on both sides of the issue are open to alternative interpretations. Under these circumstances, an appropriate next step is to consider theoretical models and corresponding research designs that could yield stronger evidence for – or perhaps against – their admirably qualified conclusions.

With an equal degree of tentativeness, we suggest a theoretical model and corresponding research design that may enable future investigators to address questions about the relative contribution of innate versus environmental influence on giftedness. Because of space limits, the model can be presented here only in condensed form (for details, see Bronfenbrenner & Morris 1998). The potential strength of the model is based on testing of heritability (h^2) levels under contrasting amounts of training and practice, which allows the independent contribution of "innate talent" to the quality of development outcomes to be estimated. The corresponding research design also allows the investigator to estimate how the independent contribution varies systematically as a function of other influential factors mentioned by Howe et al. (Abstract and sect. 5).

The proposed "*bioecological model*" redefines several of the key assumptions underlying the classical paradigm of behavior genetics to arrive at formulations that we would view as more consonant with contemporary theory and research in the field of human development. In addition to incorporating measures of environmental and individual characteristics and allowing for nonadditive, synergistic effects in gene/environment interaction, the model posits empirically assessable mechanisms, called "*proximal processes*," through which genetic potentials for effective psychological functioning are actualized.

These processes become the focus of the first defining property of the bioecological model:

Proposition I. Especially in its early phases, but also throughout the life course, human development takes place through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate external environment. To be effective, the interaction must occur on a fairly regular basis over extended periods of *time.* Such enduring forms of interaction in the immediate environment are referred to as "*proximal processes*" (Bronfenbrenner & Ceci 1994, p. 572).

Examples of proximal processes are found in such ongoing behaviors as feeding or comforting an infant, playing with a young child, child–child activities, group or solitary play, reading, learning new skills, sports, artistic activities, problem solving, caring for others in distress, making plans, performing complex tasks, and acquiring new knowledge, and know-how. In sum, proximal processes are posited as the primary engines of development.

A second defining property identifies the fourfold source of these dynamic forces.

Proposition II. The form, power, content, and direction of the proximal processes affecting development vary systematically as a joint function of the characteristics of the *developing person;* of the *environment* – both immediate and more remote – in which

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

the processes are taking place; the nature of the *developmental outcomes* under consideration; and the social continuities and changes occurring over *time* through the life course and the historical period during which the person has lived (Bronfenbrenner & Ceci 1994, p. 572).

Propositions I and II are theoretically interdependent and subject to empirical test. A research design that permits their simultaneous investigation is referred to as a "Process-Person-Context-Time model" (PPCT).

A third defining property bears directly on the questions posed and the conclusions reached by the present authors.

Proposition III. Proximal processes serve as a mechanisms for actualizing genetic potential for effective psychological development, but their power to do so is also differentiated systematically as a joint function of the same three factors stipulated in Proposition II (Bronfenbrenner & Ceci 1994, p. 572).

Taken together, the three foregoing propositions provide a basis for deriving the following specific hypotheses. (For the theoretical and empirical grounds underlying these hypotheses and the general model from which they are derived, see Bronfenbrenner & Ceci 1994, pp. 572–84; and also Bronfenbrenner & Morris 1998.)

Hypothesis 1. Proximal processes raise levels of effective developmental functioning, and thereby increase the proportion of individual differences attributable to actualized genetic potential for such outcomes. This means that *heritability* (h^2) will be higher when proximal process are strong, and lower when such processes are weak (Bronfenbrenner & Ceci 1994, p. 572).

Hypothesis 2. The power of proximal processes to actualize genetic potentials for *developmental competence* (as assessed by an increase in h^2) will be greater in advantaged and stable environments than in those that are disadvantaged and disorganized (Bronfenbrenner & Ceci 1994, p. 578).

The final hypothesis opens the door for the design of experimental programs that could further the actualization of both of general and special talents.

Hypothesis 3. If persons are exposed over extended periods of time to settings that provide developmental resources and encourage engagement in proximal processes to a degree not experienced in the other settings in their lives, then the power of proximal processes to actualize genetic potentials for developmental competence will be greater for those living in more disadvantaged and disorganized environments (Bronfenbrenner & Ceci 1994, p. 579).

Note that the foregoing hypothesis stands in sharp contrast to its predecessor, in which proximal processes were posited as exerting a more powerful effect "in advantaged and stable environments than in those that are disadvantaged and disorganized." (For the theoretical basis and supportive evidence for this contradictory prediction see Bronfenbrenner & Morris 1998.)

We conclude by reminding the reader that, supportive evidence notwithstanding, all three of the foregoing hypotheses still need to be tested. The field is indebted to Howe et al. for providing a comprehensive background against which to formulate and test these hypotheses.

Explaining exceptional performance: Constituent abilities and touchstone phenomena

Neil Charness

Psychology Department, The Florida State University, Tallahassee, FL 32306-1270; **charness@psy.fsu.edu; www.psy.fsu.edu/~charness**

Abstract: Investigations of innate talent should narrow the definition of talent to deal with constituent abilities, identify touchstone phenomena, and provide detailed explanations of these phenomena. A list of relevant phenomena is proposed.

Howe et al. are to be commended for initiating a debate on whether talent is a useful explanatory construct for exceptional performance. Enormous individual differences between experts and amateurs are likely candidates for innate talent explanations. However, evidence cited in our earlier review (Ericsson & Charness 1994; 1995) and studies of the skill acquisition process itself indicate that ordinary learning processes are adequate to explain such extraordinary performance. Also, skill acquisition studies help researchers avoid the *fundamental attribution error of talent* (Charness et al. 1996): attributing exceptional performance to talent (disposition) rather than to deliberate practice (situations). The many hours of practice that usually underlie exceptional performance remain as out of sight to the casual observer as the base of a floating iceberg.

There are a few weaknesses in the approach by Howe et al. One is choosing too broad a definition of talent to permit a fair test of innate factors. Another is the omission of some phenomena that are central to understanding exceptional performance. A broad definition of talent may make it difficult to find genetic contributions. Studying narrower constituent behaviors seems like a more promising way to identify innate talent components; examples are Bouchard et al.'s (1996) model of drives and capacities and Gardner's (1983) learning and forgetting rates for domain-related material. Careful experimental studies of expertise already provide the level of detail needed to identify constituents of task performance.

A second weakness may be a failure to consider a broad enough range of phenomena for exceptional performance. A useful heuristic for developing a field is the identification of touchstone phenomena (e.g., Newell 1990). Below are some that range from individual to societal ones. References are given for those that are not stressed by Howe et al.

1. Children who are prodigies.
2. Absence of early signs of exceptional abilities that predict later exceptional performance.
3. An apparent critical period for facile development of absolute pitch in musicians.
4. Individual differences in time taken to attain expertise among experts.
5. Power law learning for human skills (e.g., Newell & Rosenbloom 1981).
6. The skilled memory effect for domain material compared to randomly arranged domain elements (e.g., Chase & Simon 1973).
7. Why deliberate practice is superior to general practice for skill acquisition.
8. The constant progress with practice for children playing musical instruments.
9. The 10-year requirement for attaining elite performance in a domain.
10. The apparently critical role of parents and coaches in developing skill.
11. The log-linear relation between maximal performance and population size (Charness & Gerchak 1996).
12. The characteristic backward inverted J-shaped function for (career) age and achievement (Simonton 1997).
13. Historical trends for improvements in peak performance (e.g., Ericsson & Lehmann 1996).

In some cases, the phenomenon is a robust, well-replicated one (power law learning), but in other cases, we need replication (e.g., constant progress with practice in music).

The challenge for researchers is to agree on list entries and to propose explanations that would sort the phenomena into categories (e.g., innate, acquired). What would constitute a good approach to explanation? Information processing models have been remarkably successful in explaining human performance, particularly simulation models that actually perform the task under discussion. Frameworks such as the Model Human Processor (Card et al. 1983) stress the identification of parameters such as working memory capacity, learning rates, and forgetting rates. Rate variables for domain-related materials have already been proposed as potential mechanisms underlying talent.

One way to identify and explain talent would be to demonstrate

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

reliable individual differences in information-processing parameters that relate strongly to performance in music, chess, mathematics, and languages. Failure to observe such predicted relations, assuming adequate power in the design, could refute such talent hypotheses.

Although, like Howe et al., I am pessimistic about the viability of the talent concept, I am optimistic that their target article will stimulate the field to explore and explain the phenomena surrounding exceptional performance.

ACKNOWLEDGMENTS

NIA grant 5R01 AG 13969 supported this work. I appreciate feedback from K. A. Ericcson.

Fruitless polarities

Mihaly Csikszentmihalyi

Department of Psychology, The University of Chicago, Chicago, IL 60637; **miska@cicero.uchicago.edu**

Abstract: Clear evidence of large individual differences in children's performance in talent areas can be explained either in terms of innate gifts (the "talent account") or in terms of early exposure (the "no talent account" proposed by Howe et al.). At this point, there is no conclusive support for either account, and it is doubtful that talent could be explained exclusively by only one of them.

Flogging the dead horse of the nature versus nurture controversy is particularly useless in the context of talent. Whatever we mean by it, it is clear that talent involves both personal qualities based on innate differences, and social opportunities, supports, and rewards. To claim exclusively environmental causes for exceptional performance as Howe et al. do is as misguided as the opposite, exclusively genetic explanation.

Howe et al. are right in arguing that talent is essentially a social construction; we label as such performances that at some historical moment we happen to value. In many preliterate societies, men who suffered from epileptic seizures were thought to have a gift for communicating with supernatural forces, and their "talent" was given respect and recognition. At present, talent is generally attributed to children with high IQs, but the cut-off point varies tremendously, depending on the ideology of a particular community. In Korea and Taiwan, only students who are at least 2 standard deviations above the IQ mean are considered talented, whereas in Thailand, educators believe that all students have special gifts that can and should be developed over time (Braggett 1996).

The fact that talent is a convention, however, rather than a natural phenomenon, does not mean it is not based on genetic differences. Howe et al. have set up a straw man in their strict definition of talent. For example, they write: "early ability is not evidence of talent unless it emerges in the absence of special opportunities to learn" (sect. 3.1, para. 4). No one working in this field would argue, I hope, that talent can develop without opportunities to learn. One might still claim that talent manifests itself in some children's ability to learn more, given equal opportunities to do so.

For instance, in a short paragraph, Howe et al. downplay the evidence concerning early drawing abilities (sect. 2.4, para. 2), yet there is ample evidence that by 2 years of age one can see remarkable differences in the way children express themselves visually, and that superior performance at this age does not reflect trained technical skills, but rather an overall sense of composition, fluidity of line, and grasp of significant detail (Winner 1997). Of course, it would be wrong to assume that such early ability will necessarily result in full-fledged adult artistic talent. For that transition to occur, the child will need to find opportunities for training, support, reward, and motivation. Given equal opportunities later, however, it makes sense to expect that the child who showed talent at age 2 will produce art that is considered more valuable when he grows to be an adult. As in the Biblical parable, talent is not an all-or-nothing gift but a potential that needs to be cultivated to bear fruit (Csikszentmihalyi et al. 1993).

Howe et al. dismiss the evidence of superior early performance by arguing that it does not reflect innate differences, but differences in training, motivation, self-confidence, and so on (sect. 4, para. 2). They may be right, but of course they could also be wrong. The more likely explanation is that children whose neurological makeup makes them particularly sensitive to sounds will be motivated to pay attention to aural stimulation, be self-confident in listening and singing, and likely to seek out training in music – and the same argument would apply to children with innate sensitivities to light, kinesthetic movement, or any other kind of stimulation that underlies different kinds of valued performance.

In the last analysis, we have two "accounts" to explain the phenomenon of superior performance. The first is the "talent account" that Howe et al. criticize in their article; the second is the "no-talent account" they propose as a substitute. At this point, the evidence does not support either account conclusively. It would be quite a challenge to design an experiment that would resolve this issue once and for all. In fact, given the interactive nature of the phenomenon, I am not sure that one could even imagine in principle how such an experiment should be designed, let alone carried out. For instance, if one were to divide a cohort of children at random, and then give one-half of the group intensive training in mathematics, let us say, whereas the other half was kept ignorant of numbers, and then one were to find that there were more gifted mathematicians in the first group, what would that prove?

While we are waiting for a way to resolve this conundrum, Howe et al. argue that it makes more sense to assume that their "no-talent" account is right, because this would have the more beneficial social consequences. Instead of providing the extensive social supports needed for developing superior performance to only those children we believe to be talented, we would offer them to every child who wants it. This application of an egalitarian ideology sounds attractive, but I am not sure it makes much sense. Given limited resources – and the Lord knows they always are – wouldn't we provide training opportunities first to those children who, for whatever reason, show interest and ability in a given domain? I do not think Howe et al. wish to argue that all children have the same interests and abilities, or that opportunities for intensive training should be provided across the board, regardless of a child's inclination. So practical implications do not recommend the no-talent account either.

Absurd environmentalism

Douglas K. Detterman, Lynne T. Gabriel, and Joanne M. Ruthsatz

Department of Psychology, Case Western Reserve University, Cleveland, OH 44106; **dkd2@po.cwru.edu**

Abstract: The position advocated in the target article should be called "absurd environmentalism." Literature showing that general intelligence is related to musical ability is not cited. Also ignored is the heritability of musical talent. Retrospective studies supporting practice over talent are incapable of showing differences in talent, because subjects are self-selected on talent. Reasons for the popularity of absurd environmentalism are discussed.

The position advocated in the target article by Howe et al. as well as by Ericsson and Charness (1995) should be called "absurd environmentalism." Although superficially credible, the argument for absurd environmentalism is based on a number of serious errors.

Failure to cite relevant literature. It is well known that human intelligence fits the criteria specified in the target article, although

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

the authors ignore it. (1) There is strong evidence of genetic transmission, accounting for 40% to 80% of the total variance. (2) IQ tests as early as the first year of life are good measures of general intelligence (see Brody 1992 for support of these points). (3) IQ tests predict adult academic and vocational achievement better than anything known (Matarzazzo 1972). (4) Intellectual ability is normally distributed and so high ability is limited. Attempts to increase general intellectual ability by early training have had small or no effects (Spitz 1986).

The one hook in the argument is the specification that talents are relatively domain specific. The measurement of domain-specific abilities is admittedly crude. However, there is no doubt that attainment in even very specific abilities such as music is influenced by general intellectual ability. Several studies have found significant relationships between musical ability and general intelligence (Lynn et al. 1989, factor loadings of musical subtests on general intelligence range from .49 to .59; Phillips 1976, $r[\text{IQ} \times \text{Music}] = .61$ to .69). Other studies have shown that mentally retarded persons are predictably low in musical ability (McLeish & Higgs 1982). These studies confirm a general relationship between musical ability and general intelligence.

Studies of more specific musical abilities also show that there is a heritable component, even though solid measurement is lacking. Coon and Carey (1989) surveyed twins on subjective items concerning musical interest and performance. They found heritabilities between .1 and .2 for females and .2 and .7 for males. Given the subjective nature of the measurement, these heritabilities cannot be discounted. They show a heritable component to musical ability. Coon and Carey suggest that the high proportion of common environmental variance is due to large variation in musical training. If training were more uniform, heritable variance might be higher.

Retrospective accounts of musical talent. Much of the literature on musical accomplishment is retrospective, as acknowledged by Howe et al. Groups of musically skilled subjects are identified and then studied. This approach is useless for identifying musical talent. The problem is that the groups are self-selected on the very variable of interest.

Suppose we correlate the height of National Basketball Association (NBA) players with the number of points they score. This correlation is close to zero. Should one conclude that height is unimportant in professional basketball? Clearly not. However, that is what Howe et al. do.

The reason the correlation is close to zero is that NBA players are so highly selected on height that it no longer discriminates. Variables other than height such as practice, determination, and personality predict scoring. For many of the studies cited, Howe et al. conclude that practice, not ability, is important for accomplishment, but they are making the same error as concluding that height is not important for NBA players.

Why is absurd environmentalism such an attractive hypothesis to so many if it is so wrong? First, everyone wants to believe they can be anything they want. Second, we would prefer to believe that our accomplishments are due to our own hard work and not to a lucky roll of the genetic dice. Third, for teachers and parents, it may be advantageous to think of accomplishment as totally due to environmental interventions. Because environment is the only part of total variance they believe they can change, the larger they see the environmental piece of the whole pie, the more meaningful and powerful they see their ministrations as being.

Adopting the assumptions of absurd environmentalism has a dark side, though. If one believes that accomplishment is totally the result of individual effort, then those persons who fail to accomplish much have only themselves to blame. This seems to us to be a very harsh judgment. Should mentally retarded persons or persons with low IQs be blamed for their failure to enter a high-paying, prestigious occupation? We don't think so.

If Howe et al. still believe in absurd environmentalism, they can easily convert us to their point of view. Simply randomly select 100 persons with mental retardation and 100 persons of high IQ and give them 10 years of deliberate practice. If, at the end of the 10 years, both groups are equally outstanding musicians, we will be instantly converted to their position. Furthermore, they will have done an exceptional social service by supplying mentally retarded persons with a profession. Unfortunately, we know from existing literature that it will become clear that they are wrong well before the 10 years are up. Deliberate practice, important though it is to exceptional accomplishment, will not equalize outcome despite the best of intentions.

ACKNOWLEDGMENTS

Parts of this work were supported by grant no. HD07176 from the National Institute of Child Health and Human Development, Office of Mental Retardation.

Achievement: The importance of industriousness

Robert Eisenberger

Department of Psychology, University of Delaware, Newark, DE 19716-2577; **eisenber@udel.edu**

Abstract: The emphasis on innate talent as the basis for outstanding achievement underestimates the importance of hard work. Learned industriousness helps supply the sustained effort required for superior achievement. The goal of having a productive, well-educated citizenry can be furthered by rewarding students for high effort and attending carefully to their individual educational needs.

Seeking a clear example of an eminent scientist or mathematician whose success was clearly influenced by innate talent, I recalled Robert Kanigel's (1991) biography of the Indian mathematician, Ramanujan. As a youth at the turn of the century, Ramanujan primarily taught himself mathematics, and had within a few years achieved remarkable theoretical innovations. No better example of innate talent seems possible, yet, Kanigel interpreted the evidence differently. To an interviewer, Kanigel said of Ramanujan, "Somebody said you do best what you do most. He loved this stuff, so he worked at it. The story is wonderful enough without adding the extra ingredient of sudden, freshly appearing insights out of the blue" (Johnson 1991, p. 12). Kanigel also cited Ramanujan's immersion in Brahmin culture in which "devoting yourself to spiritual, intellectual and cultural pursuits raises you in the estimation of other people." For Ramanujan's biographer, then, the mathematician's achievements were based on industriousness resulting from love of the subject matter and the community's encouragement.

The Romantic tradition in Western civilization claims unique potentialities for each individual, which are believed to require gentle nurture. As reflected in the writings of humanistic psychologists and many cognitive–social psychologists who study creativity and intrinsic interest, the Romantic view gives little weight to the hard work needed to become proficient, let alone eminent, in a field of endeavor (Eisenberger & Cameron 1996). Biographical studies of the lives of such notable scientists and mathematicians as Einstein, Feynman, von Neumann, and Ramanujan reveal the remarkable persistence required for creative achievement.

Howe et al.'s emphasis on practice as a source of expertise harks back to the claims of the behaviorist, J. B. Watson (1930/1970, p. 212), who stated that "the formation of early work habits in youth, of working longer hours than others, of practicing more intensively than others, is probably the most reasonable explanation we have today not only for success in any line, but even for genius." Although Howe et al., like Watson, may have been exaggerating for emphasis, their arguments provide an important counterweight to the overemphasis on innate talent as a determinant of achievement. The unique achievements of creative geniuses such as Ramanujan or Einstein would not have occurred without the dogged determination to keep working on seemingly intractable theoretical issues for months or even years.

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

Howe et al. recognize the importance of perseverance for the acquisition of superior skills and abilities. The psychological mechanisms underlying sustained human effort are beginning to be better understood. Extensive research with animals and humans shows that rewards for high effort contribute to durable individual differences in industriousness. According to learned industriousness theory (Eisenberger 1992), if an individual is rewarded for putting a large amount of cognitive or physical effort into a task, the sensation of high effort acquires secondary reward properties, and the aversiveness to high effort is thereby decreased. This reduced aversiveness to effort would increase the individual's general readiness to expend effort in a variety of goal-directed tasks. For example, rewarding a high level of performance by preadolescent students in their spelling assignments increased the effort they subsequently applied to math problems (Eisenberger 1992). Rewarding children for a high level of creative performance in one task increased their subsequent creativity in an entirely different task (Eisenberger & Armeli 1997). Learned industriousness helps supply the sustained effort required for superior accomplishment.

Howe et al. (sect. 5, para. 6) argued that the attribution of superior achievement to innate talent prevents those young people not thought to be talented "from pursuing a goal because of teachers' or parents' unjustified conviction that they would not benefit from the superior opportunities given to those who *are* deemed to be talented." In the United States, the overemphasis on innate differences in ability has had additional pernicious effects. Poorly performing elementary and high school students are often promoted from one grade to the next under the unspoken assumption that they lack the talent to do well in school and so should not be held responsible for their poor performance. In addition, many superior students are denied admission to college or graduate school because they fail to obtain better-than-average scores on standardized tests of academic aptitude, despite the limited validity and reliability of the tests. The misuse of standardized tests is promoted by the belief that individual differences in native ability are a key determinant of success; by enrolling only those students with high scores on standardized aptitude tests, educational institutions seek to show their exclusivity. However, to restrict the career prospects of highly able students because they score poorly on standardized tests designed to measure innate talent carries the emphasis on innate talent to an unfortunate extreme.

At the same time, it would be a mistake to dismiss individual differences in skills and talents that may have a genetic basis. One problem of the Japanese educational system involves the common presupposition that unless a student has a demonstrable neurological disorder, he or she can excel. Poor performance is thought to result solely from laziness. The unfortunate consequence has been to deny the individual attention needed by Japanese students with learning disabilities. The goal of a productive, well-educated citizenry can be furthered by rewarding children for high effort and attending carefully to their individual educational needs.

Basic capacities can be modified or circumvented by deliberate practice: A rejection of talent accounts of expert performance

K. Anders Ericsson

Department of Psychology, Florida State University, Tallahassee, FL 32306; **ericsson@psy.fsu.edu**

Abstract: To make genuine progress toward explicating the relation between innate talent and high levels of ability, we need to consider the differences in structure between most everyday abilities and expert performance. Only in expert performance is it possible to show consistently that individuals can acquire skills to circumvent and modify basic characteristics (talent).

At the CIBA Symposium on "The Origins and Development of High Ability," Ericsson et al. (1993a) argued that there was no firm empirical evidence for innate talent influencing expert performance with the exception of height – with its advantages (e.g., basketball) and disadvantages (e.g., gymnastics). During the lively published discussion, a famous behavior geneticist commented: "I don't disagree with a thing you said . . . but you cannot conclude from it that talent is unimportant" (p. 240). In their target article, Howe, Davidson & Sloboda propose a new synthesis and conclude that talents "may be said to exist" (sect. 5, para. 9), but current psychometric tests of basic capacities are not effective for talent selection. Howe et al.'s conclusions, however, refer to a different and more general phenomenon, namely, the development of "high levels of ability" (sect. 5, para. 1), and their review reflects evidence that earlier reviews (cf. Ericsson & Charness 1994) had excluded as irrelevant to the acquisition of expert performance. In my opinion, the new, expanded scope of Howe et al.'s review leads us away from the original theoretical question: Can the lack of innate immutable talent preclude healthy, normal individuals from attaining expert performance?

The talent account's core assumption is that because most basic human capacities cannot be changed by training and experience, they must be determined by innate factors. During the early phases of the acquisition of skills, increases in performance are large and assumed to reflect new knowledge and better strategies. However, with further experience, the improvements in performance become smaller and smaller and eventually the individual's performance is automated and reaches a stable asymptote that is determined by basic primarily unmodifiable components of the individual (innate talents). Howe et al.'s compromise position is consistent with this account, and they cite Ackerman's (1988) explication of it to support their argument. Hence their article does not reject the talent account in principle, but rather rejects the pragmatic value of current methods of talent-based selection, which, however, doesn't allow them to rule out "the as-yet-unmapped influence of biology on special expertise" (sect. 5, para. 10).

To refute the logical argument that the asymptote for performance has to be constrained by unmodifiable components (innate talents), it would be necessary to identify practice conditions under which individuals could acquire skills to circumvent basic innate characteristics (talent) or modify the basic components. Ericsson and Charness (1994) claimed that the acquisition of expert performance involved practice conditions in which the performance attained after years and decades of daily deliberate practice (Ericsson et al. 1993b) is often mediated by qualitatively different mechanisms compared with those observed for everyday skill acquisition. There are at least three qualitative differences between expert performance and everyday skill acquisition (Ericsson & Lehmann 1996):

1. Many biological characteristics, such as width of bones, flexibility of joints, size of heart, metabolic characteristics of muscle fibers, and so on, do not change much during everyday skill acquisition. However, in response to years of intense and carefully designed training, they will eventually exhibit large, desirable physiological adaptations. These anatomical changes are influenced by biochemical processes that attempt to preserve equilibrium during intense training. For example, when subjects run, the mechanical impact of the feet hitting the ground can deform the cell walls of bone cells in specific ways that might stimulate growth of the bones' diameter but not their length. This proposed mechanism would explain why height is currently the only confirmed instance of innate talent that influences expert performance but cannot be modified by training.

2. Expert performance reflects the acquisition of qualitatively different skills and representations that allow the expert performer to bypass information-processing constraints imposed by basic capacities. For example, the increased capacity of the experts' working memory for planning and reasoning does not correspond to any superiority of basic capacity of short-term

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

memory, but reflects acquired domain-specific memory skills for efficient storage in long-term memory (Ericsson & Kintsch 1995). Elite athletes can rely on predictive perceptual cues to initiate actions and processes earlier than less skilled performers. Consistent with this argument for bypassing basic capacities with acquired skills, Howe et al. report that heritabilities for skilled (not expert) performance were low, much lower than those estimated for basic capacities. Even more supportive are studies of Olympic athletes cited by Ericsson et al. (1993b), where no reliable heritabilities for elite performance were found. Furthermore, twins (fraternal and especially identical) and adopted individuals are so severely underrepresented among famous authors and other eminent individuals (Bouchard & Lykken, in press) that it raises serious issues for the measurement and validity of heritability for eminent achievement.

3. In everyday activities, most individuals strive for effortless execution. As soon as they have attained an acceptable level of performance, the process of automation begins, thereby prematurely arresting further development. In direct contrast, the primary goal of the expert performers is to increase their ability to plan, control, and monitor their performance through continued improvements in their mental representations. Consequently, experts can remember the relevant information encountered and can on request modify their behavior with far more accuracy than less accomplished performers. The real key to understanding expert and exceptional performance is in the motivational factors that lead a small number of individuals to maintain the effortful pursuit of their best performance during their productive career – when most other individuals have already settled for a merely acceptable level.

If we are to progress toward a consensus on the relation between innate talent and high levels of ability, we need to distinguish expert performance from everyday abilities because of the complex cognitive structure that experts acquire through extended, deliberate practice.

Natural talents: An argument for the extremes

David Henry Feldman and Tamar Katzir

Eliot-Pearson Department of Child Development, Tufts University, Medford, MA 02155; **dfeldmal@emerald.tufts.edu**

Abstract: The existence of natural talent becomes easier to see at extremes in performance. Practice alone could not account for the differences in performance that exist at the highest levels. Practice and other factors are no doubt important contributors to outstanding performance, but not enough to explain great creative works. Talent is essential.

Irvin Rosen, principal violinist of the Philadelphia Orchestra's second violin section, said after a performance by the then 11-year-old MiDori, "If I practiced three thousand years, I couldn't play like that. None of us could" (*Geo Magazine,* October 1986, p. 79). In the presence of superior talent, most practitioners would acknowledge that such talent is a natural gift. This does not mean that a gift will be fully expressed in sublime performances like MiDori's when, as on this occasion, she played Paganini's First Violin Concerto. Here is where the new data about practice, experience, opportunity, training, and the like come into play. No matter how great the natural talent, there are many other things that are involved in the process of becoming a great performer, there has never been a great performer who was not also blessed with great natural ability.

The great merit of Howe, Davidson & Sloboda's target article is that it shows just how challenging it will be to prove what we think we know. For example, it is widely known among teachers at the highest levels in a number of fields that exceptional natural talent is both essential and easy to spot (Feldman 1991). There are even specialized terms that try to capture the essence of the particular talent: one has an "ear" for music, and "eye" for art or design, or displays "athleticism" in tennis or other sports. John Collins, a great chess teacher and mentor of former world champion Bobby Fischer, coined the term "chessical" for the special sensibility that marks a potentially great player (Collins 1974). Granted, these terms lack precise definitions and are difficult to measure, but their existence is a marker for the elusive "innate talents" that high-level practitioners in many domains seem to agree are essential.

In section 3.3, Howe et al. cite evidence of untalented people who perform at high levels in a specific field as refuting the importance of talent. Working memory is not at all what is typically meant by talent. Improving memory can contribute to one's *expertise,* but that is not the same as showing that talent is unimportant. There are elderly men who spend several hours a day playing chess at the Marshall Chess Club in New York City. Their game quality has not improved appreciably in decades, but they have logged two or three times the 10,000 hours of deliberate practice said to produce expert performance. Practice and the other factors reviewed in the target article were probably necessary for the expertise achieved, but beyond a certain point the absence of talent looms larger and larger. Mozart started composing at age 4 and wrote credible minuets by age 6; it is hard to imagine even by the numbers that he was able to spend the requisite 10,000 hours to achieve expertise between ages 3 and 6, so we must assume that talent sped his progress from novice to master. Indeed, there is some documentation from Mozart's early years that supports this assumption (Marshall 1991).

As Winner (1993) has recently argued regarding precocity in drawing, there may be markers that point to the existence of abilities that naturally vary from child to child. One is the almost obsessive desire among extreme cases to do the activity. In our studies of prodigies in several fields (Feldman 1991), this quality was strikingly apparent, but perhaps it is better seen as deep commitment to mastering a domain rather than the more pejorative "obsessive." A second marker noted by Winner is the presence of qualitatively different features in the activity from more typical developing abilities; in Winner's sample, the more extreme cases were able to reinvent things that most other children never master, such as perspective and foreshortening. Finally, there are the intriguing biological markers that have continued to accumulate since Geschwind first began to document associations between, for example, myopia and giftedness, suggesting that atypical brain and central nervous system development produces linked anomalies, including larger areas associated with certain areas of talent (Gardner 1993; Geschwind & Galaburda 1985).

As Donald Hebb once wrote about the nature/nurture issue, behavior is caused 100% by nature . . . and also 100% by nurture. The fact that practice and other things are important for developing expertise in no way rules out the role of talent. To try to say that the one (practice) prevails to the exclusion of the other (talent) is not a productive way to move the state of knowledge forward. Those of us who believe that talent exists should be trying to document as clearly as we can, with as much rigor as we can muster, that it can be defined and assessed, but putting things in either/or terms is not likely to move beyond simplistic accounts of what is manifestly a subtle and complex process.

We are as committed to rigorous empirical research as are our colleagues; nonetheless, we offer the following anecdotal data. If anyone can prove that the works of these individuals can be explained without recourse to a construct like natural talent, we will concede that talent does not exist: Mozart, Picasso, Shakespeare, Martina Hingis, Baryshnikov, Pavarotti, Ramanujan, Judit Polgar, Michael Jordan, and Robin Williams. Practice, indeed.

Inborn talent exists

Joan Freeman

School of Lifelong Learning and Education, Middlesex University, London N14 4YZ, United Kingdom; **j.freeman@mdx.ac.uk**

Abstract: Evidence shows that outstanding talent is more than the product of determined effort by people of much the same inborn ability. Indications of inborn individual differences come from very early studies of childhood. No randomly selected child has ever reached world-class achievement by practice alone, which, though essential, cannot itself produce greatness.

In their attempt to demolish the idea of the generally accepted "talent account," that outstanding performance comes from innate potential, Howe, Davidson & Sloboda have set up two straw men:

1. They write that "some people believe that talent is based on an inborn ability that makes it certain that its possessor will excel" (sect. 1.1, para. 2). However, in all my many years of research in this field, I have never heard or seen this supposed belief that excellence follows potential without the means to develop it.

2. It is widely assumed, they say, that talent "can be detected in early childhood" (sect. 1, para. 2). However, one might equally well say that there is a widespread assumption that it is never too late to develop unrecognised talent, Grandma Moses style.

Howe et al. cannot find any "firm" evidence of early manifestations of advanced abilities, which must emerge "in the absence of special opportunities to learn" (sect. 3.1, para. 4). However, because all children have some opportunities, it is necessary to look at the strong indications from very early development. For example, work at the Fels Institute (Lewis & Michalson 1985) found that by 2–4 months, measured infant memory could indicate future IQ and early motor development could predict subsequent physical aptitude; moreover, there are distinct but related paths of development that are stable over the first 3 years of life. The strongest path, which can be traced from 3 months, is verbal. Even newborns who habituate faster are providing indications of future higher level intelligence (Colombo 1993; Messer 1993), and they do have innate preferences, such as for flavour and colour (Rosenblith 1992).

This denial of early signs appears to be based on questionnaire responses from the parents of 257 children selected for a prestigious school of music: no such signs were recalled. However, when I had carried out similar research at the same school of music with personal interviews of the parents of 24 children, they often recalled distinct early signs, which was why they had taken the trouble to encourage them (Freeman 1995). All the children I investigated had enjoyed equal and virtually free access to instruments and tuition, but those who were selected for the school had indeed received more family support and practised harder than the controls. However, later follow-up work with adolescent pupils at the school (Freeman 1991) showed that what had appeared as great promise was at times the mistaken result of effort. That early advancement was not sustainable at an outstanding level, no matter how hard the youngsters worked. In fact, the music school has been forced to broaden its initially highly focused music education to accommodate such pupils, who discover that talent is more than practice and enthusiasm. This also happened in Feldman's study of six boy prodigies (Feldman with Goldsmith 1986): despite heavy tutoring and practice, their advancement fizzled out.

Howe et al. are right to question historical claims of exceptional precocity, but stating that early reading has only ever been reported second-hand is not acceptable. For example, Zha Zi-Xiu (1985) in China found 3-year-olds reading very complicated characters, Gross (1993) in Australia found 3-year-olds reading and calculating, and Clark (1976), in her classic British study of early readers, reported under-5s starting school already reading fluently. Very early reading, however, is not in itself a sure sign of talent, because it depends on access to reading material and parental involvement (Jackson 1988).

The thrust of Howe et al.'s thesis is that those at the top of the talented achievement scale are not inherently different from those much lower down, although no mention is made of slow learners. However, no one has ever taken a number of children at random and obliged them to practice to a world-class level of talent in any area. Until the authors can produce some evidence that inborn talent is not necessary for outstanding adult performance, as distinct from an improvement in skill, the "talent account" will remain in force among researchers. Indeed, in the end, Howe et al. need not only to accept the existence of innate individual differences, but also to state that certain attributes that can be called "talent" may only be possessed by a few individuals. Either inborn talent exists or it does not, and the evidence and arguments presented do not illuminate the phenomenon any further. One can only conclude that although dedicated effort might be essential for world-class performance, it cannot by itself produce it.

A biased survey and interpretation of the nature–nurture literature

Françoys Gagné

Department of Psychology, Université du Québec à Montréal, Montreal, Canada, H3C 3P8; **gagne.francoys@uqam.ca**

Abstract: This commentary samples some of the major bodies of counter-evidence omitted by Howe et al., including the strong relationship between IQ and academic excellence, the limited effects of early stimulation programs, and the measurement of musical aptitudes. The authors' selective review and analysis of the surveyed literature, especially studies of prodigies and in behavioral genetics, is discussed.

I would have liked to discuss the appropriateness of the term chosen by Howe et al. to describe what I would call natural abilities, "giftedness" being their high end (see Gagné 1993). However, space in these pages being as scarce as in downtown Tokyo, I have chosen to focus on the authors' very selective survey of the relevant literature and their unbalanced review and discussion of the literature.

Selective survey. First, Howe et al. do not mention the extensive literature on the close relationship between general intelligence and school achievement. Correlations commonly attain .60 at the elementary level and decrease slowly thereafter (Sattler 1988). Thus, high cognitive abilities (innate talent), whose partial dependence on genetic endowment is well recognized, are very good predictors of academic excellence. Among the five criteria cited by Howe et al. in section 1.1, only the fifth (domain-specificity) might be considered as not having been met in this example, but the relevance of that criterion is itself questionable. Indeed, if "innate" talents are domain-specific, how are they to be distinguished from the learned skills that characterize the developed talents? For instance, manual dexterity is very important not only in music, but also in countless fields of human activity (e.g., dentistry, sculpture, typing, trades). An unclearly defined domain-specificity requirement increases the risks of confusing innate talents with developed ones, thus fulfilling the authors' prophecy of circular reasoning (sect. 3.4).

Second, Howe et al. totally ignore the extensive literature on the limited impact of early stimulation on the growth of IQ. If cognitive abilities were very responsive to environmental influence, one would expect intervention programs such as Head Start to produce major positive changes in IQ scores, yet careful evaluation studies (Haskins 1989) have shown that average IQ increases rarely exceed 10 points, and that IQs tend to regress back to their initial level soon after the program ends. These results clearly support the argument that the genotype imposes definite limits on the maximum attainable level of cognitive development.

Space allowing, I would have discussed in more detail the fact that (1) even though two of the authors of the target article are specialists in music, there is no mention of interesting efforts to measure musical aptitudes; (2) the authors cite only one (supportive) reference from the very large (mostly nonsupportive) literature on the genetic underpinnings of physical abilities (e.g., speed, strength, endurance, balance, and even trainability); and (3) in a perspective of phylogenetic continuity, the successful breeding of animals strongly implies a genetic endowment for abilities and temperament.

Selective analysis. First, Howe et al. brush aside the whole literature on prodigies and other exceptionally talented individuals (sect. 2.1), judging it unreliable because of its anecdotal, retrospective, and hearsay nature. According to them, information from parents, teachers, friends, colleagues, biographers, and even the subjects' own recollections should not be believed. They refuse to discuss such information, even from direct observers. What would they say of the following example? Dorothy DeLay, a renowned professor at New York's Julliard School of Music, recalled as follows her first encounter with the young prodigy Sarah Chang, who subsequently became her pupil. "I think she was six, or perhaps five, and she played the Mendelssohn concerto with real emotional involvement, and I said to myself, 'I have never seen or heard anything quite like it in my entire life'" (Lang 1994, p. 123). Is professor DeLay an unreliable witness? How can one explain such extreme precocity without invoking some form of natural talent? Examples like these abound; they show ease of learning at its most extreme.

In my own developmental model of the transformation of gifts into developed talents (Gagné 1993), ease of learning is *the* hallmark of natural abilities. It produces speed of learning, which gives rise to precocious achievements. Prodigies are the tip of the iceberg, the most striking embodiment of giftedness, but below them are thousands of others who, even if less extremely gifted, show enough advance over their peers to be judged "innately talented."

Because they are unable to explain such a troublesome body of facts without introducing the concept of giftedness, Howe et al. had no choice but to discard and discredit it. Their decision shows the precariousness of their position when confronted with facts that illustrate in a most convincing way the impact of exceptional natural abilities on the learning process.

Second, in their discussion of Thompson and Plomin's (1993) chapter, Howe et al. mention out of context the few caveats voiced by the authors, omitting major information that contradicts their thesis. For instance, they do not mention two major sections – half of the chapter – titled "Quantitative genetics and high cognitive ability" and "Molecular genetics and high cognitive ability." Thompson and Plomin's conclusion "that genetics plays a major role in the story, and our DF analysis (DeFries & Fulker's 1985 technique to assess group heritability) indicates that high ability is strongly heritable" (p. 111), sends quite a different message from Howe et al.'s own statement that "relatively little is known about the genetic origins of high-level ability." Finally, space allowing, I would have shown that among the best pieces of evidence for a *negative* relationship between practice and achievement in music can be found in Table 7 of two of these authors' own publications (Sloboda & Howe 1991); this reduces the impact of their one-sided presentation in section 4.1.

These are just a few of the selective presentations I noted; they make me wonder about the reliability of their analysis of other texts I have not read. All in all, my own analysis of the existing literature on the nature–nurture debate leads me to conclude that Howe et al.'s extreme position is not at all representative of the available knowledge on the subject.

Might we adopt the learning-related account instead of the talent account?

Giyoo Hatano
Department of Human Relations, Keio University, Tokyo, Japan 108;
a87036@m-unix.cc.u-tokyo.ac.jp

Abstract: Although Howe et al.'s survey shows little evidence for the talent account, it is premature to conclude that individual differences in achievement can be attributed largely to training and early experience. Moreover, such an empiricist account has problematic social implications, especially in cultures in which effort is emphasized. The aptitude account is thus proposed as a third alternative.

As I am not a proponent of the talent account described in the target article, I am willing to accept Howe et al.'s claim that there is little evidence for it. However, whether concentrated and effective training combined with favorable early experiences can always produce exceptionally high achievement is another issue. I do not think Howe et al.'s survey supports such a view, which might be called the "learning-related (experience) account," for two reasons. First, some dimensions of human variability that influence the level as well as the ease of mastery, such as preference for, commitment to, and persistence in a particular domain of expertise, do not constitute a talent as defined in the target article, but they are not learning-related experiences either. Thus, denying an over-nativist account for high achievement is not the same as accepting an empiricist account. Second, the strongest pieces of evidence for the learning-related account are not about high achievements in socially significant domains. Some of them concern highly specific experiment- or job-related skills; others progress from beginner to lower intermediate, not to the attainment of real expertise.

Of course, it is possible to deny the talent account and tentatively adopt the learning-related account based on the available evidence, as Howe et al. seem to do, because there is little evidence that clearly contradicts the latter account. However, it is equally reasonable to adopt a third alternative, namely, weakening the talent account so that it can fit with the behavioral evidence. I believe that considering the social implications of these accounts, we might choose the latter at this stage of the research on high achievement.

As Howe et al. point out, the talent account for high achievement has social implications that are clearly undesirable. It discourages students who are diagnosed as lacking the talent, their parents, and their educators from continuing the teaching–learning in the domain. It may even justify their exclusion from the community of experts and novice learners.

The learning-related account, however, also has social implications that are highly problematic. It assumes that what is critical is the amount and quality of early experience and training in the target domain. In other words, it implies that everyone can achieve a very high level of performance in any domain, if they engage in exercise or deliberate practice for an extended period. If they cannot, then educators or parents must be to blame – because it means that either the training provided by the educators was ineffective or the early experience provided by the parents was insufficient. The failure to attain high achievements must be the fault of students, educators, or parents.

I believe that these social implications are as undesirable as those derived from the talent account. They could be even worse in cultures that emphasize effort over ability in causal attribution. It seems that, very roughly speaking, people in East Asian countries think that effort makes a difference everywhere (i.e., even when one lacks ability), whereas North-American or European people tend to regard effort as meaningful only insofar as one is talented enough in the domain (Hatano & Inagaki, in press). Thus, in Japan, for example, the talent account does no practical harm. It does not justify depriving those who are not talented of a chance to excel. In contrast, the learning-related account may lead to overemphasizing the responsibility of learners and their parents for not achieving well. It may result in initial good performance in a majority of beginning learners, as in the Suzuki method of violin teaching. It may lead to more time being devoted to an area in which students may initially be poor. However, it inevitably puts strong stress on learners and their teachers and parents, and induces guilt feelings for achieving less well than others.

What is the weakened talent account like, then? Howe et al. admit in the end, individuals may differ in their ability to achieve in a particular domain, this may have partly genetic origins, and the number of learners who are likely to reach the highest levels of achievement, even though they spend much time and effort in practicing, cannot be very large. Moreover, because general intelligence correlates only minimally with expert performance, the relevant individual differences in gaining expertise must be domain-specific. To avoid a too nativistic flavor, I will refer to this view as "the aptitude account." Unlike the talent account defined by Howe et al., the aptitude account does not assume that the presence of talent is all or none: some individuals are better endowed with the relevant talent, but the differences are a matter of degree. In addition, it is not committed to the early-indication assumption. How early gifted individuals distinguish themselves depends on training and assessment procedures. Real experts often stand out gradually – it is hard to believe that even experienced teachers can always identify with confidence the most promising learners at the beginning stage, when their performances are eventually evaluated a few decades later. However, the aptitude account, like the talent account, indicates that one needs greater aptitude to achieve a very high level of performance (e.g., becoming successful professionals) especially when the target domains require such cognitive factors as imagination, creativity, and sensitivity to subtle changes in the environment including competitors. However, like the learning-related account, it denotes that most can become excellent students or proud amateurs in most domains of expertise, if they spend decades in deliberate practice, especially in the domains where the requisite skills can be analyzed and taught systematically. It thus allows individuals to judge their own aptitudes as they gain expertise and to choose domains that seem to best fit their patterns of aptitudes.

Experience is no improvement over talent

Kurt A. Heller and Albert Ziegler

Department of Psychology, University of Munich, D-80802 Munich, Germany; **heller@mip.paed.uni-muenchen.de**

Abstract: Our recapitulation of the work by Howe et al. is a clear approval of the passages in which the talent concept is critically questioned. On the other hand, Howe et al. must themselves come to terms with most of the accusations they place at the door of talent researchers. The evidence they present to support the experience concept is lacking with respect to current theoretical and methodological standards.

Conservative figures in the field of behavior genetics estimate the amount of variance explained by individual differences in personality and cognition to be about 50%. In reading the work of Howe et al. one gets the impression that the influence of genetic factors is next to nothing, experience being all-important. How can this enormous discrepancy be explained?

An obvious answer can be found in the inconsistency among the objects investigated. Behavior geneticists usually do not investigate the exceptional achievements of people who have invested thousands of hours of intensive practice to expand the limits of their performance abilities. In a certain sense, this effort is intended to deceive the natural genetic configuration in that with every forward step taken through learning, this genetic configuration is altered in some way by additional amount of competence. Behavior genetics has exposed the unreflected coupling of behavioral complexity and raised levels of environmental influence as a grave error. The reference to behavioral complexity does not suffice to completely reprieve the talent concept from the death sentence.

One thing is certain: the authors have shed light on a problem that has proved to be an impediment in gifted research: the almost universally observed and all too unworrisome application of the talent concept. We want to protect Howe et al. from the charge, which will probably be made by certain defenders of the talent concept, that they have characterized the talent concept inadequately. In our opinion, the applied working definition is completely fair because it presents a relatively accurate description of its usual applications. We can follow Howe et al. a step further in their argument in that they call the fragile empirical basis of the talent concept seriously into question and prove such illusions to be groundless. Their argument becomes problematic, however, at the point where the alleged evidence *against* the concept of talent is presented. We wish to raise two further points. First, Howe et al. demand different criteria in evaluating studies that yield empirical evidence pro and contra the talent concept. Findings favoring the talent construct are rejected on methodological grounds. Findings contrary to the talent construct are, on the other hand, readily accepted despite comparable shortcomings. For example, retrospective interviews are rejected as methodologically unreliable; then in the same breath they are celebrated as welcome bearers of evidence supporting their own position. Second, their theoretical analysis of the alleged counterevidence is totally insufficient. One example is the training experiments, which are represented as evidence that "untalented" people can also produce exceptional achievements; this is not at all illuminated from a talent perspective. In this study, the general reports of individual differences in acquisition rates are completely ignored, although this alone could entirely reflect differing talents.

Above all, Howe et al. remain vague where it concerns theoretical alternatives. The frequent reference to the experiential component as an alternative to the talent concept is based on a concept of experience that in some ways is inferior to the standards held by behavior genetics. This perhaps indicates the possibility of a talent–environment interaction, although the authors do not come around to the conclusion that in this situation there is next to no empirical evidence available.

Although we are just as skeptical of the talent concept as Howe et al. are, we find their argumentation less than convincing and see their alternatives as theoretically underdeveloped. We would like to show the conditions under which we would allow ourselves to be infected by their enthusiasm for the experience concept. First, we would demand a new theoretical orientation that would replace the black-and-white depiction of talent versus experience. The focus of the explanation of exceptional achievements should not be on either experience (however one conceptualizes it) or talent (however resourceful the future defenders of this construct prove to be), but rather on variance explained through individual differences in the acquisition of exceptional talents. We place great importance on calculating the phase-like influences of talent from the start, as found, for example, by Ackerman (1988) in his studies. Talent might play an important role at the beginning of one's experience with a domain, but later on it is seen as having less and less influence. The cause here can be a performance-dependent selection process in which only genetically advantaged people maintain a high level of domain-specific activity. This would result in an extremely limited variance in genetic configuration through which the influence of the experiential component in empirical studies would be relatively overestimated. Talent–environment interactions of this form must be completely excluded, otherwise talent researchers will only be able to see talent in cases of eminent performance, and the proponents of experience will only see, with the same amount of (non)validity, experience.

Methodologically speaking, studies are needed in which environmental similarity would be subject to the same amount of control that is already being ascribed to genetic similarity between subjects. For example, why should one determine from Howe et al.'s favorably cited training studies with "untalented" persons that the learning rates and achievements of siblings can be compared to those of unrelated persons? Why is it that within a random sample of unrelated persons, the performance variances *within* sports clubs are not compared to those *between* sports clubs. These and other study designs are much better suited for an explanation of the capacity of the talent construct.

Our recapitulation of the work by Howe et al. is with clear approval of the passages in which the talent concept is critically called into question; nor have they taken on a straw man here, but a being living and working in the field of practice-oriented research. On the other hand, Howe et al. must themselves come to terms with most of the accusations they place at the door of talent researchers. The evidence they present to support the experience concept is, with respect to current theoretical and methodological standards, wanting.

General intelligence is central to many forms of talent

Lloyd G. Humphreys

Departments of Psychology and Education, University of Illinois, Champaign, IL 61820; **lhumphre@s.psych.uiuc.edu**

Abstract: Howe et al.'s rejection of traditional discussion of talent is clearly acceptable, but their alternative has a weakness. They stress practice and hard work while referring vaguely to some basic biological substrate. High scores on a valid test of general intelligence provide a cultural-genetic basis for talented performance in a wide variety of specialties, ranging from engineering to the humanities. These choices may be entirely environmentally determined, and the highest levels of achievement do require practice and hard work.

The properties of hypothetical talents, as derived by Howe et al. from their reading of the literature, allow them to reject convincingly the construct so defined. The rejection is appropriate: "multiple talents" is a construct with little measurement appeal. Talent is commonly conceived as a categorical construct, not the high end of a distribution of individual differences. Talents are uniquely determined genetically. Environmental contributions are minimal. However, Howe et al.'s alternative represents a strongly environmental approach with only an occasional vague reference to some form of biological substrate.

In a strange way, the rejected construct has democratic, egalitarian appeal. It provides multiple ways to be talented, replacing the single dimension obtained from a standard test of general intelligence. In this respect, multiple talents are similar to the multiple intelligences of Gardner (1983). On the same grounds, the vagueness of Howe et al. concerning the biological substrate of their alternative, hard work and practice, makes their alternative seem even more attractive.

There is a third way to describe the development of talent that is more precise about the biological substrate than the alternative presented here. It accepts hard work and practice, but in a limited role. It is also not an account of all kinds of talent. Music, the graphic arts, and athletics are specifically excluded, but it does include talent in the learned professions, the "hard" and "soft" sciences, and the humanities.

Prototypic general intelligence has a central role in the development of talented achievement in the areas I have named. It starts by defining the biological substrate for talented achievement. In doing this, I make use of the account of the genetics of general intelligence found in the report of the Task Force of the American Psychological Association (1995). In the late teens and young adulthood, heritability may be as large as .75, but this leaves .25 unexplained. A contribution from variance *between* families, however, is excluded at this age. In young children, on the other hand, heritability is about .45, and there is a substantial component of between-family variance.

At a different level of analysis, the stability of scores on a valid measure of general intelligence from year to year is quite high even from age 6 to age 7, but falls substantially short of perfect stability. The stability from age 17 to age 18 is higher, but still falls short of what might be expected from an innate capacity. More important, the stability of scores from ages 6 to 18 is substantially lower. The small amount of instability from year to year accumulates over the course of development to a value possibly as low as .50 to a high of .70 between ages 6 and 18. (This problem has not been studied as thoroughly as its importance dictates.) The net effect, of course, is that intellectual talent, even at the highest levels (1 in 100, 1 in 1,000), is not expected to be manifest in all persons at a very early age.

It is both plausible and probable that future engineers and humanists start differing from each other early in development owing to environmental influences, and that these small ways become larger as future talented persons advance up the educational ladder. These sources of environmental variance become greater within and less between families with increasing age. There is severe restriction of range of talent on general intelligence by the time students graduate from professional or graduate school. This restriction is described statistically by the reduction in variance of the scores of the graduates on intelligence tests, whereas the mean indicates that the restriction was, as expected, from the lower end of the distribution. There are few persons in these occupations who were not in the upper 10% of the distribution during their senior year in high school. By the standard at age 6, appreciable numbers were lower than the 90th centile.

Hard work and practice do become relatively more important in populations drastically restricted in range of talent or intelligence. Because general intelligence is not a stable capacity, and it is clearly not 100% heritable, hard work and practice may well make a contribution to the phenotypic scores of young adults when started early in development and continued as the child moves up the educational ladder. However, if the vague references to a biological foundation for talented achievement are accompanied by a belief that providing opportunity and encouragement late in development will work wonders in the right biological constitution, then this represents wishful thinking.

It is both plausible and probable that the present estimate of the heritability of general intelligence does not extend to numerical, verbal, and other narrow abilities as those abilities appear in the hierarchical model of intellectual abilities. General intelligence is at the top of the hierarchy, immediately below are a small number of broad group abilities, and below them are a large number of narrow abilities. As defined factorially, the entire hierarchy is defined by residuals. General intelligence represents what cognitive tests have in common with each other after the variance of scores due to differing content and differing cognitive operations have been removed. All factors below general intelligence represent the remaining variance when the variance of factors higher in the hierarchy has been removed. There is general factor variance in the raw score of a verbal test, but to determine verbal heritability per se, general intelligence must be controlled. The sum of squares of hierarchical factor loadings of each variable in the analysis remains constant from the unrotated principal factors in the first order of the analysis to the hierarchically rotated loadings.

That high levels of narrow talented achievement develop out of superior levels of general intelligence with practice and hard work has a good deal of support in the wide acceptance of the hierarchical model of cognitive abilities. The hypothesis that this development is environmentally determined can be tested by the existing methods of behavior genetics. Care must be taken to base the heritability of general intelligence on a highly valid estimate of the general factor and then to exclude that variance from estimates of heritability of factors lower in the hierarchy.

Innate talents: A psychological tautology?

Sidney H. Irvine
U.S. Air Force Armstrong Laboratory, San Antonio, TX 78235;
irvines@alhrm.brooks.af.mil

Abstract: The tautological implications of "innate talents" are outlined. Analogies are drawn between the present review and the nature–nurture controversies of 40 years ago. Ferguson's (1954; 1956) theoretical positions are proposed as a context in which to consider present and future attempts to resolve this long-standing issue.

Howe et al. pull together diverse opinions and even more diverse data to conclude that to describe talents as innate is probably systematically misleading. It is difficult to disagree with them. In fact, one might wonder why psychology considers the issue to be any more than a modern version of what was once known as the nature–nurture controversy. Semantic analysis of the words "innate" and "talent" reveals that the phrase is tautological. A talent is innate, in popular or dictionary parlance. To describe it as innate means that it is an innate set of innate abilities. Perhaps this is why the perennial issues of the nature–nurture controversy are revisited on us in Howe et al.'s adversarial form, which may itself be misleading.

It seems appropriate to advise using the time machine to discover what problems the nature–nurture controversy might have posed to psychology 40 years ago, and to find out what seemed, in theory, to resolve it then. Howe et al. might still add this knowledge to their own analyses for a key to understanding the problems they so carefully enounce. Ferguson's two remarkable insights, one of which Irvine and Berry (1988) have designated as a law, help to put the review in a consistent theoretical perspective. The first is Ferguson's (1956) definition of ability, which is "a skill learned to a crude level of stability." The second is Ferguson's Law, which is that culture will prescribe what is learned by whom and at what age (Ferguson 1954).

Given these basic propositions, talents, like all other abilities, are skills learned to a crude level of stability. Moreover, they exist whenever customs sanction their development. What *changes* any genotype to a measurable phenotype is the enduring puzzle, and little in the way of a solution will emerge from any adversarial account.

The sudden emergence of talent is pivotal in the debate. How could such changes be accounted for? Perhaps the best large-scale empirical example of the sudden appearance of talent in recent times is provided by the remarkable initiation, growth, and flowering of the Shona sculptors of Zimbabwe. Before the discovery of a huge deposit of malleable stone on a farm called Tengenenge owned by a white farmer, no tradition of indigenous carving was to be found in the Shona culture. Two important preconditions, apart from the discovery of serpentine, allowed sculpting skills to be learned and talent to emerge. The owner permitted anyone who wanted to come and try to carve in stone to stay on his land, and modest provisions were provided. In addition, Frank McEwen, the late curator of the Zimbabwe National Gallery, promoted the product as part of an independent national identity not available to the white settlers. In the space of a few years, sculptors of international reputation emerged from Zimbabwe. Thirty years on, the Zimbabwe stone carvers have diversified and increased. Talent there is in abundance.

One might be tempted to assert that these sculptors were by nature disposed to work in stone. A visit to Tengenenge shows, however, that many were called but few were chosen. The site contains acres of discarded and unrecorded stone carvings, many overgrown with weeds, a cemetery of those whose skills did not stabilize, and for whom some conflict, not custom, dictated their disappearance. Occasionally, more than one member of a family has emerged as an artist of note, in particular the Takawira brothers, of whom the late John Takawira is recognized as preeminent in his generation. This is an isolated example, but relatives of eminent sculptors go to study and learn with them and, literally, try their hands at the craft. This has less to do with genetic gifts than the politics of kinship.

Talent requires opportunity, sponsorship, and dispositional qualities, of that one may be certain from Ferguson's definitions and from the sudden large-scale emergence of "hidden talent" such as the work of the Zimbabwe sculptors. For a science of individual differences to emerge, we need to find out exactly how much of each is required and in what curious alchemy they combine. Of course, the eighteenth century poet, Thomas Gray, knew what he was talking about when he wrote that *many* persons with potential for great achievements were "born to blush unseen and waste [their] sweetness on the desert air."

Historical increases in expert performance suggest large possibilities for improvement of performance without implicating innate capacities

Andreas C. Lehmann
Department of Psychology, Florida State University, Tallahassee, FL 32306;
lehmann@psy.fsu.edu www.psy.fsu.edu/post.docs/lehmann.dp.html

Abstract: Innate talents supposedly limit an individual's highest attainable level of performance and the rate of skill acquisition. However, Howe et al. have not reviewed evidence that the level of expert performance has increased dramatically over the last few centuries. Those increases demonstrate that the highest levels of performance may be less constrained by innate capacities than is commonly believed.

This commentary attempts to support Howe et al.'s general claim that "individual differences in learning-related experience are a major source of the variance in achievement" (sect. 5, para. 5) by adding a piece of evidence not considered by the authors. In some domains of expertise, experts agree that although lower levels of performance can be attained without the contribution of talents, the highest levels are limited by a person's innate capacities. If we can show that the highest levels of performance can be dramatically increased, the importance of innate capacities for constraining performance diminishes, and even becomes negligible.

In many domains of expertise, we observe substantial historical increases in expert performance. For example, Olympic records in many sports events have been repeatedly broken, even in events without many changes in equipment (Schulz & Curnow 1988). Talent is supposedly manifest in the world's best performances, such as winning the gold medal in the marathon race at the Olympic Games early in this century, yet when decades later the same performance (running time) is attained by serious amateurs, even athletes in their 60s, talent is not used as an explanation (Ericsson 1990). In the domain of music performance – as in other artistic domains – talent has traditionally been considered a major source of excellence. Therefore, it would be important to show that levels performance can be increased without involving the need for talent. I suggest that by looking at biographical data of successful individuals in history, we can infer the (current) limits of performance and assess the influence of training. If talent were truly a limiting factor, it should be impossible to considerably improve performance over time (unless one assumes an increase in innate talent).

Naturally occurring biographical performance data are available for domains where performance is objectively measurable, and the records cover sufficiently long periods of time. A recent chapter (Lehmann & Ericsson, in press) has documented available evidence for the increase in levels of music performance and the factors that seem to drive such increases.

When assessing the level of complexity of written music that was available to piano performers at different times in history, Lehmann and Ericsson found that the skills required to master more recent pieces were greater than those needed to perform

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

older ones. Also, there are pieces of music that, at the time of their composition, even trained professionals regarded as "unplayable." For example, the nineteenth century violin virtuoso Nicolo Paganini was considered a magician with sinister powers because of his mindboggling, inaccessible technique. Today, a great number of his "unplayable" pieces of music are standard fare for every violinist, adult musician, or child prodigy. Other somewhat less complex pieces are known and mastered by serious amateurs. Thus, a performance that was once attainable only by "geniuses" is reached today by a large number of musicians.

How can we account for this apparent "explosion of talent"? Is this broad-based increase in performance simply due to the much larger numbers of individuals engaged in the domain with the associated effects of (self) selection of "gifted" individuals? Lehmann and Ericsson suggested an alternative, three-part explanation including professional specialization, innovative contributions by instrument makers and expert performers, and the optimization of training.

First, since the seventeenth century, there has been a strong trend toward professional specialization of musicians, culminating in the elite performers of our century who play only a single instrument in public and play thoroughly rehearsed existing music. Unlike in former times, improvisation and unrehearsed performances are rare in today's classical music practices. Thus, modern music performers can focus on a single skill during their extensive training period, allowing for higher final levels of performance.

Second, instrument makers, by themselves or in close collaboration with expert performers, have tried to improve the design of musical instruments. For example, the number of keys on the piano has grown by almost half since its invention. In close interaction with the development of the instrument, elite performers invented techniques that took advantage of, and even challenged current possibilities. For example, Mozart's piano music was considered quite difficult for the left hand. However, the complexity of his music is far removed from specialized "left-hand-only" music of recent times, which sounds to the uninitiated as if both hands were playing. Although improvements and inventions allow for greater control over the instrument, they impose skill demands that have to be mastered in addition to previously required ones.

Third, to train performers with all the prerequisite skills to become successful professionals, training methods and materials have been optimized. For example, starting ages for instrumental music lessons have been reduced, carefully sequenced teaching materials have become available, and specialized teachers have appeared. These developments have led to an acceleration of skill acquisition. In fact, for a random sample of famous piano prodigies, we found that more recent generations were playing more difficult pieces at younger ages and after fewer years of training than former prodigies. Improved music instruction has also had an effect on modern audiences, who, through media and private music instruction, have become musically literate with ensuing higher expectations than was formerly possible.

In summary, expert levels of performance have increased continuously during many generations for the reasons outlined, suggesting that talent may not be the limiting factor for human performance (at least thus far). The fact that former expert levels can today be achieved routinely by a large number of unselected but motivated individuals indicates that "talent" may not have been a necessary prerequisite for past exceptional performances. Instead, specialized instruction and extensive, deliberate practice have allowed more recent performers to adapt to the new and heightened performance demands.

Genetic influence and cognitive abilities

Robert Plomin

Social, Genetic and Developmental Psychiatry Research Centre, Institute of Psychiatry, London SE5 8AF, United Kingdom; **r.plomin@iop.bpmf.ac.uk**

Abstract: Much has been learned about genetic influence on cognitive abilities that might be helpful in thinking about genetic influence on other abilities such as art and sports, which have not yet been investigated using genetic research strategies. Some new findings on cognitive abilities go beyond merely demonstrating genetic influence. Misinterpretations of the meaning of genetic influence are discussed.

Most discussions of talent focus on the arts and sports: What about talent in the core educational domain of cognitive abilities? This commentary focuses on cognitive abilities, because much more research has been done on the genetic and environmental origins of cognitive abilities than all other areas of talent put together. The results of this research can provide an empirical perspective on some of the issues Howe et al. raise concerning the origins of other talents.

Genetic research on general cognitive ability ("g") and specific cognitive abilities such as verbal and spatial skills consistently converges on the conclusion that genetic factors make an important contribution. Model-fitting meta-analyses of family, twin, and adoption data on "g" yield significant estimates of genetic influence, with effect sizes (heritabilities) typically estimated to be about 50%, meaning that about half of the observed variance in "g" can be attributed to genetic differences among individuals (Plomin et al. 1997). Yet another summary of the literature on genetics and IQ has recently appeared, this time in *Nature* (Devlin et al. 1997). In a meta-analysis of 212 familial IQ correlations, these authors tweaked their model-fitting analyses in an attempt to attribute as much variance as possible to prenatal environmental factors, yet their estimate of broad-sense heritability of "g" was 48%. A commentary on that article by McGue concludes:

> That the debate now centres on whether IQ is 50% or 70% heritable is a remarkable indication of how the nature–nurture question has shifted over the past two decades. The anti-hereditarian position that there are no genetic influences on IQ has crumbled for want of any empirical data that would support such a radical review. (1997, p. 417)

Forget the complexities of model-fitting and just look at the basic data (Plomin et al. 1997). Why are identical twins more similar than fraternal twins (.86 vs. .60)? Why are identical twins who are reared apart so similar (.78)? Why are first-degree relatives adopted apart so similar (.24)? Although specific cognitive abilities have not received as much attention, evidence for genetic influence on verbal and spatial abilities is nearly as strong as for "g" (Plomin & DeFries, in press).

Because the answers to the rudimentary questions about whether and how much genetic factors contribute to cognitive abilities now seem sufficiently clear ("yes" and "a lot"), genetic research on cognitive abilities has moved beyond these rudimentary questions. Here is a sampler of new discoveries during the past decade that may be relevant to the origins of other talents (for details and references, see Plomin et al. 1997; Plomin & Petrill 1997):

1. Genetic influence on "g" increases from infancy (20%) to childhood (40%) to adulthood (60%). A recent study of twins age 80 years and older reported a heritability of about 60% (McClearn et al. 1997).

2. Genetic effects on "g" largely contribute to continuity from age to age, but some evidence for genetic change has been found during infancy and during the early school years, which means that heritability should not be equated with stability or with early appearance.

3. High cognitive ability appears to be just the high end of the same genetic and environmental factors responsible for individual differences throughout the normal distribution.

4. Specific genes responsible for genetic influence on "g" are beginning to be identified (Chorney et al., in press).

5. Nonadditive genetic effects are important but have been masked in earlier research by the high assortative mating for "g."

6. The substantial correlation between "g" and school achievement is largely mediated genetically.

7. Shared family environment contributes importantly to "g" until adolescence, but it is of negligible importance in the long run; nonshared environmental factors that make children growing up in the same family different from one another are the long-term source of environmental effects.

8. Genetic factors affect our experiences; the way forward in research is to investigate the developmental interplay between nature and nurture (Plomin 1994).

Because genetic influence appears to be ubiquitous for all domains of behavior investigated so far, I predict that when genetic research has been done on other talents, evidence for genetic influence will also be found. However, such evidence is often misinterpreted:

1. Genetic does not mean innate. *Innate* implies hard-wired, fixed action patterns of a species that are impervious to experience. Genetic influence on abilities and other complex traits does not denote the hard-wired deterministic effect of a single gene but rather probabilistic propensities of many genes in multiple-gene systems (Plomin et al. 1994).

2. Genetic influence refers to "what is" rather than "what could be." As research on expert training shows, children can be trained to be very much better at many skills ("what could be"). However, such findings do not mean that environmental factors are responsible for the origins of individual differences in those skills or that genetic factors are unimportant ("what is"). An a propos demonstration of this point, reported recently in *Science,* shows that the heritability of performance on a motor task is substantial before, during, and after training (Fox et al. 1996).

3. Genetic influence refers to "what is" rather than "what should be." What we do with scientific knowledge is a matter of values. Thus, it does not follow that finding genetic influence on cognitive ability means that we deny help and encouragement needed to reach high levels of competence.

Given the evidence for the importance of genetic influence in other domains of behavior such as cognitive abilities, I did not find the conclusion by Howe et al. persuasive "that differences in early experiences, preferences, opportunities, habits, training, and practice are the real determinants of excellence" (Howe et al., Abstract). Genetic research is needed to settle the "what is" question of the relative influence of genetic and environmental determinants of talent, despite the impressive results of expert training research that addresses the "what could be" question.

Talent scouts, not practice scouts: Talents are real

David C. Rowe

School of Family and Consumer Resources, University of Arizona, Tucson, AZ 85718; **dcr091@ag.arizona.edu**

Abstract: Howe et al. have mistaken gene *x* environment correlations for environmental main effects. Thus, they believe that training would develop the same level of performance in anyone, when it would not. The heritability of talents indicates their dependence on variation in physiological (including neurological) capacities. Talents may be difficult to predict from early cues because tests are poorly designed, or because the skill requirements change at more advanced levels of performance. One twin study of training effects demonstrated greater heritability of physical skill *after* than before training. In summary, talents are real.

Professional sports teams typically send out *talent scouts,* they do not send out *practice scouts.* They seek a first-round draft pick. They do not try to increase practice time for their own players. A few years ago, Australia wanted to field a competitive team of women rowers. They conducted a national talent search for women of the right body build, and then tested them for aerobic capacity and strength. The women who had the highest test scores were then trained; their rowing team led Australia to the championship level. Before the fall of the Berlin Wall, the East Germans had the same strategy for producing a disproportionate number of Olympians from a small population base. In all cases, the strategy was first to spot talented children and then to train them intensively. It was not to pick randomly from the population and then train, train, and train. Howe, Davidson & Sloboda are virtually alone in thinking that talent can be trained in *anyone.*

Howe et al.'s mistake is to confuse gene *x* environment correlation for environmental main effects. Gene *x* environment correlation is technically the nonrandom assignment of genotypes to different environmental contexts. These gene *x* environment correlations occur when people actively self-select into different activities, as well as when social institutions make those selective decisions. In any area of human skill and performance, whether physical or intellectual, some selection occurs at each stage of the process. In preschool, any singing voice is permitted; in junior high, children themselves can recognize that they sing poorly, and opt out of the choir, whereas other students with especially beautiful voices are recruited for it. The more talented receive more training, practice more, and gain more from their efforts. No matter how many hours the average person practices, he will not hit a tennis ball like Pete Sampras, sing like the Three Tenors, solve a differential equation like the late physicist Richard Feynman, or program a computer like Microsoft's founder, Bill Gates.

There is substantial evidence of innate differences in many areas of human achievement, some of which is cited by Howe et al. For example, they cite the heritability of musical abilities for twins raised apart, where $h^2 = .44$. This is a large genetic effect on musical abilities. Unfortunately, few behavior genetic studies of musical abilities have been conducted, and both studies cited by Howe et al. relied on self-report of musical abilities. More work on the genetics of talents outside the IQ domain is surely needed.

Within the IQ domain, high "g" individuals are responsible for most great intellectual achievements in mathematics and the sciences. A substantial genetic component to IQ is well established (Plomin et al. 1997). Contrary to Howe et al.'s assertions, IQ is highly heritable across its full range, including the upper tail of the ability distribution (Sundet et al. 1994).

Howe et al.'s statement that "general intelligence need not limit the final levels of achievement" is wishful thinking. High levels of "g" are required for high achievement in math and science (and in many other fields); the intellectually dull have not contributed to *Homo sapiens*' great intellectual achievements (Spitz 1986). Because specific and general abilities are correlated, their assertion that general abilities have no bearing on specific ones is misleading (Brody 1992). In addition, associations among intellectual abilities of various kinds are also mediated genetically (e.g., Casto et al. 1995).

Few (or possibly none) of civilization's great scientific literary achievements have been contributed by individuals with the *savant syndrome.* Savants work within a narrow range of fields (e.g., artistic works, music, rapid calculations) that are outside many domains of intellectual achievements. The genetics and environmental components of savants' achievements have not been investigated. They could be genetically based. In any case, the achievements themselves may not be "intelligent" at all in the sense of psychometric "g" (Nettelbeck & Young 1996). That is, they show neither the capacity to understand complex material nor flexibility in the application of thought. I believe the savant syndrome should be avoided in the study of talent, because these savants constitute a minuscule proportion of all talented people and because the underlying processes for their talents also may be unrepresentative.

As with musical abilities, talent in sports has been too little studied using genetically informative research. Work on the genetics of aerobic capacity and strength, however, demonstrates that variation in physical performance is highly heritable.

Howe et al. have not done the type of scientific work that would strongly test their hypothesis. They have not taken a *random*

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

sample of people, tested them before training, and then tested them again after training in a genetically informative research design. Their prediction would be that modest heritability exists before training and almost none after training because, according to their theory, training is a great leveler of human performance (i.e., "talents are myths").

A study of training of a physical skill, the pursuit rotor task, however, contradicts Howe et al.'s claims (Fox et al. 1996). Before training, twins varied widely in their performance on the "pursuit rotor" task (i.e., following a target on a rotating disk with a pen). The heritability of motor accuracy was about 55%. The mean time on target was about 15%.

Next, everyone practiced the test. The twins got better with practice – as Howe et al. suggest, expert performance requires practice. The mean was 60% on target. After practice, the worst scoring person scored higher than the *best scoring* person had before practice. As individuals differed in their level of improvement, variability of the accuracy scores also increased with training. Before practice, variance (s^2) equaled about 100; after practice, it equaled about 400. The fourfold increase in variance with practice means that practice actually increased the range of individual differences. Heritability also *increased* after practice (from $h^2 = .55$ to .65).

Nonetheless, championship rotor pursuit performance was not very well predicted from initial performance (Bouchard, personal communication, 1997). One explanation is that speed is particularly important among highly skilled individuals, and the demand for speed was not apparent before training. A change in the mix of skills demanded at high performance levels may explain why, in some examples cited by Howe et al., there were few early cues that would predict the ultimate level of performance. A lack of predictability, however, does not rule out that a "genotype" of talent will emerge with practice: for example, genetic differences did distinguish the pursuit rotor champions from the losers. On the other hand, it may be that too little work has been done to create the proper test items for prediction of performance. For example, it was once thought that children's IQ was not predictable from behavior in their infancy. Now, cleverly designed tests of infants' ability to recognize novelty have changed this received wisdom; these tests do predict childhood IQ (McCall & Carriger 1993).

Howe et al.'s implicit requirement for a *single* physiological marker of talent is outlandish. No biologist would claim that a single physical measure would suffice to characterize a complex trait. For example, cholesterol level may tell something about heart attack risk, but certainly not everything. Composites of physical measures should be able to provide a biological marker for different talents, but this is an arduous endeavor. Already, though, there is clearly progress in the IQ domain, where some physical measures such as brain size (Willerman et al. 1991) and nerve conduction velocity (Rijsdijk & Boomsma 1997) correlate with IQ. With a suite of distinct physical markers, it may be possible in the future to predict some talents directly from physiological traits.

As Howe et al. assert, practice makes perfect, but it is an adage that should be qualified, "for the talented."

What can we learn from highly developed special skills?

Michael Rutter

MRC Child Psychiatry Unit and Social, Genetic and Developmental Psychiatry Research Centre, Institute of Psychiatry, London, SE5 8AF, United Kingdom; **spjwghr@iop.bpmf.ac.uk**

Abstract: Skills cannot be divided into the innate and the acquired. Also, genetic effects may not come into play until well after early childhood, and evocative gene-environment correlations are to be expected. Special talents are common in autism and warrant more detailed study, but whether they have the same meaning as talents in nonautistic individuals is not known.

Howe et al.'s denial of the reality of talents is based primarily on the outdated notion that skills can be subdivided into those that are innate and those that are acquired. Modern genetic findings have shown the importance of genetic influences on cognition, but there has been no suggestion that, even when such influences are very strong, skills can develop in the absence of pertinent experience (Plomin et al. 1997).

That talents are not usually evident in very early childhood does not necessarily imply the preponderant influence of experiences. The timing of the menarche is subject to strong genetic influences, yet it does not occur until adolescence. Similarly, Alzheimer's disease involves substantial genetic influences, the effects of which are not usually evident until old age. There are no identifiable cognitive precursors in childhood of this dementia of late onset. Genes are in place at birth, but they may come into operation only much later in the lifespan. The notion that genetic effects have to be apparent in early childhood is invalid.

Two points apply to the evidence that individuals with outstanding skills have usually had an advantageous upbringing that has fostered those skills. First, because both genes and experiences operate together, it is to be expected that skills of exceptional quality would be more likely to be fostered if *both* the genetic background and the rearing environment were exceptionally favorable. Second, environments experienced by children are not independent of their genetically influenced personal characteristics (Rutter et al. 1997). Children with outstanding talents in sports, music, or some other domain are likely to evoke parents' and teachers' interest in such skills and, by their positive responses, will reward the intensive high-level tutoring, training, or practice involved. Evocative gene–environment correlations are to be expected and are likely to be influential. All of this is commonplace and requires no special explanation.

Howe et al. acknowledge that the "idiot savant" skills seen in some individuals with autism may be different, but dismiss them on the unsubstantiated ground that any innate component "augment[s] the individuals' obsession rather than their specific skills as such" (sect. 2.4, para. 4). The specific association with autism is almost certainly significant, and it is likely that the behavioral features favoring stereotypy and circumscribed interests may well be influential. However, there is abundant evidence that such skills are indeed of an exceptionally high order and not reliant on special "tricks" of any kind (Heavey 1997). Also, although "genius" level talents may be rare even in autistic individuals, outstanding isolated skills well above the person's overall level of intellectual functioning are much more common. Thus, whether assessed psychometrically or on the basis of real-life performance, about one in five individuals with autism have isolated skills at least 2 standard deviations above their overall mental level and at least 1 standard deviation above general population norms (Goode et al. 1994). The reason for association between such skills and the very high genetic component in the underlying liability to autism (Bailey et al. 1996) remains unknown, but it is certainly implausible that the skills have been fostered by teaching. Indeed, it is not uncommon for parents to remain unaware of the talents for many years. On the other hand, it is unclear how far the talents represent specific skills for which there was an exceptional genetically influenced potential, or skills that have flourished largely because of deficits in other intellectual domains, or because of highly constrained circumscribed interest patterns, or some combination of the three. What the findings do demonstrate, however, is that, for whatever reason, there can be a remarkable modularity of intellectual skills, with an isolated talent in one cognitive domain quite out of synchrony with the overall level of cognitive functioning.

Are idiot savant skills in autism, however, a special case without implications for the exceptional early emerging talents in music, mathematics, or art shown by nonautistic individuals? Clearly they are different in two respects: these nonautistic individuals are not generally impaired intellectually in the way that idiots savants are, and they put their unusual skills to good use. Many autistic idiots

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

savants do not. They exhibit remarkable skills (frequently of memory or calculation), but only rarely are they able to use these productively in real life. Indeed, perhaps surprisingly, their talents often do not even seem to provide a source of personal satisfaction or relaxation or pleasure.

The question may equally well be posed the other way round. Are the unusual talents of, say, Mozart different in *kind* from those exhibited by others, of simply different in *degree?* No satisfactory answer is available but, at least so far, there is no convincing evidence of a qualitative or categorical distinction. Is the genetic component greater (or lesser) at the extremes of the range of multifactorially influenced traits such as mathematics, music, or general intelligence? Again, the answer is not known (but it has to be added that, unless the difference was a very large one, it would have very limited theoretical or practical implications). Could the findings, however, be important with respect to the dispute over the extent to which cognitive skills are modular rather than general? That seems a more fruitful avenue to explore, although I doubt that a focus on the extent to which talents are innate will be the best way forward. Rather, advances are likely to come from the study of unusual and distinctive cognitive patterns characteristically associated with specific (often genetic) medical conditions, and from the use of functional imaging techniques to study brain activity during different types of task performance.

Given the substantial continuing scientific uncertainties, further research seems to be called for and the phenomena of unusual talents, as observed, seem a reasonable starting point, provided they are stripped of their implication of innateness. Howe et al. may well agree with that. Their passion for rejecting the concept of talent seems to stem from a concern that practitioners are exercising selective discrimination on the mistaken assumption that some deserving individuals have an innate talent that requires special fostering, whereas other undeserving individuals simply have a range of more ordinary skills that require no privileged access to skilled teaching. If that is indeed their concern, we are in agreement. Skills cannot be divided into those that are, and are not innate; cognitive performance ebbs and flows over the course of development (as a result of both genetic and environmental influences); and all skills warrant fostering, regardless of the extent to which they are genetically or environmentally influenced. The author Marx has gone out of fashion, but the wisdom of the dictum remains: "From each according to his abilities, to each according to his needs."

Innate talent or deliberate practice as determinants of exceptional performance: Are we asking the right question?

Wolfgang Schneider

Department of Psychology, Wuerzburg University, D-97074 Wuerzburg, Germany; **psy4020@rzbox.uni-wuerzburg.de**

Abstract: Howe et al. proposed that the "talent account" is not suited to explain exceptional performance in specific domains. Their conclusion that early experiences and deliberate practice are highly important for high levels of skill is supported by numerous studies on the acquisition of expertise. However, the two popular views they contrast (experts are born versus experts are made) do not seem representative of current theorizing. Models that integrate the effects of basic abilities and deliberate practice are more appropriate in light of the available evidence.

Howe et al.'s target article deals with an important topic that has generated controversy in the literature for quite a while. I basically agree with the authors that there are convincing alternatives to the "talent account," and that large amounts of deliberate practice are crucial for excelling in many domains. However, there seem to be several problems with the authors' view of "talent" and their discussion of the evidence in support of the "talent account." Developmental models describing the acquisition of expertise cannot completely ignore information about individual differences in to-be-specified basic abilities.

Conceptualization of talent. At the beginning of their concluding comments, Howe et al. state that their definition of talent coincides with how the term is used by scientific researchers as well as teachers and practitioners. Although it may be true that most teachers and laymen agree about the five properties of talent explicated in section 1.1, I doubt that many scientists doing research on giftedness would do so. Admittedly, we are dealing with a fuzzy concept. There are probably more than 100 definitions of giftedness and talent around, and several may be close to what Howe et al. suggest. More recent views of giftedness and talent, however, seem more comprehensive and define them in a different way.

For example, Gagné's (1993) model associates giftedness with naturally developed human abilities (aptitudes), and talent with systematically developed abilities or skills that constitute expertise in certain human activities. In this model, it is assumed that certain aptitude domains (e.g., intellectual, creative, sensimotor, etc.) influence certain talents (e.g., arts, sports, science, etc.) through "intrapersonal catalysts," such as motivation and self-esteem as well as "environmental catalysts" such as significant persons, events, and opportunities. These "catalysts" determine the amounts of training or practice that eventually lead to high levels of performance. Clearly, the definition of talent proposed by Howe et al. does not coincide with the distinction between aptitude and talent in this rather popular approach, and also does not correspond well with Tannenbaum's (1983) definition, according to which giftedness is a potential that actualizes itself in "developed talents," mostly apparent in adulthood.

A second problem related to the view of talent in the target article concerns the role of genetic factors and the definition of unusual abilities. According to Howe et al., "early ability is not evidence of a talent unless it emerges in the absence of special opportunities to learn" (sect. 3.1, para. 4). Of course, this is always difficult to prove, and also reflects a rather uncommon assumption regarding the expression of "innate" abilities in "overt" behavior. In my view, this claim goes far beyond Howe et al.'s proposition 1, in that talent originates in genetically transmitted structures and is hence at least partly innate. It is also much stricter than proposition 2, according to which full effects of talent may not be evident at an early stage. Meanwhile, there is plenty of evidence from behavioral genetic research and research on intelligence that environmental experiences can shape and modify "innate" basic abilities. It is difficult to think of any aspect of human behavior for which genetic as well as environmental differences will not explain part of the variability.

A third problem is closely related. Howe et al. seem to conceive of talent as an "all-or-none" phenomenon. In the Introduction, they refer to talent as "the presence or absence of inborn attributes" (para. 2) or a "special biological potential that can be identified in some young children but not others" (para. 2). It seems better to use an individual-differences approach instead. The claim that early individual differences in some kind of basic ability predict individual differences in mature performance is much more compatible with modern research on talent than is an "all-or-none" view (see Heller et al. 1993).

Evidence supporting or contradicting the talent account. Probably owing to problems with this unusual view of talent, Howe et al.'s line of argument is not always very clear and consistent. For example, in section 2.1 the authors argue that reports on child prodigies should be regarded with caution, because in most cases the data consists of retrospective studies and anecdotal information. On the other hand, the evidence pointing to a lack of early signs of unusual abilities and to an absence of differences in the ease of learning between "talented" individuals and others (cf. sects. 3.1 and 3.2) is also exclusively based on retrospective interview studies in which adult experts (and their parents) try to remember whether early signs of promise were identifiable at the very beginning of their careers. It is difficult to

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

see why retrospective reports about unusual musical ability (as in the case of Mozart) or unusual language skills (as in the case study described by Fowler 1981) should be less reliable than reports about the lack of early signs of excellence.

If one accepts that individual differences in basic abilities can be identified in early childhood, then the crucial question is whether these early differences have an effect on later development in the domain under investigation. To generate suitable data on this issue, researchers must first develop indicators of basic abilities relevant for a given domain, and then conduct *prospective* longitudinal studies that explore the importance of such basic abilities for subsequent progress.

To my knowledge, only two prospective longitudinal studies with child experts assess the long-term impact of individual differences in basic aptitudes on subsequent performance (Horgan & Morgan 1990; Schneider et al. 1993). Whereas Horgan and Morgan analyzed the progress of elite child chess players, Schneider et al. investigated the careers of young German tennis "talents." Both studies confirm the view of Howe et al. in that improvement in domain-specific skill was due predominantly to deliberate practice, motivation, and parental support systems. However, individual differences in nonverbal intelligence accounted for about 12% of the variance in the chess-skill data reported by Horgan and Morgan.

Similarly, causal modelling conducted by Schneider et al. revealed that the influence of individual differences in basic motor abilities on later tennis performance was small but reliable. When the motor ability factor was omitted from the causal model, it no longer fit the data. The fact that individual differences in basic abilities had long-lasting effects in these two studies seems particularly remarkable, given that they deal with very homogeneous samples. Taken together, these results indicate that experience, although extremely important, cannot completely substitute for individual differences in aptitude.

The need for alternative models. Although I am very sympathetic to the model of skill acquisition initially developed by Ericsson and colleagues (1993) and also proposed in the target article, I question the basic assumption that progress in a given domain is solely a function of deliberate practice. The empirical evidence already described seems to support a somewhat different model that considers both basic abilities/aptitudes and deliberate practice as determinants of exceptional performance. In contrast to the model proposed by Gagné (already described) that considers basic aptitudes to be particularly relevant, the findings from research on expertise suggest that the effect on performance of individual differences in basic aptitude is rather modest compared to the enormous impact of practice and expertise.

In my view, "threshold" or "partial compensation" models fit better the interplay of expert knowledge and basic abilities in predicting exceptional performance (Schneider 1993; 1997). According to the "threshold model," if the ability parameter of a person is close to or beyond a critical or "threshold" value (typically assumed to be slightly above the population mean), then individual differences in predominantly noncognitive variables such as commitment, endurance, concentration, or motivation determine peak performance. In other words, if the ability parameter exceeds the threshold value, it does not matter at all whether the person is gifted or of normal aptitude. Problems with this model concern the definition of threshold values for different domains. The "partial compensation model" may be more appropriate, indicating that expertise reduces the contribution of basic aptitude more and more as the amount of domain knowledge increases.

Defining and finding talent: Data and a multiplicative model?

Dean Keith Simonton

Department of Psychology, University of California at Davis, Davis, CA 95616-8686; **dksimonton@ucdavis.edu**
psychology.ucdavis.edu/option2.htm simonton

Abstract: The Simonton (1991) study of 120 classical composers may provide evidence for the existence of innate talent. A weighted multiplicative model of talent development provides a basis for evaluating the adequacy of Howe et al.'s conclusions.

Although I am sympathetic with much of what Howe et al. are trying to accomplish in their target article, I have two reservations. The first is empirical: the authors conclude from my study of 120 classical composers that musical genius does not appear without considerable training and practice (Simonton 1991), yet the same investigation may provide evidence in favor of innate talent. It shows that the most eminent and prolific composers – in terms of both annual rates and lifetime output – required *less* musical and compositional experience before they began to make lasting contributions to the classical repertoire. Thus, this study seems to suggest that some musical talents can lead more quickly to world-class levels of compositional expertise.

The second reservation is conceptual. I believe that the issue of innate talent cannot be resolved without first formulating a more precise model of talent. I am currently working on a mathematical model of individual differences in talent development. Space does not permit me to present the details, but I will try to offer enough of a sketch to highlight deficiencies in traditional views of talent.

In this model, the potential talent of the *i*th individual at age t can be expressed as a weighted multiplicative function of the various genetic components that constitute the hypothesized talent. In more formal terms,

$$P_i(t) = \prod_{j=1}^{k} C_{ij}(t)^{w_j}$$

where P_i is the predicted talent potential, C_{ij} is the *i*th person's score on the *i*th component, and w_j is the weight assigned to the *j*th component for the particular talent domain ($i = 1, 2, 3, \ldots n$, $j = 1, 2, 3, \ldots k$, $w_j > 0$, and each C is a ratio variable with a zero-point that indicates the complete absence of the genetically based trait). An important feature of this function is that the value of each component is not stable, but develops over time. Hence, C_{ij} is a function of t, which represents the individual's age in years (where, say, $0 \leq t \leq 20$). These developmental functions may assume a wide variety of forms, including step, linear, logarithmic, logistic, power, exponential, and so on, depending on the epigenetic program for each component. Moreover, the timing of the onset of a specific component will itself constitute an individual-difference variable. A youth might get an early start on one component but may have to wait years before the development of another essential component "kicks in."

From this multiplicative model, it is possible to derive several predictions about talent. Four predictions are especially relevant to Howe et al.'s thesis. First, because $P_i = 0$ whenever there exists a single $C_{ij} = 0$, there will exist a large number of individuals who harbor no innate talent whatsoever. This will be especially true in the younger ages, when many components have not yet begun to develop. Second, even in that subset for whom all $C_{ij} > 0$, the distribution of talent will be highly skewed, with a small number of individuals possessing an inordinate amount of talent. Indeed, even if cross-sectional variation on all components were normally distributed in a given cohort, the distribution of potential talent would be lognormal. Third, because the components function in multiplicative trade-off relationships, two individuals can have exactly the same level of talent but entirely different scores on the various components. By the same token, there are many ways of being untalented. Someone might be extremely high on all com-

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

ponents but one, that lone exception becoming the Achilles' heel. Fourth, talent potential is not a static property but a dynamic transformation. Not only may an untalented child become a talented teenager, but under certain circumstances a child prodigy may become an adolescent mediocrity.

Put together, these predictions would oblige us to issue the following precautions with respect to the target article. To begin with, the correlation between P and any particular C_j across any heterogeneous sample will have to be extremely small. Not only is the variance in P truncated for those with at least one $C_j = 0$, but multiplicative terms will have correlations with their components that get extremely small as the number of components increases. The developmental instability of P and its components only serves to undermine expected empirical relationships even further. Hence, finding predictors of talent should be no easy task. Moreover, if the onset of a components's development is itself an individual-difference variable, then it may not be possible to identify any single component as a reliable precursor of talent. For one youth, component C_1 may be the first to exhibit precocious development, whereas for another youth it will be C_2 or C_3 or yet some other component. Only in the case of monozygotic twins would we expect both the composite value $P_i(t)$ and the separate component values $C_{ij}(t)$ to be the same for all t. Under this model, then, Howe et al. are expecting too much in the way of empirical evidence. Only much more sophisticated twin studies than those to date can really resolve this issue, and even then for only one talent domain at a time.

On the other hand, the multiplicative model just sketched does lead us to endorse the main policy implication of the Howe et al. target article. If there can be no reliable precursor of innate talent, if the prediction of talent using the currently popular additive models is inherently weak, and if the development of the germane genetic endowment itself is highly unstable as a youth matures, then the population should abound in both "late-bloomers" and once-talented children who have experienced inexplicable "burnout." Under such conditions, the early identification of children and adolescents for exclusive societal investment may indeed prove highly discriminatory, as well as quite wasteful of scarce educational resources.

Practice, practice, practice – Is that all it takes?

Janet Starkes[a] and Werner Helsen[b]

[a]*Department of Kinesiology, McMaster University, Hamilton, Ontario, Canada L8S 4K1;* **starkes@mcmaster.ca;** [b]*Motor Learning Laboratory, Katholieke Universiteit Leuven, B-3001 Leuven, Belgium;* **werner.helsen@flok.kuleuven.ac.be**

Abstract: Support for Howe et al.'s conclusion that musical talent is largely a myth is garnered from the sport literature. One issue germane to the nurture argument is how and when motivation to practice is formed.

We applaud Howe, Davidson & Sloboda for their careful review of the literature, their constructive delineation of the notion of talent, and their courage in bucking traditional views. However, we would challenge one of their outlined properties of talent: that talents are relatively domain specific. It is easy to understand how learned or acquired skills are inherently domain specific, but difficult to conceive how talents are. This may be a semantic issue, but presumably talents are evolutionary in nature and not related to any one specific domain or task. Nevertheless, it may be that a particular constellation of talents is efficacious in a specific domain where the task requirements closely match the underlying abilities.

The issue of talent and musical skill is critical; however, there is no domain in which the role of talent detection, selection, and nurturance has figured more largely than in sport. Coaches scour the country looking for it, professional scouts claim they can identify it, the media wager on the basis of it, and athletes judge their own worth based on others' perceptions of it, yet like the search for talent in music, precursor talents in sport remain elusive.

So strong is the acceptance of talent in sport that the position put forward by Ericsson and colleagues (Ericsson & Crutcher 1990; Ericsson et al. 1993b) has been seen as heretical. Ericsson maintains that with certain exceptions (i.e., height) those physical attributes seen as critical to particular sports are the result of adaptation to long-tern deliberate practice. Even within the sport literature, it has repeatedly been shown that performance can be readily predicted by domain-specific skills (approximately 65% of variance accounted for), but not by innate abilities related to visual, motor, or central nervous system function (Abernethy et al. 1994; Starkes 1987). In addition, recent studies have shown that in many individual and team sports, performance level is related monotonically to accumulated practice. (Helsen et al., in press; Starkes et al. 1996).

Still, highly skilled coaches maintain that they can "see" talent (Starkes et al. 1996); so it is germane to ask what it is that they focus on. Recent evidence shows that for many sports, early talent is most closely related to early physical maturation and the interaction with age categories for athlete selection. There is a consistent asymmetry in the birth-date distribution of successful athletes in many sports (Baxter-Jones & Helms 1994; Dudink 1994). Recently, we have found that this holds true for senior professional soccer players as well as players from national youth teams and from regular youth categories right from the age of 6 years. Players born from August to October (the early part of the sport selection year), even from as early as 6–8 years, are more likely to be identified as "talented," be exposed to top-level coaching, play for national teams, and eventually be involved in professional soccer. Unfortunately, the reverse is also true; players born toward the end of the selection year have increased dropout from as early as 12 years (Helsen et al., submitted). In sports known for their physical nature, "talent" can largely be explained by physical precocity, and "lack of talent" can stem from delays in maturation. Granted that musical talent may not be as directly linked to physical maturation, but one wonders whether precocity in other dimensions may be linked to early promise in music.

Finally, Howe et al. do an admirable job of countering arguments for talent. If practice is what it takes to be an expert, however, then motivation to practice and early emotional connection to that experience must be crucial. This is especially true when it is noted that experts routinely begin before the age of 6 years and put in more than 10 years or 10,000 hours of practice (Ericsson & Crutcher 1990). With notable exceptions (Scanlan et al. 1993; Sloboda 1991; Sosniak 1990), this is an area largely avoided by those steeped in traditional experimental psychology.

If the key's not there, the light won't help

Robert J. Sternberg

Department of Psychology, Yale University, New Haven, CT 06520-8205; **robert.sternberg@yale.edu**

Abstract: Howe and colleagues demonstrate that deliberate practice is necessary for proficient levels of competence, a fact that is uncontroversial. They fail, however, to demonstrate the role of biology in talent, because the studies they cite are almost all irrelevant to the issue.

The approach of Howe and his colleagues is like that proverbial man who loses his key in the dark but keeps vainly searching for it near the lamp-post because the light is better there. Howe et al. invite us to join them at the lamp-post. They are looking in the wrong place; the key is not to be found there. Howe et al. make two main points. The first is uncontroversial, the second, unsupported by their evidence or arguments.

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

The first point is that deliberate practice is necessary, or at least extremely desirable, for the development of expertise. Although Howe et al. spend a great deal of space making this point, no one I know would deny it, so there is not much point to discussing it. At times, the authors seem to come close to suggesting that deliberate practice may even be sufficient, but as they do not quite reach that point, again, I leave it alone.

The second point is that there is little or no documented evidence in favor of innate talents. Virtually all the evidence they review is irrelevant to their point, adding bulk but no substance to their article. The problem is their misunderstanding of what would constitute evidence in favor of a genetic basis for talents.

The only available evidence relevant to claims about genetic bases of talents are documented heritability statistics. Eventually, we may have compelling direct evidence from wet-lab genetic studies; we don't yet. The numerous studies reviewed showing mean increases in performance as a result of environment are all irrelevant to the claims being made in this target article. Here's why: mean effects – the basis of almost the entire article – are irrelevant to claims about heritability (which is a correlational statistic unaffected by mean levels). The irrelevance of mean effects is easy to show, and has been shown myriad times in literature the authors apparently ignore.

For example, recent behavior–genetic studies using a variety of converging operations show heritabilities for IQ of about .5 in childhood, and somewhat higher later in life (see essays in Sternberg & Grigorenko 1997). (One can question whether the IQ tests are adequate measures of intellectual talent, but that is a different question.) At the same time, levels of performance on tests of IQ have risen dramatically through most and probably all of the century (Flynn 1984; 1987). In other words, an attribute can be partially controlled genetically, but subject to environmental modification. Height has a heritability of more than .9, but mean heights have risen over the generations with improved nutrition and health. Perhaps the best-known example is hypothetical, but makes the point simply: place corn seeds with highly heritable attributes in an Iowa farm field or in the Sahara desert, and you will notice drastic mean differences in height or any other observable properties of the corn, regardless of the heritability of the attributes of the corn.

The large majority of the studies cited by Howe et al. simply do not differentiate between biological and environmental explanations: they are irrelevant to the case being made. Even studies showing biological differences in groups, for example, are nondiscriminative, because biology might be generating differences in behavior, or behavior might be generating differences in biology, or both.

Mean effects on measures of behavior are always subject to gene–environment covariation, which can be of three types (Plomin 1994): (1) passive: children grow up in environments correlated with their genotypes (e.g., the child with innate musical talent grows up in a family that encourages development of this talent); (2) reactive: caretakers react to children on the basis of their genetic predispositions (e.g., the parents provide music instruction on realizing the extent of the child's innate talent); or (3) active: children seek or create environments conducive to the development of their genetic predispositions (e.g., the innately talented child requests musical instruction of the parents, and then gets it). None of the mean-effects studies cited by Howe and colleagues contains adequate controls fully to rule out $g \times e$ covariation, or interaction, for that matter.

Worst of all is that the biological *versus* environmental argument is a red herring. No serious geneticist doubts that both genes and environments have independent effects on development, and that there are covariance and interaction effects as well.

Useful studies could be done to disentangle genetic and environmental effects, but so far, they remain undone. These studies would use behavior–genetic designs to study criterion performances of various kinds at extremely high levels of proficiency. Such studies would be difficult to do, because the cases would be hard to find. We would need to go beyond anecdotes about the families of great composers or other highly proficient individuals to the actual behavior–genetic study of such families. Only in this way would we be able to document not whether talent is innate or environmental (almost certainly it is both), but the extent to which genetic and environmental main effects, covariations, and interactions account for individual differences in achieved levels of proficient performances.

The answer to the problem posed by Howe et al. is not to look for the key in the illuminated area, where it is not; nor to look in the dark, where it is but cannot be found; the answer is to shift the illumination to the key area in which we should conduct research.

Training quality and learning goals: Towards effective learning for all

Rosemary J. Stevenson
Human Communication Research Centre, Department of Psychology, University of Durham, Durham, DH1 3LE, England, United Kingdom;
rosemary.stevenson@durham.ac.uk psyint.dur.ac.uk/staff/rjs/rjs.htm

Abstract: Howe, Davidson & Sloboda's focus on learning has important implications because the amount and quality of training are relevant to all learners, not just those acquiring exceptional abilities. In this commentary, I discuss learning goals as an indicator of learning quality, and suggest that all learners can be guided towards more effective learning by shifting their learning goals.

Ng and Bereiter (1995) have identified three kinds of learners who spontaneously adopt different goals. Learners with performance goals focus on completing the learning tasks. Learners with instructional goals focus on manifest learning objectives, using background knowledge to help them understand the material but not using the new material to restructure prior knowledge. Learners with knowledge-building goals focus on going beyond the instructional material in pursuit of wider learning goals, using the new material to restructure prior knowledge and prior knowledge to understand the new material. Stevenson and Palmer (1994) make a comparable distinction between problem solving, memorising, and understanding.

These individual differences suggest how some people may attain excellence in specific fields. Such people may adopt knowledge-building (understanding) goals. Of course, this leaves open the question of why some people choose more effective goals than others. However, a more intriguing possibility is that learners may be guided to adopt more effective learning goals. Recent evidence supports this possibility.

Geddes and Stevenson (1997) have shown that the learning goal determines whether instances or rules are learned. They used a dynamic control task (Berry & Broadbent 1984), which shows an apparent dissociation between learning and awareness. Subjects interact with a "computer person" called Clegg, trying to get him to become and stay *Very Friendly*. Clegg initiates the interaction by displaying one of 12 attitudes (e.g., *Polite, Very Friendly, Loving*) on the computer screen, after which the subject responds by typing in another attitude. The attitudes reflect an intimacy scale from low to high, and Clegg's attitude on each trial is a simple numerical function of the subject's response on that trial and Clegg's previous output. Berry and Broadbent found that subjects successfully learned to carry out this task, but when questioned afterwards, they were unable to describe what they were doing or what the underlying rule was. Thus, subjects demonstrated implicit but not explicit learning.

Geddes and Stevenson gave one group of subjects the same goal as the one Berry and Broadbent and others had used, calling it a specific learning goal. In contrast to previous studies, however, another group of subjects was given a pattern search goal to discover Clegg's underlying pattern. Subjects had 30 learning trials on their assigned goal, after which they were tested on what they had

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

learned. Pattern-search subjects learned a novel specific goal (to make Clegg very friendly) more easily than the specific-goal subjects did; they also gave more correct or partially correct descriptions of the rule underlying Clegg's behaviour than the specific-goal subjects did (83% versus 17%), and more correct predictions of Clegg's next response, given a sequence of three responses. In addition, pattern-search subjects made correct predictions from novel-response sequences as well as from familiar-response sequences.

These results suggest that pattern-search subjects learned the rule underlying Clegg's behaviour, whereas specific-goal subjects memorised specific learning instances (see also Owen & Sweller 1985; Vollmeyer et al. 1996; Whittlesea & Dorken 1993). Geddes and Stevenson's pattern-search subjects, however, did not optimise their learning. They seemed to construct hypotheses about the underlying rule during the initial learning trials, but did not revise their hypotheses in the light of subsequent feedback. For example, only 50% of them gave completely correct rule descriptions. Stevenson and Geddes (1997) found that asking subjects to explain their responses in the learning trials improved considerably the performance of pattern-search subjects. All the pattern-search subjects who gave explanations gave completely correct rule descriptions.

Stevenson and Geddes suggested that (1) specific-goal subjects were problem solving by searching the problem space for a route to the goal and that (2) the pattern-search subjects who did not give explanations were memorising by using prior knowledge to construct a possible hypothesis but not revising the hypothesis in the light of subsequent learning trials. Finally, Stevenson and Geddes suggested that (3) the pattern-search subjects who gave explanations were learning through understanding. Giving explanations seems to have encouraged them to modify and refine their hypotheses until the underlying rule was correctly acquired. These findings suggest ways in which learners can be guided to learn more effectively, because they show that goal orientation and the use of explanations can be modified to the advantage of the learner. A focus on learning rather than talent may help to identify learning programmes that facilitate learning for all and not just the few.

ACKNOWLEDGMENT

The Human Communication Research Centre is funded by the Economic and Social Research Council of Great Britain.

Attributed talent is a powerful myth

Clemens Tesch-Römer

Institute of Psychology, Ernst Moritz Arndt University, Germany; **tesch@rz.uni-greifswald.de**

Abstract: Whereas the reality of "innate talent" is questioned by the authors, the role of "attributed talent" is not discussed fully. "Attributed talent" is the imputation of high, not yet unfolded ability to an individual. Only if talent is attributed to a novice will resources be invested in the development of expertise. An alternative for estimating future achievement is discussed.

Howe, Davidson & Sloboda argue convincingly against the concept of innate talent. They sketch an alternative theory of expertise development based on early experiences, preferences, opportunities, training, and practices. In this context, they mention but fail to elaborate on attribution of high potential to novices by parents, educators, and admirers and by the individuals themselves. Whereas "innate talent" may exist in reality (but probably does not, according to the evidence presented), "attributed talent" resides only in the minds of the observers.

Although talent attribution seems to be based on false beliefs about reality, it serves a useful role in the current practices for developing expertise. Parents may be convinced that their children have promising potential, and educators may believe that there exist gifted children waiting to be recognised and deserving promotion (Bloom 1982). Novices themselves might trust their own slumbering abilities. Hence, "attributed talent" might serve as a source of hope and confidence in an unknown future. Also, on the institutional level," "attributed talent" serves an important function. There are elaborated procedures of identifying individuals with high potential, and resources are often allocated on the basis of apparent future potential. Indeed, only if the individual and the surrounding support network is convinced that talent is waiting to emerge in full, will individuals begin training early in life, devoting tremendous amounts of time to relevant activities and money for teachers and equipment.

It is important to stress, however, that the talent perspective also assumes that practice and training are indispensable for the development of high ability (e.g., Rollett 1994). Because talent alone is not believed to be a sufficient condition for reaching the highest levels of expertise, individuals with "attributed talent" are expected and even obliged to practice in the particular domain they are thought to be gifted for. Hence, belief in talent is an important factor in the motivation to practice over extended periods. Moreover, because success is not reached swiftly and temporary drawbacks are frequent during the course of the development of expertise, the belief in hidden potentials might support novices at times of doubt helping them to persevere (Seligman et al. 1990). It is interesting that even final failure may not invalidate the belief in the potential of a person, because necessary conditions never guarantee success. In the case of failure, talent might not have blossomed for a variety of reasons: laziness, bad luck, or adverse circumstances. Convictions regarding the existence of talent and talented children may not necessarily be changed even facing defeat.

Summarizing, one might say that "talent" is a powerful myth in the development of expertise. Howe et al. demystify this myth, but unfortunately do not propose alternatives that might serve the same function. It should be stressed that their main objective was to examine evidence and arguments for and against the talent account. If "innate talent" does not exist, belief in talent is fallacious and irrational. Attributions, however, are quite often illusory yet helpful, as in the case of the optimistic attribution pattern of explaining success by internal forces and failure by external ones (Heckhausen 1987). What alternative idea can Howe et al. give to the beginner that is as protective and productive as the belief in talent? What is implied in their alternative account of expertise development is a "success calculus." Estimating the probability of success might rest on the assumption that it is possible to predict the course of a career if all relevant circumstances are considered: age of onset, amount and structure of practice, quality of training, commitment, and a support network, to name a few. Unfortunately, there are two obstacles in predicting a future career. First, for the time being, it seems unlikely that all relevant factors can be measured reliably and validly. Hence estimates of future success will be very vague. Second, the estimated probability of success will probably tend to be very low in many cases, because the base rates of success for the highest levels of expertise are near zero. The rejection of the "talent" concept leaves a theoretical void that has to be filled by a more rational but equally powerful idea that helps to fuel motivation for the long and stony road toward excellence.

Cultural determinism is no better than biological determinism

Sandra E. Trehub[a] and E. Glenn Schellenberg[b]

[a]*Department of Psychology, University of Toronto at Mississauga, Mississauga, Ontario, Canada L5L 1C6;* **trehub@erin.utoronto.ca;**
[b]*Department of Psychology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1;* **gschelle@is.dal.ca**

Abstract: Deliberate practice and experience may suffice as predictors of expertise, but they cannot account for spectacular achievements. Highly variable environmental and biological factors provide facilitating as well as constraining conditions for development, generating *relative* plasticity rather than *absolute* plasticity. The skills of virtuosos and idiots savants are more consistent with the talent account than with the deliberate-practice account.

On the basis of observed correlations between accumulated practice and skill in various domains, Howe, Davidson & Sloboda reject the idea that "innate talent" contributes to expertise. They give new meaning to the old joke: "How can I get to Carnegie Hall?" "Practice, practice." In effect, they embrace cultural determinism and reject biological determinism. Neither model of linear causality offers a plausible explanation of exceptional skill. Instead, the question posed by Howe et al. although verifiable in principle, may be untestable in practice because of dynamic interactions between genotypes and environments, both of which vary greatly.

According to Webster's New World Dictionary (Third College edition), "talent implies an apparently native ability for a specific pursuit and connotes either that it is or that it can be cultivated by the one possessing it." Instead of predictability from early to later abilities – a cornerstone of the Howe et al. account – Webster's acknowledges the need for cultivation. Talent, in this view, is merely the *potential* for excellence, which can either be nurtured or wasted. Adult abilities in various domains accordingly stem from some combination of genetic and environmental factors, with stellar abilities presumably requiring abundant inspiration (talent) and perspiration (practice). Reciprocal interactions among highly variable biological and environmental factors would probably obscure the sources of phenotypic variation, including possible contributions of talent.

The problem is exacerbated, no doubt, by our ignorance of the specific talents that facilitate the development of unusual ability. Although predictability in the Howe et al. sense requires precise specification of outcome as well as predictor variables, the authors provide numerous criteria for talent (the predictors) but not a single defining feature of exceptional achievement (the outcome variable). Their indices of outcome vary widely, verging, at times, on the mundane, as in grade levels on standard music examinations or orders recalled by cocktail waitresses. These accomplishments reflect the high levels of knowledge or skill possessed by *ordinary* specialists (e.g., musicians, cognitive scientists, navigators). Much more is involved in the exceptional achievements of prodigies, geniuses, or virtuosos for whom the talent account is generally proposed. Rare skill levels are the only appropriate outcome variables for rare predictor variables.

Our quarrel is not with deliberate practice and experience as predictors of expertise, but rather with similar explanations of spectacular achievement (e.g., the accomplishments of Ingmar Bergman or Mozart). Suppose extraordinary skills can be achieved only if talent, as indexed by unusual early skills (relative to age-mates) without unusual exposure, is noticed, nurtured (through parental encouragement, skilled instructors, and intensive practice), and accompanied by personality factors that foster the expression of exceptional ability. Because individuals with less talent, motivation, and encouragement along with less suitable personalities are likely to engage in less focused practice, the most noticeable relations will be those between levels of cultivation and skill. In other words, highly variable environmental and biological factors interact in complex ways to provide facilitating as well as constraining conditions for development, a situation that affords *relative* rather than *absolute* plasticity (Ford & Lerner 1992). The hours of deliberate practice that are the hallmark of the Howe et al. account imply a form of radical empiricism that offers a poor fit to the facts and to contemporary theories of development.

Unfortunately, we cannot provide proof for the talent account of spectacular achievement, just as Howe et al. cannot mount a convincing argument against it. Definitive evidence for either side would require programming the lives of talented children so that all potentially relevant environmental factors could be controlled. In short, the question may not be amenable to empirical analysis. Nonetheless, a number of "natural" experiments are at least consistent with the notion of talent. Michael Jackson, for example, outperformed his comparably reared siblings at an early age, as have numerous world-class composers and artists. The remarkable skills of idiots savants are equally difficult to explain in terms of environmental factors, including obsessional interest. Despite claims that autistic individuals engage in extensive "practice," such practice is not marked by the goal-setting, evaluation, and feedback that are considered essential for exceptional achievement (Lehmann 1997). Idiots savants do not become world-class performers, being celebrated, instead, for achievements considerably beyond what would be expected on the basis of their training and general ability. Their failure to achieve virtuoso status is not a failure of talent but rather an inability to develop that talent systematically.

The key questions, however interesting, remain unanswered, perhaps unanswerable. Is some threshold of initial ability necessary for exceptional skill levels later in life? If accumulated practice is the principal determinant of unusual abilities, why do "late starters" fail to catch up? At the very least, their skills should match those of individuals with equivalent practice (e.g., a 38-year-old beginning at 18 and a 26-year-old beginning at 6). Early starters are thought to have privileged access to the best teachers and other resources (Ericsson et al. 1993b), but serious older players may be more likely to seek master teachers. Moreover, their superior cognitive abilities would promote greater efficiency and optimization of practice time (Lehmann 1997). Changing plasticity throughout the life cycle, an important developmental principle, is also inconsistent with the deliberate practice account of Howe et al.

Howe et al. ultimately concede that "the talent account is not totally wrong, but simply exaggerated and oversimplified." Likewise, the deliberate-practice account may not be totally wrong, but simply exaggerated and oversimplified.

The rage to drink, or: Frontiers of expertise

Oliver Vitouch

Music Psychology Unit and Brain Research Laboratory, Institute of Psychology, University of Vienna, Vienna, Austria;
oliver.vitouch@univie.ac.at

Abstract: Current evidence shows that "talent" is an unreliable concept, but the competing concept of "expertise" suffers from inadequacies too: its research designs are structurally incomplete (talent and training are confounded) and individual factors are largely ignored. The deliberate practice account should be advanced by investigating in more detail the motivational and individual determinants of successful practice.

Howe, Davidson & Sloboda's target article gives an excellent juxtaposition of evidence for and against the "innate talent" and "deliberate practice (expertise)" theories of exceptional ability. I will discuss some critical points on an empirical, conceptual, and practical level.

Empirical evidence. Although Howe et al. review the literature carefully, they do not draw their conclusions with the same care. Howe et al. tend to interpret the evidence in favor of expertise more benevolently than the evidence favoring biological influences, which they first describe and then ignore. For example, they state that self-rated musical talent correlated *"considerably less" among monozygotic twins reared apart* (r = .44) versus reared together (r = .69), ignoring that .44 is still a rather considerable correlation in itself (sect. 2.3).

In section 3, Howe et al. demonstrate that practice is a *necessary* condition for exceptional performance, but some of their conclusions suggest that it is a *sufficient* condition. This notion is only sparsely supported because of an inherent asymmetry in the design of expertise research (Vitouch 1996): consider a two-by-two cross-tabulation of the factors "talented/not talented" and "prac-

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

ticing/not practicing." There is ample evidence about one diagonal, "talented people – practicing" and "untalented people – not practicing," less or more blurred (anecdotal) evidence about "talented people – not practicing," and very little but especially interesting experimental evidence about "untalented people – practicing" (sect. 3.3). This asymmetry exists because talent and practice are hopelessly confounded in real life. As Sternberg (1996) states convincingly, it is everyone's everyday experience that people practice what they are good at and succeed in, and stop practicing when they feel that their time is better invested elsewhere. Apart from strict experimental studies (constrained by ethical and resource factors) only true longitudinal studies following "talented" and "untalented" people, both "practicing," can help to disentangle these relationships. Present evidence is largely retrospective and based on groups defined post festum, but Sloboda et al. (1996) have taken a big step in the right direction.

Conceptual critique. Howe et al. aim to show that "talent" is fundamentally ill-defined in both the everyday and the laboratory context. The concept of deliberate practice does not solve the essential questions either, however, only shifting the problem to a meta level. Even if talent is a superfluous construct, nobody is talented, and everyone can attain everything with enough practice, the same questions arise: instead of "Who are the talented?" we have "Who are the people deliberately practicing in a specific domain?" or "Why do some people persevere while others drop out?" Although it is positive to shift the focus from cognitive factors (such as "intelligence" or "talent") towards conative factors (such as motivation, endurance, or tolerance of frustration) – Howe et al. provide an eight-factor taxonomy in sect. 4 – this does not mean that individual differences should be ignored.

To further expose the problem, let me introduce "the alcohol parable": Degree of alcoholism, operationalized by an array of clinical symptoms, is a nice monotonic function of the retrospectively assessed amount of alcohol consumed. However, this finding allows no statement at all about the reasons for alcoholism and does not rule out a genetically based predisposition or vulnerability. It is obvious that one has to drink (i.e., to practice) regularly for quite a time to become an alcoholic (the "10-year rule of necessary preparation" from expertise research): drinking is a necessary condition. It is even evident here that *everybody* who drinks excessively, regularly, and long enough will develop severe symptoms of alcoholism; thus, drinking is *even a sufficient condition* for becoming an alcoholic. However, no one would happily accept "He became an alcoholic because he drank" as a useful research finding, because the really interesting question is *why* he did, and why did *he* of all people do so, whereas the others did not? Why do some people drink (or practice) voluntarily, persistently, and, if you wish, deliberately? And so some people have a "rage to master" (Winner 1996) as others have a "rage to drink"?

This parable (if you dislike alcoholism, use obesity) shows that the expertise versus talent discussion resembles various nature–nurture problems: clinical concepts of vulnerability can be viewed as the negative counterpart of concepts of talent.

Practical perspectives. Practical, psychological, and political implications of the talent versus training debate should be addressed frankly. In general, the practice account tends to be the more motivating one because it does not exclude people a priori from a certain domain by labeling them "untalented," whereas focusing on talent often ends in dangerous elitism. The deliberate-practice account is Janus-faced, however, and may inadvertently turn against its own ideology: imagine a young man who wants to be a tennis ace, but unfortunately comes from a poor family and is forced to spend a lot of time driving a taxi to pay for his training. Leave him a fragment of the talent construct, and he can say to himself: "I don't have the money to afford the best trainer, and I have to drive a taxi all night instead of getting my sleep, but I will make it anyway – talents get their way." Without the notion of talent, he must despair. Although the training view seems idealistic and anti-elitist at first glance, it is not a supportive perspective that only those who can pay the best trainers will reach the top. "Untalented" can be a devastating label, but "talented" can be a stimulating and inspiring one.

Another practical aspect is that our society takes interest in winners. No one really bothers about who is number 2 (or even 4) today; everyone wants to see who wins the game, the Nobel prize, the Academy Award. Look at tennis again: international competition is so hard now that the best 20 players in the world all have the best trainers available and spend the maximum possible amount of training. Nevertheless, only one of them is number 1. Again, the deliberate practice approach is inattentive to these differences *within* the expert group. Concerning the prognostic power of the talent account, unreliable predictions are commonplace in psychology and are usually not sufficient reason to ban the entire construct.

Conclusion. It sometimes seems that psychological researchers need to take extreme positions to set things into motion. In principle, the innate-talent versus deliberate-practice debate is nothing other than the good old nature–nurture pendulum, still swinging. Decades of evidence have shown that none of these standpoints alone is sufficient to explain why some people have extraordinary success whereas others do not. "Deliberate hardliners" take up a Neo-Watsonian view best described by Watson's (1914) citation classic: Give them a healthy infant, and they'll guarantee to train him to become any type of expert you might select, regardless of his talents, penchants, tendencies, abilities, and vocations.

Howe et al.'s review shows impressively that a lot can be achieved with efficient training, and we are still not able to reliably identify "young talents" in any field or to predict success (and probably never will be). Thus, it is much more reasonable and inviting to focus on education, training, and promotion for everyone who wants to try, instead of aiming at early screening and preselection in the sense of a "quest for the gifted." It is also helpful to deconstruct the exaggerated "tales of talent," those histories of born prodigies who were never supported by anyone or anything but their own innate genius. The deliberate practice account does make perfect sense as an invitation to research on the conditions of practice and deliberateness, but not as the sole explanation for extraordinary achievements. Neglecting differences can become as discriminatory as preaching prodigy.

Creativity and practice

Robert W. Weisberg

Psychology Department, Temple University, Philadelphia, PA 19122;
rweisber@nimbus.ocis.temple.edu

Abstract: The target article examines the role of practice in the development of excellence in several domains that vary in the degree of innovation involved. The authors do not differentiate domains, but they discuss the development of specifically creative skills only in passing. This commentary presents evidence that practice plays a role in the development of musical composition, through an examination of the careers of Mozart and the Beatles.

The present commentary addresses the relationship between practice and outstanding achievement in specifically creative endeavors (Weisberg, in press). Howe, Davidson & Sloboda examine the relationship between practice and outstanding achievement in many different domains: athletics (e.g., swimming and tennis), musical performance, chess playing, sculpture, and memory skills. One can arrange these domains on a continuum reflecting degree of innovation. At the noninnovative end is swimming (and related activities, such as diving or figure skating), where the individual attempts to do something in exactly the same way each time. Some innovation is seen in skills in memorizing, where the material to be remembered is new. Innovation is also involved in the performance of classical or popular music, in individual interpretation and expression. Finally, in playing tennis or chess

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

(or basketball, or composing classical or popular music, or playing jazz), much of the product is novel.

As mentioned in the target article, it is often assumed that outstanding creative accomplishment is based on innate talents. The classic example of this is Mozart, who was a prodigious child and high in creative accomplishment as an adult, both presumably as the result of innate talent. As one possible objection to the generality of their view, Howe et al. consider that practice might be more important in the skills requiring more rote repetition or technical skills, such as swimming, and less so in the skills requiring expressivity and innovation. They respond by discussing evidence that musical expression is dependent on practice. They do not explicitly address the question of the role of practice in expressly creative achievement, such as musical composition, except to mention that similar factors can be adduced to explain Mozart's achievements, such as his years of extensive training from his father. The authors also cite Hayes's (1989) finding that classical composers invariably required significant amounts of preparation time between introduction to music and making a significant contribution. Hayes reported similar findings for other areas of creative achievement, including poetry and painting.

These findings, although consistent with the view that practice is important for the development of creative capacity, provide only indirect support: no direct evidence of practice was presented. The remainder of this commentary provides stronger evidence for the role of practice in musical composition: during the preparation years, the novice composer is becoming immersed in the discipline (i.e., is undertaking extensive practice). After this immersion, we see the production of works of significance (Weisberg, in press).

Evidence of practice and its positive effects can be seen in the career of Mozart – specifically, in his development as a composer of concerti for piano and orchestra. Mozart's first seven works in the genre (K. 37, K. 39–41; K. 107, 1–3), produced between the ages of 11 and 16, are not, strictly speaking, works by Mozart: they are arrangements of works by several other composers. Thus, these early works are a visible manifestation of practice. In addition, of the concerti that are wholly music by Mozart (No. 5ff), it is not until No. 9 (K. 271) that one reaches a work that is acknowledged as a masterwork (Landon 1956). Mozart, then 21, had been immersed in music for 16 years, and had worked in the genre for 10 years. Thus, in Mozart's case, the preparation years were filled with learning from practice, in the sense of immersion in the works of others, rather than the simple outflowing of innate talent.

Similar conclusions can be drawn from an examination of the development of the Lennon/McCartney song-writing team (Weisberg, in press). The Beatles evolved out of the Quarrymen, formed by Lennon in 1956; McCartney joined in that year. By 1961, the time of their first hit song, they had put in some 1,200 hours in performance alone, playing initially at school dances and small local clubs, and later in larger venues. This averages close to one performance per day. This figure was surely augmented by practice sessions. In addition, the performances themselves were much like practice, because their early repertoire consisted mainly of very faithful cover versions of works of other performers; only gradually did their performances center on their own material. In addition, as with Mozart, Lennon/McCartney compositions from these early years have been regarded less favorably than their later work. For example, early songs were recorded significantly less frequently than later works, even after the Beatles achieved worldwide fame. Only with the release in recent years of anthologies of their career were these works recorded. Thus, the Beatles' early career consisted in large measure of learning their trade through immersion in the works of others and in practice in the skills of composition. In addition, their early works were of lower quality than later ones, which is consistent with the claim that this preparation was necessary for development of creative skills.

These results amplify the conclusions drawn in the target article: practice may be as important in the development of creative skills as it is in rote skills. It must be noted, however, that the evidence presented here is correlational; perhaps during preparation time, something else happened that facilitated creative development. Maturation, for example, might be crucial; the individuals in question might have gotten better no matter what had occurred in those years. The present analysis cannot differentiate between explanations based on maturation versus a causal role for practice. It is impossible to carry out a controlled experiment with random assignment of Mozart and comparable individuals to practice and nonpractice groups, to control for maturational effects.

Unfortunately, if one wishes to deal with individuals such as Mozart, one has no choice but to use a case study method, which leaves some questions open. It seems significant, however, that the preparation time in these cases and many others (Weisberg, in press) was spent in extensive work within the domain, even for individuals who reached the highest levels of creativity in those domains.

Talent: Don't confuse necessity with sufficiency, or science with policy

Ellen Winner
Department of Psychology, Boston College, Chestnut Hill, MA 02167;
ellen.winner@bc.edu

Abstract: Howe et al. fail to provide evidence that practice is *sufficient* and ignore evidence of high ability before instruction. They unsuccessfully discount savants; provide weak evidence against heritability of music, criticize retrospective evidence selectively, using it when it supports their position; and ultimately both accept and deny talent. Finally, they conflate a scientific question with one of policy.

Practice is necessary, but is it sufficient? In their attempt to explain high achievement by practice, Howe et al. confuse necessity with sufficiency. No one would deny the necessity of hard work for adult eminence. However, explanations in terms of practice are not enough, and individual differences in aptitude cannot be discounted (Schneider 1997). The fact that musicians received lessons and had supervised practice in childhood does not argue against the existence of innate differences in the ability to become a musician. Although we cannot directly measure "innate talent," heritability differences are most likely to manifest themselves in differences in ease of mastery and level reached. Sloboda et al.'s own (1996) study in favor of practice over innate ability yielded no individual differences in the amount of practice needed to make successive grades. Furthermore, the measures of achievement were not fine grained: passing minimally and passing with distinction were treated as equivalent.

That hard work correlates with high achievement says nothing about causality. The motivation to work hard may well be an integral part of innate talent. Children with high ability voluntarily spend hours doing math, programming, chess, and so on. One cannot bribe an ordinary child to do this. (Incidentally, not all musicians were pushed to practice. Leonard Bernstein had to fight his parents to play the piano.)

The fact that we can get ordinary people to achieve at high levels is also not an argument against talent. Although math achievement is more widespread in East Asia than in the United States or United Kingdom, this is not evidence against innate math differences. Rather, it shows that children can accomplish more when demands are higher.

Nor do training studies show that practice is sufficient for high performance. High performance in trained individuals is not inconsistent with innate differences in ease of mastery or attainable level. Moreover, the kinds of abilities training studies instill (e.g., digit recall) are a far cry from those the talent account attempts to explain (e.g., composing a symphony).

Finally, Howe et al. admit that it is quality rather than quantity of practice that is important, but the quality of practice is itself likely to be constrained by innate ability. To practice well in music, one must be able to imagine how a piece should sound, and then aim for this. Without this "musical ability," one is doomed to repeat the same mistakes over and over again.

Existence of precocious behaviors prior to instruction. In arguing against the existence of precocity before instruction, Howe et al. dispute the claim that some children learn to read entirely unaided. Why? Because parents of such children keep elaborate records of their children's progress, and ergo must be "actively involved in the child's early learning" (sect. 2.1, para. 3). However, keeping records is not the same as instructing. Although the average child learns to read between 6 and 7 years of age with considerable instruction, some children learn to read at age 3 or 4 years with the minimal instruction. Winner (1996) described a 3-year-old who cracked the code of reading after his mother (at his request) read him two books repeatedly for 2 weeks, pointing to the words as she read (also at his request). To conflate this kind of instruction with the kind of support that the average child needs runs against common sense.

Howe et al. go on to cite Sosniak's (1985) work on pianists as further evidence against early signs. Although this is a frequent interpretation of Sosniak and the other chapters in the same book (Bloom 1985), a careful reading shows that as children, the eminent adults studied typically showed early signs of domain-specific talent: the mathematicians were "brilliant," the pianists learned easily at the piano.

Savants. Idiot savants cannot be accounted for by obsessionality; domain-specific talent is at least as plausible an explanation. Many obsessional (autistic and nonautistic) individuals do not reach high levels of performance. Moreover, obsessionality cannot explain why savants are restricted to certain domains – piano but rarely other instruments; realistic drawing but rarely abstract painting; calculation but not physics.

Heritability of musical talent. The evidence presented against heritability of musical ability is not convincing. Comparisons of monozygotic twins reared together versus apart can tell us only about the influence of the environment. Coon and Carey (1989) carry out the relevant comparison, and find only minimally higher correlations between dizygotic than monozygotic twins, but if their sample contained only musically average individuals, this study cannot inform us about innate precursors to high achievement.

Retrospective evidence. Howe et al. criticize others for relying on retrospective evidence, yet they rely on biographies to claim that the emergence of unusual skills in composers followed rather than preceded a period of high expectations and opportunity (sect. 2.1, para. 4). They themselves (sect. 3.1, para. 6) asked parents to report retrospectively whether their children showed early signs of musical ability, found that the accounts of parents of more versus less successful musical children did not differ, and use this as evidence against innate differences. If these (and Sosniak's 1985) retrospective accounts are permissible, why not the many (consistent) retrospective accounts of early high abilities in prodigies?

The authors want it both ways. Howe et al. admit that individual differences in ability can have partly genetic origins (sect. 5, para. 9). They admit the biological differences contribute to level of expertise, yet they insist this is different from finding a neural predictor of talent (sect. 2.3, para. 4). However, to "contribute" to expertise implies a causal (predictive) relationship. The authors cannot both deny and accept talent.

Science versus policy. The authors conclude that to identify some children as talented results in discrimination against those not so identified, but the scientific question of whether innate talents exist should be kept separate from policy issues. Moreover, discriminatory policies do not follow from the acknowledgment of talent. There is no contradiction between admitting the existence of talent and making sure that all children benefit from exposure to and training in various domains.

Individual differences in some special abilities are genetically influenced

Ada H. Zohar
Scheinfeld Center for Human Genetics in the Social Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel 91905;
mszoharepluto.mscc.huji.ac.il

Abstract: There is a problem with the definition of talent as presented by Howe et al. that makes it dependent on experts' ability to detect it in the untrained. In addition, the choice of musical performance as the example for innate talent is inappropriate, and musical board results are selective and biased tests of it. Outstanding mathematical reasoning ability offers much better evidence of genetic influence.

The definition of talent according to Howe et al. includes: "Its full effects may not be evident at an early stage, but there will be some advance indications, allowing trained people to identify the presence of talent before exceptional levels of mature performance have been demonstrated" (sect. 1.1, para. 3). This is not a necessary part of the definition. It confuses the ontological with the epistemological. It may be that talent is present and that experts cannot currently detect it, and it can be demonstrated that individuals differ constitutionally in their ability to develop certain skills. If behavior genetic methods such as twin studies or adoption studies can show that there is genetic influence on the eventual expression of a specific ability such as musical or mathematical skill, then it is not relevant that it cannot be detected before any training takes place. If the marriage between behavioral genetics and molecular genetics helps identify alleles of genes that predispose individuals to excel in certain fields, then again – all that is needed is a demonstration that individuals carrying these alleles outperform individuals who receive the same training but do not carry the same alleles. If current educators or other experts are making unsubstantiated claims about early identification, it is a problem – ethical, educational, and professional – but it does not invalidate the concept of talent.

The argument by Howe et al. is based nearly completely on evidence from musical achievement measured by English music board tests. The board tests are primarily tests of musical performance. They are voluntary, not part of the school curriculum, and they are quite expensive to take. Unless parents are motivated to support their children's musical education by paying for their children's music lessons and board examinations, the children will not be tested. Although a very high standard of performance is required to pass level 8 of musical boards, there are many musically accomplished children who do not take the boards. There is selection for parents who are ambitious for their children among those who do. Thus, it is not surprising that passing level 8 boards in music is correlated with parents' values, expectations, and so forth.

It is not clear a priori what evidence Howe et al. will accept for innate talents. Innate talents, like all genetically influenced traits, can only be expressed in an environment over time. Thus, all their evidence of correlation between practice and musical performance may reflect gene–environment correlation (active, reactive), and the correlation between parental investment, beliefs, and values and child's performance may reflect passive gene–environment correlation (Scarr & McCartney 1983).

Musical performance is not the best candidate for detecting innate talent, because there is so much structure in the culture that supports it. It is an expensive activity – musical instruments, music lessons, and leisure for practice all require parental support. It is less likely to flourish in a discouraging milieu, which in turn will make it more difficult to tell apart the nature and nurture components. A much better domain is outstanding mathematical reasoning ability (OMRA). [See also Benbow: "Sex Differences in Mathematical Reasoning Ability in Intellectually Talented Preadolescents" *BBS* 11(2) 1988; Geary "Sexual Selection and Sex Differences in Mathematical Abilities" *BBS* 19(2) 1996.] This ability is often expressed in very young children, and precocity is

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

the rule rather than the exception. The history of mathematics is rich with examples of youths who had no cultural background in mathematics and yet taught themselves classical mathematics and went on to be prolific creative mathematicians of great distinction. Two examples will suffice:

1. The Indian mathematician Ramanujan Srinivasa, 1887–1920. Born of poor parents in Southern India, Ramanujan had no formal training in mathematics. At the age of 15, he found a book containing a list of 6,000 theorems; these excited his interest and he proved them and went on to generate important theorems of his own. After scraping a living as an Indian civil servant, Ramanujan published results in the *Journal of the Indian Mathematical Society*. His creative genius was recognized by the British mathematician, Hardy, who became his mentor, and who said on his death that his greatest achievement was having worked with Ramanujan. This unschooled but brilliantly talented mathematician was not a product of his upbringing and culture; rather, his gifts caused him to be uprooted from his original environment to a very different one. Ramanujan died at the age of 33, but his contribution to mathematics and to number theory remains unquestioned (Kolata 1987).

2. George Boole, English mathematician, 1815–1864. Boole was the son of a poor shopkeeper and received only the most rudimentary education. Perceiving that the key to upward mobility lay in classical education, Boole taught himself Greek and Latin, and achieved some proficiency. At the age of 20, after a long struggle to educate himself, he opened his own school, and realized that other than teaching the classics he would also have to teach mathematics. He reviewed the textbooks of the day, and found them wanting. He turned instead to Lagrange's *Mechanique Analytique* and not only mastered it, but was inspired to original contributions. In his lonely studies, he discovered invariants, the formulation of which was necessary for the development of the theory of relativity. Although he spent most of his life teaching elementary students, to support his family, he continued his mathematical creativity, which culminated with his conceptualization of logic in "An Investigation of the Laws of Thought, on which are founded the Mathematical Theories of Logic and Probabilities." Boolean algebra was not only a conceptual breakthrough, but was to become the cornerstone of electronic design and computation theory (Bell 1937).

These two men epitomize OMRA, and would meet the criteria of the Howe et al. definition of innate talent. There has been extensive discussion of a possible mechanism of transmission of OMRA (Zohar 1990) and some preliminary evidence of recessive X-linked transmission, which requires replication and substantiation. Thus, not all innate talent is mythical, although individuals who are talented tend to assume mythical proportions in the history of civilization.

Authors' Response

Natural born talents undiscovered

Michael J. A. Howe[a], Jane W. Davidson[b], and John A. Sloboda[c]

[a]*Department of Psychology, University of Exeter, Exeter EX4 4QG, England;* **mjahowe@exeter.ac.uk.**
[b]*Department of Music, University of Sheffield, Sheffield S10 2TN, England;* **j.w.davidson@sheffield.ac.uk.**
[c]*Department of Psychology, Keele University, Keele, Staffordshire ST5 5BG, England;* **j.a.sloboda@keele.ac.uk.**

Abstract: This Response addresses eight issues raised in the commentaries: (1) the question of how innate talents should be defined; (2) relationships between the talent account and broader views concerning genetic variability; (3) the quality of the empirical evidence for and against the talent account; (4) the possible involvement of innate influences on specific abilities; (5) the possibility of talent-like phenomena in autistic savants; (6) alternative explanations of exceptional expertise at skills; (7) practical and educational implications of the talent account and alternative positions. Finally, (8), we conclude by discussing the impact of the commentaries on our own views.

R1. Defining talents

The fact that people hold strong views about talents is reflected in the commentaries. The authors of a number of them, including **Baron-Cohen, Bronfenbrenner & Ceci, Charness, Eisenberger, Ericsson, Irvine, Lehmann, Simonton, Starkes & Helsen, Tesch-Römer,** and **Weisberg** arrive at firm conclusions about the existence of innate talents that are broadly in line with our own highly sceptical viewpoint. Most of those commentators who do not fully concur with the conclusions of the target article express reservations that go beyond straightforward disagreement with our interpretation of the evidence. A number of the commentaries challenge our list of the defining attributes of innate talents and imply that our criterion is in the same respects too stringent. For example, **Schneider** questions whether the concept of talent need include a predictive component, and both **Zohar** and **Rutter** question our decision to include early identification as a necessary condition. Rutter also notes that inherited characteristics may not become evident until relatively late in life. **Charness** suggests that our definition of talent may be too broad, whereas **Simonton** would prefer a more precise specification. **Winner** suggests that a definition of talent should include a motivation to work hard. **Starkes & Helsen,** despite agreeing with our main conclusion, find it hard to conceive of talents that are genuinely domain-specific. **Rowe** complains that we call for a single physiological marker of talent (but we can find nothing in the target article indicating or implying that and we agree that a talent can take different forms; sect. 1.1).

The diversity of these concerns highlights the difficulty of arriving at a universally acceptable set of defining attributes. We are convinced that we must determine whether innate talents actually exist because teachers' and other adults' beliefs about their presence or absence influence practical decisions with important social and educational consequences for many children. As **Rowe** rightly observes, sports teams and organisations do not pick randomly. They send out talent scouts, conduct talent searches, and make efforts to spot talented children. Correctly or otherwise, selectors clearly believe that talent is there to be identified and selected. It is the fact that people make these assumptions and act upon them that prompted us to write the target article.

We wanted to ensure that our defining attributes coincided with the ones used by those who make practical decisions about the music education.

For most people there is a clear distinction between specific talents and general intelligence despite the fact that these are related. This consideration makes it impossible for us to agree with **Plomin, Detterman et al.,** and **Gagné** that talent ought to be defined in a way that allows general intelligence or cognitive ability to count as an instance of it. The finding that intelligence is heritable does not seem to us to have much bearing on the viability of the talent account. We were also aware, however, that some laymen hold beliefs about the characteristics of talent that scientific researchers would consider absurd. Had we insisted on a definition that included all the qualities that have ever been associated with talents, we would have been setting up a straw man. It is for this reason that we went to some pains to establish (in sect. 1.2 of the target article) that all our attributes were not only crucial to practitioners but were also agreed upon by at least some researchers. We confirmed that for researchers as well as for practitioners the phrase "innate talent" is indeed tautologous, as **Irvine** suggests. Although some researchers might have introduced the word as a purely descriptive term designating an unusual level of ability without implying the existence of innate causes, that does not appear to have happened.

Explanations that account for above average achievements might not be enough to account for the most exceptional accomplishments of all ("genius"). Various practical problems make it difficult to determine the causes of achievements at this very high level. Few cases are available for direct study, and there may be no agreement about the degree to which individuals are outstanding until after their death and perhaps not even then. Our target article is concerned mainly with the putative role of innate talents in excelling at the level that thousands of people in every generation achieve. Such excellence, unlike the rare accomplishments of a few geniuses, is amenable to scientific study, because enough cases are available for study. **Winner** and **Trehub & Schellenberg** raise the question of how far above average an individual's performance must be in order to be considered exceptional; we do not claim to have a satisfactory answer.

R2. Genetic variability and the talent account

A number of commentators express reservations about our distinction between the possible effects of innate talents, on the one hand, and broader influences of differing genetic factors, on the other. For **Winner,** for example, accepting that biological differences may contribute to variations in expertise amounts to accepting the existence of talents. We disagree because this would make the notion of talent too vague for what talent scouts purport to seek. **Rutter** suggests that we deny the reality of talents because we hold the outdated notion that skills are either innate or acquired. Yet the very notion of an innate skill can be seen to be self-contradictory, even though it is clear that genetic factors do affect our experiences, as **Plomin** observes. We do not deny that various innate differences between people can contribute to variability in the acquisition of abilities. Our main concern is whether or not there are influences that take the specific form of innate talents.

Despite our repeated insistence that genetic differences are influential and that biological variability can contribute to individuals' differing capabilities, **Detterman et al.** inexplicably describe out position as "absurd environmentalism." We think this terminology is unjustified. It wrongly implies that we consider only environmental factors to be important. Environments as such are not among the direct influences we acknowledge. People are affected by environmental factors, of course, but the particular way in which an individual *experiences* environmental events is always crucial. Experiences are invariably determined in part by inherited biological mechanisms. For that reason, we also disagree with **Baltes,** who suggests that our view that differences in early experiences and other nongenetic influences are the real determinants of excellence amounts to a rejection of biology-based individual differences. Similarly, despite the importance of learning and experience in the acquisition of superior skills, the fact that genetic factors can affect an individual's experiences prevents us from fully agreeing with **Baron-Cohen** that excellence must in principle be accessible to everyone; yet we do reject the talent account. **Ericsson** suggests that we object to it largely on pragmatic grounds rather than on principle; that is only partly true.

Whereas environmental parameters are often readily measurable, mapping a person's experiences is difficult at best. Nevertheless, **Bronfenbrenner & Ceci's** discussion of "proximal processes" draws attention to the importance of focusing on the interactions between an experiencing child and the immediate external environment. **Csikszentmihalyi** has devised effective ways to record people's reports of how they experience various daily events and activities (Csikszentmihalyi et al. 1993).

R3. The quality of the evidence

Our review of the evidence for and against innate talent is discussed by a number of commentators. **Winner** and **Schneider** draw attention to the fact that many of the findings are retrospective, and **Heller & Ziegler** suggest that we are harder on retrospective evidence when it appears to oppose rather than support our point of view. We are indeed especially critical of some retrospective accounts of child prodigies because the data are not only retrospective but anecdotal. Anecdotal accounts such as the ones introduced by **Feldman & Katzir** and **Gagné** raise some interesting questions, but they rarely provide evidence solid enough to support firm conclusions.

In research on practising especially, many of the findings are indeed retrospective, they are supplemented by confirmatory evidence from diaries. **Freeman** claims that we identified no early signs of ability in a large sample of young musical performers. What we actually discovered was that such early signs were no more common in those children who later excelled than in those who did not. **Feldman & Katzir** draw attention to statements which illustrate how firmly many artistic performers believe in natural gifts. Unverified beliefs, however, even very strong ones, do not amount to conclusive evidence.

Unjustified or unverified theoretical assumptions appear in a number of commentaries. For example, **Detterman et al.** assume that inherent ability has the same explanatory status as practice but that would require independent evidence of a causal influence, just as talent has to be shown to exist before it can be used as an explanatory construct. Ability can of course be defined without introducing unsupported theoretical assumptions, as **Irvine** shows when he refers to Ferguson's (1956) definition of ability as a skill learned to a degree of stability.

Trehub & Schellenberg and **Freeman** suggest that the talent account should be considered correct until disproved. We strongly disagree. The talent account is essentially a theory that purports to explain certain events and that has social and educational implications. The onus is

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

accordingly on its proponents rather than its critics to provide adequate justification.

Weisberg notes that some of the positive correlations between skills and experience can be explained equally well as the effects of practice or maturation. **Sternberg** goes further, suggesting that much of the evidence for and against talents is merely suggestive. He disputes neither our conclusion that there is little evidence for the talent account nor our view that no one source of evidence would be definitive. He instead suggests that we are looking for evidence in the wrong place, and later he concedes that the right evidence does not yet exist and would require further research that would be difficult to conduct. **Baltes** suggests that an investigation in which a random or heterogeneous sample of individuals were given massive amounts of practice could yield firm evidence of biological indicators of talent.

We are not convinced, because every possible nonbiological source of variability cannot be ruled out. As **Tesch-Römer** concludes, any attempt to predict the course of a career is handicapped by the fact that for the time being it is impossible to measure all relevant factors validly and reliably. **Sternberg** expresses the hope that we will eventually acquire compelling direct evidence from wet-lab genetic studies, but **Csikszentmihalyi** is pessimistic about the possibility of even imagining an experiment that could conclusively verify or disprove the talent account. We are convinced that for the present the most effective strategy is to combine the available findings as we did in the target article.

R4. Innate influences

Unlike **Rowe,** we found the evidence of innate influences on specific areas of human achievement sparse except in the case of general intelligence. It is noteworthy that **Humphreys**'s heritability estimates pertain only to general intelligence. As Rowe concedes, the data on musical abilities consist of self-reports from a sample of individuals whose accomplishments are not exceptional. **Ericsson** suggests that there are no reliable heritabilities for elite performance in Olympic athletes. **Bronfenbrenner & Ceci** claim that their bioecological model will make it possible to assess heritability with different levels of training and practice. One hopes that this will apply to specific fields of ability.

Csikszentmihalyi and **Winner** both note that children occasionally demonstrate impressive capabilities considerably earlier than is usual, sometimes even without formal instruction. The early emergence of a skill, however, is not necessarily indicative of special innate influences. **Zohar** points out that individuals such as Ramanujan and George Boole have made remarkable advances for reasons that were not clear to their biographers but this is hardly a basis for concluding that they had no special opportunities to learn. Indeed, in the case of Ramanujan, as **Eisenberger** makes very clear, a variety of favourable motivational and cultural influences aided his progress.

We do not deny the importance of hereditary influences on expertise but we do not think that firm conclusions about the form and extent of genetic effects can be drawn: one of us has expressed reservations about some of the arguments and evidence used in estimating heritability (Howe 1997); **Sternberg** apparently agrees. One difficulty is that in heritability estimates from twins reared together and apart, most of the separated twins may have spent substantial periods of their lives together. Another problem is that shared prenatal environments may have contributed to the similarities between the monozygotic twins (Davis et al. 1995; Devlin et al. 1997). Moreover, until recently, estimates of the genetic component of the variance have been indirect. **Plomin,** however, raises the possibility that specific genes responsible for genetic influences on intelligence will be identified in the near future.

A further problem (not addressed by any commentators) is that although there are abundant neural correlates of ability, they do not predict specific kinds of expertise selectively (sect. 2.3). Where specific indicators have been identified (e.g., the distinctive cortical representations of the digits of string players' left hands; Elbert et al. 1995), they are probably the effects rather than the causes of differences in early learning experiences.

For these reasons, we think that the evidence for biological precursors of specific abilities is weaker than a number of our commentators do (e.g., **Feldman & Katzir, Gagné, Plomin,** and **Rowe**). This is no justification, however, for advocating the exclusively environmentalist approach that **Detterman et al.** mistakenly ascribe to us. A variety of dimensions of biological variability (such as skin colour or even the appearance of one's hair) could influence events that in turn influence on an individual's learning experiences. This makes it inevitable that biological differences will be among the indirect determinants of differences in ability, but there is little evidence of direct and selective biological influences on skills. They may instead make themselves felt as general temperamental factors that contribute to attentiveness, determination, and the capacity to persevere at a task.

R5. Talents in idiots savants

We do not dispute **Rutter**'s suggestion that idiots savants may exhibit isolated pockets of achievement that are well above population norms, having ourselves studied some of these people at first hand (e.g., Howe & Smith 1988; Sloboda et al. 1985). We also accept that in the majority of cases such individuals cannot be formally instructed. Yet they do learn, and lifespan evidence suggests that their skills improve gradually with practice, just as the skills of ordinary individuals do. What often contributes to making idiots savants special is their special commitment, which may be involuntary and perhaps obsessive. This permits them to focus on one limited activity for thousands, if not tens of thousands, of hours. The reasons for this unusual degree of commitment to one particular kind of activity may differ from one individual to another, but the inability to engage in conventional forms of cognition, such as those based on language, may help them direct attention exclusively to a specific alternative activity.

Winner points out that the areas in which savants excel are restricted; not every activity that might benefit from unusual commitment or obsession is a candidate for savant skill. Unfortunately we do not have the kind of exhaustive meta-study on savant skills that could clarify this. Winner suggests that there are more musical savants for piano than for other instruments. We agree, although we know of some savants who are competent on several instruments. (The popularity of the piano could reflect its relative availability, or some contextual feature. For example, it does not have to be taken out of a case or assembled before it can be played, hence it may make fewer demands than other instruments on activities that are not directly related to a savant's interests.) Expertise in some activities may require a level of conceptual sophistication that autistic savants are very unlikely to have.

Baron-Cohen suggests that the superior performance of some autistic individuals in the Embedded Figures Test may indicate talents in the restricted sense discussed in sect. 2.4 of the target article. The differences in average performance levels between autistic and normal individuals and between males and females may indicate a broader divergence in cognitive style. The possibility that genetic differences provide the cause is consistent with Baron-Cohen's observation that there are no obvious differences in children's early environment that could account for the sex differences in test performance. (As **Zohar** makes clear, similar issues have been raised in relation to sex differences in mathematical reasoning ability [see Benbow: "Sex Differences in Mathematical Reasoning Ability" *BBS* 11(2) 1988; and Geary: "Sexual Selection and Sex Differences in Mathematical Abilities" *BBS* 19(2) 1996].) However, the fact that autistic children tend to do well in the Embedded Figures Test is equally consistent with the suggestion that superior performance is tied to some kind of restriction in mental functioning. For example, doing well in the test could be aided by perceptual activities in which the stimuli tend to be recorded literally rather than being more abstractly coded. There may also be acquired sex differences in the extent to which interpretative processing accompanies the perception of certain visual stimuli. We agree with Baron-Cohen that definite proof of genetic causation will only come when (and if) it becomes possible to identify genes contributing to performance in the test, together with evidence of how the genes actually function.

R6. Exploring alternatives to the talent account

We happily agree with **Heller & Ziegler** that we are vague about theoretical alternatives to the talent account. Our primary aim was to determine whether or not that account is correct; we did not aspire to provide a full or definitive explanation for the acquisition of exceptional skills. But the target article did suggest that a substantial number of interacting influences contribute. We argued that exceptional abilities can be accounted for without recourse to innate talents as a causal factor. We appreciate **Tesch-Römer**'s concern that although we demolish the talent myth we do not propose alternatives that might serve precisely the same function. We are not at all convinced that an alternative cause exists. There are many potential factors, but their effects on abilities depend on particular circumstances. We also agree with **Hatano** that concentrated and effective early training, even when combined with favourable early experiences, will not always lead to exceptionally high achievements.

Lehmann provides historical examples of substantial increases in expert performance levels, as indicated by repeated breaking of Olympic records. Such examples go against the notion of innate abilities. As Lehmann notes, substantial numbers of serious amateurs are capable of marathon race times for which gold medals were awarded early in the present century. New opportunities can create previously unrecorded abilities, as **Irvine** illustrates in his description of the recent emergence of the Shona sculptors in Zimbabwe. It is hardly possible that a sudden explosion of innate talents could be responsible for these new developments.

Similarly, substantial numbers of today's musicians reach standards of performance that would have been rare in Mozart's time, when they would have been regarded as special talents. This again points to the importance of opportunities and learning experiences, rather than innate gifts. **Lehmann**'s observations even raise the possibility that levels of performance in children that would have been regarded as indications of innate talent in prior generations might be seen as indicating a lack of talent in a child today. Of course, improvements in training and increased expectations may contribute to intergenerational improvements in standards. All the same, the assumption that reaching a particular level of achievement can have been a sure indication of talent in the past but not the present seems highly questionable.

Our own research has drawn attention to the importance of practice activities among the various influences that contribute to high attainments. The amount of practice a person has undertaken is a good predictor of performance level, even though such estimates are somewhat crude. In most cases these data are retrospective, which limits their reliability. A further limitation of practice measures is that they ignore other potentially important factors, such as the effectiveness of practising and the individual's motivation and commitment to practising. Practice studies have also failed to consider individuals' differing learning goals, an influence upon attainments to which **Stevenson** draws attention. Contrary to **Rowe**'s suggestion, however, we definitely do not believe that everything depends on practice.

A number of factors may contribute to the likelihood that late starters fail to catch up, as noted by **Trehub & Schellenberg.** To the best of our knowledge there have been no studies in which the effects of equivalent amounts of practice by equally motivated young adults and children have been compared in controlled experiments. This is not to deny that older adults may fail to reach the same levels of attainment as younger adults. As **Schneider** observes, initial differences between individuals may remain even after extensive periods of practice. In certain cases, individual differences even magnify as practice increases, as **Baltes** points out. On the other hand, as **Rowe** acknowledges, in some instances performance levels after practice bear little relation to performance prior to practice. This is further evidence against the importance of innate differences. Yet another contrary result is Sloboda et al.'s (1996) observation that the most able of the young musicians who took part in their study required as much practice as the least able to make an equivalent amount of progress. Even when people do differ in the extent to which practice improves their skills, without precise measures of the kind and quality of practice a fuller analysis is not possible.

As **Vitouch** notes, correlations between amounts of practice and skill levels do not provide firm evidence of the effectiveness of practising. People may spend time practising what they are already good at. **Feldman & Katzir** rightly observe that spending time on an activity does not inevitably lead to large improvements in skills, but the fact that Sloboda et al. (1996) observed no instance of extensive

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

musical practising that was not accompanied by improved performance suggests that appropriate practising does lead to improvement usually if not always. **Weisberg** observes that much of the research on the effects of practice has been based on skills in which the expressive or creative elements are relatively limited. For this reason it has sometimes been assumed that practice is more important in technical skills such as swimming than skills in which innovation is crucial. Weisberg notes, however, that practising activities not unlike the ones that promote performance skills in music may make a substantial contribution to creative activities such as composing too.

The importance of the quality and appropriateness of practising activities is stressed by **Winner** and by **Stevenson.** As **Ericsson** observes, expert performance may require a kind of deliberate practising that is very different from the learning activities used to acquire everyday skills. For example, whereas ordinary individuals may reach a stage at which they are happy that performance becomes relatively automatic and effortless, the expert needs to continue to be fully aware during skilled activities, in order to plan and monitor the performance increasingly efficiently.

Nevertheless, practice of some kind always does appear to be an essential component of high levels of expertise. **Feldman & Katzir** suggest that an exceptional individual like Mozart may have been able to achieve very high levels of attainment without devoting large amounts of time to practice. This view is contradicted, however, by **Weisberg**'s evidence (see also Hayes 1981; Simonton 1991) that even Mozart's best work appeared only after a long period of concentrated training and preparation. In fact, as Weisberg demonstrates, it was not until Mozart had been immersed in music for 16 years that he first produced a composition that is acknowledged as a masterwork. The persistent myth that some people reach high levels of performance without devoting numerous hours to training and practice owes much to the fact that practising activities are usually outside the casual observer's view. They are, to use **Charness**'s phrase, like the base of a floating iceberg.

Undertaking large amounts of serious practice requires qualities of determination and industriousness, as **Eisenberger** emphasises. It is not impossible that these attributes reflect innate differences, even if industriousness is largely learned. Eisenberger notes, however, that being industrious and determined is at least partly a matter of acquiring the kinds of work habits that were given a prominent role in J. B. Watson's behaviourist account of the causes of success.

R7. Practical and educational implications

Talent can be regarded as a social construct, as **Csikszentmihalyi** observes. **Tesch-Römer** draws attention to the fact that people can become strongly motivated to spend time on certain activities if they become convinced that they have special talents. Hence even false beliefs may play a helpful role for some individuals, giving them the confidence to persevere in arduous training activities. In contrast however, as **Vitouch** and **Hatano** point out, a false belief that one does not possess necessary talent may affect a person negatively, deterring effort and perseverence. We also disagree with **Winner**'s suggestion that discriminative policies do not follow from the acknowledgement of talent. In musical education they undoubtedly do.

Csikszentmihalyi expresses the prevailing view when he suggests that, since resources are limited, we should direct training opportunities towards those children who, for whatever reason, display interest and ability in a given domain. That view is routinely used as a basis for making decisions about the allocation of resources in specialist areas such as music. But imagine the outcry if such arguments were put forward in relation to early education in basic mathematics or reading skills. **Simonton** agrees that the early selection of young people to receive exclusive educational privileges may be both discriminatory and wasteful. Similarly, **Rutter** agrees that there is justified concern about the consequences of the mistaken belief that a few deserving individuals have an innate talent that requires special fostering, whereas the ordinary skills of other children need no special attention. It was partly because of our concern about the unjustified yet ingrained assumptions underlying such decisions about educational opportunities in certain fields of expertise that we were moved to write our target article.

As **Hatano** remarks, a consequence of the talent account is that many students, their parents, and their teachers become discouraged. **Starkes & Helsen**'s and **Rowe**'s comments on the state of affairs in sports (where the importance of talent is rarely questioned, with some coaches insisting that they can "see" talent) make it clear that there, too, individuals who are not identified as talented lose out. **Eisenberger** argues that in the United States unjustified emphasis on innate differences in ability has had a number of pernicious effects. These range from discouraging young people not thought to be talented to wrongly assuming that individuals bear no responsibility for poor performance and to denying students admission to universities on the basis of tests that have limited validity and reliability. Even if it were discovered that a greater number of individuals have been encouraged by being told that they were talented than the number who have been discouraged or debarred from opportunities by the belief that they are untalented, the arguments in favour of allowing false beliefs about innate talents to be communicated would not be compelling.

Humphreys makes the point that the talent account is not totally without some democratic or egalitarian appeal, because by pointing to the multiple ways in which a person may excel, it avoids the idea that the potential to succeed depends upon a single dimension of general intelligence. Other commentators point out that dogmatic assertions that all people are capable of each and every human achievement may be discouraging for individuals who fail. In Japan, according to **Eisenberger,** the common view that almost any student can excel and that poor performance results solely from laziness, has led to denying individuals with genuine learning disabilities the individual attention they require. **Hatano** makes a similar observation, noting that excluding the possibility of innate differences may lead to the assumption that whenever there is a failure to achieve someone must be blamed. As Hatano remarks, the consequences of introducing the talent viewpoint in cultures where it is widely (and unrealistically) believed that all children are equally capable of succeeding could have a favourable outcome. It is not necessary to choose between two incorrect alternatives, however; one can accept that the innate talent account is wrong but also that it is equally wrong to assume that any diligent child can excel at anything, especially in the absence of expert teaching, special opportunities, plenty of encouragement, and unusual motivation.

R8. Have our views changed?

To what extent have the commentaries influenced our own views? Apart from becoming better informed on a number of specific issues, we have certainly become even more aware of the factors that make it hard to reach decisions about the role of biological factors in individual differences in expertise. Although some commentators, including **Baltes, Bronfenbrenner & Ceci,** and **Plomin,** have provided hints about possible research designs that would provide clarification, we are not optimistic about the likelihood of enlightenment in the immediate future. Our initial decision to focus the target article on innate talents rather than attempting a broader appraisal of the role of biological and genetic influences was influenced in part by our doubt that this would lead to any firm conclusions. These doubts remain.

From a purely scientific standpoint, the main question raised by the target article might be a less than ideal one to address, if only because it revolves around imprecisely defined concepts. We are convinced that the question is an important one, however, with immense policy implications, and that only by addressing it in a direct manner can we answer it authoritatively. On the central question of whether innate talents (as defined in the target article) are real or mythical, we have not encountered in the commentaries any convincing reasons for changing our position. Innate talents are, we think, a fiction, not a fact.

The wide range of positions taken by the authors of the commentaries could be seen as the result of adopting different decision criteria (in the sense made familiar by signal detection theory). We, along with some commentators and not others, adopt a stringent criterion and do not accept the talent account on the basis of the existing evidence. A number of commentators have a laxer criterion, and believe that suggestive evidence is enough to confirm what they, along with a substantial proportion of the population, see as common sense. Some of these commentators have made their preference for a laxer criterion explicit by challenging our list of the defining attributes of a talent.

It is a feature of the assumptions underlying signal detection theory that one cannot determine the "best" criterion by consulting the data about which one is trying to make a decision. Decision criteria are determined by external factors, such as the relative pay-offs involved. In the case of the talent debate, it is inevitable that a range of philosophical, ideological, and political factors can come into play in determining the criterion that individuals will judge to be optimal. A number of considerations have determined our decisions. First, we believe that scientific parsimony requires that one not accept the existence of causal entities until there is strong evidence that their existence is required in order to account for the available data. Second, we believe that the social consequences of promoting the talent account in the public arena are discriminatory and divisive. Our awareness that many individuals see their belief in talents as legitimising discrimination influenced our decision to insist upon the inclusion of a predictive function among the defining attributes.

References

[Note: The letters 'a' and 'r' before author's initials refer to the target and response articles, respectively]

Abernethy, B., Neal, R. J. & Koning, P. (1994) Visual-perceptual and cognitive differences between expert, intermediate, and novice snooker players. *Applied Cognitive Psychology* 8:185–211. [JS]

Ackerman, P. L. (1988) Determinants of indvidual differences during skill acquisition: Cognitive abilities and information processing. *Journal of Experimental Psychology: General* 117:299–318. [aMJAH]

American Psychological Association. (1995) Intelligence: Knowns and unknowns. Report of a Task Force established by the Board of Scientific Affairs of the American Psychological Association, Science Directorate, Washington D. C. [LGH]

APA (1994) *DSM-IV diagnostic and statistical manual of mental disorders, 4th edition.* American Psychiatric Association. [SB-C]

Bailey, A., Phillips, W. & Rutter, M. (1996) Autism: Towards an integration of clinical, genetic, neuropsychological and neurobiological perspectives. *Journal of Child Psychology and Psychiatry* 37:89–126. [MR]

Baltes, P. B. (1987) Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. *Developmental Psychology* 23:611–26. [PBB]

(1993) The aging mind: Potential and limits. *Gerontologist* 33:580–94. [PBB]

(1997) On the incomplete architecture of human ontogeny: Selection, optimization, and compensation as foundation of developmental theory. *American Psychologist* 52:366–80. [PBB]

Baltes, P. B. & Kliegl, R. (1992) Further testing of limits of cognitive plasticity: Negative age differences in a mnemonic skill are robust. *Developmental Psychology* 28:121–25. [PBB]

Baltes, P. B., Lindenberger, U. & Staudinger, U. M. (1997) Life-span theory in developmental psychology. In: *Handbook of child psychology, vol. 1: Theoretical models of human development,* ed. R. M. Lerner. Wiley. [PBB]

Baltes, P. B., Reese, H. W. & Nesselroade, J. R., eds. (1988) *Life-span developmental psychology: Introduction to research methods* (reprint of 1977 edition). Erlbaum. [PBB]

Baron-Cohen, S. & Hammer, J. (1997a) Parents of children with Asperger syndrome: What is the cognitive phenotype? *Journal of Cognitive Neuroscience* 9:548–54. [SB-C]

(1997b) Is autism an extreme form of the male brain? *Advances in Infancy Research* 11:193–217. [SB-C]

Baxter-Jones, A. & Helms, P. (1994) Born too late to win? *Nature* 370:18. [JS]

Bell, T. E. (1937) Complete independence. In: *Men of mathematics.* Simon and Schuster. [AHZ]

Benbow, C. P. & Lubinski, D. (1993) Psychological profiles of the mathematically talented: Some sex differences and evidence supporting their biological basis. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [aMJAH]

Bennett, H. L. (1983) Remembering drink orders: The memory skills of cocktail waitresses. *Human Learning: Journal of Practical Research and Applications* 2: 157–70. [aMJAH]

Bernstein, M. H. & Sigman, M. D. (1986) Infant habituation: Assessments of individual differences and short-term reliability at five months. *Child Development* 57:87–99. [aMJAH]

Berry, C. (1990) On the origins of exceptional intellectual and cultural achievement. In: *Encouraging the development of exceptional abilities and talents,* ed. M. J. A. Howe. British Psychological Society. [aMJAH]

Berry, D. C. & Broadbent, D. E. (1984) On the relationship between task performance and associated verbalisable knowledge. *The Quarterly Journal of Experimental Psychology* 36A:209–31. [RJStev]

Blacking, J. (1973) *How musical is man?* Faber & Faber. [aMJAH]

Bloom, B. S. (1982) The role of gifts and markers in the development of talent. *Exceptional Children* 48:510–22. [CT-R]

Bloom, B. S., ed. (1985) *Developing talent in young people.* Ballantine. [EW]

Bolton, P., MacDonald, H., Pickles, A., Rios, P., Goode, S., Crowson, M., Bailey, A. & Rutter, M. (1994) A case-control family history study of autism. *Journal of Child Psychology and Psychiatry* 35:877–900. [SB-C]

Bouchard, T. (1997) E-mail communication, August, 1997. [DCR]

Bouchard, T. J., Jr. & Lykken, D. T. (in press) Genetic and environmental influence on correlates of creativity. 1995 Henry B. & Jocelyn Wallace National Symposium on Talent Development, The University of Iowa, Iowa City, Iowa. [KAE]

Bouchard, T. J., Lykken, D. T., McGue, M., Segal, N. L. & Tellegen, A. (1990) Sources of human psychological differences: The Minnesota study of twins reared apart. *Science* 250:223–28. [aMJAH]

Bouchard, T. J., Jr., Lykken, D. T., Tellegen, A. & McGue, M. (1996) Genes, drives, environment, and experience. EPD theory revised. In: *Intellectual talent: Psychometric and social issues,* ed. C. P. Benbow & D. Lubinski. The Johns Hopkins University Press. [NC]

Brady, P. T. (1970) The genesis of absolute pitch. *Journal of the Acoustical Society of America* 48:883–87. [aMJAH]

Braggett, E. (1996) Issues in the identification and assessment of academically and artistically gifted students. In: *Optimizing excellence in human resource development,* ed. U. Mundanar & S. Semiawan. University of Indonesia Press. [MC]

Brody, N. (1992) *Intelligence,* 2nd edition. Academic Press. [DKD, DCR]

Bronfenbrenner, U. & Ceci, S. J. (1994) Nature-nurture reconceptualized: A bioecological model. *Psychological Review* 101:568–86. [UB]

Brophy, J. & Good, T. (1973) *Individual differences: Toward an understanding of classroom life.* Holt, Rinehart & Winston. [aMJAH]

Bynner, J. M. & Romney, D. M. (1986) Intelligence, fact or artefact: Alternative structures for cognitive abilities. *British Journal of Educational Psychology* 56:13- 23. [aMJAH]

Card, S. K., Moran, T. P. & Newell, A. (1983) *The psychology of human-computer interaction.* Erlbaum. [NC]

Casto, S. D., DeFries, J. C. & Fulker, D. W. (1989) Multivariate genetic analysis of Wechsler intelligence scale for children – Revised (WISC-R) factors. *Behavior Genetics* 25:25–32. [DCR]

Ceci, S. J. (1990) *On intelligence . . . more or less: A bio-mechanical treatise on intellectual development.* Prentice Hall. [aMJAH]

Ceci, S. J., Baker, J. G. & Bronfenbrenner, U. (1987) Prospective remembering, temporal calibration, and context. In: *Practical aspects of memory: Current research and issues,* ed. M. M. Gruneberg, P. Morris & R. Sykes. Wiley. [aMJAH]

Ceci, S. J. & Liker, J. (1986) A day at the races: A study of IQ, expertise, and cognitive complexity. *Journal of Experimental Psychology: General* 115:255–66. [aMJAH]

Charness, N. & Gerchak, Y. (1996) Participation rates and maximal performance: A log-linear explanation for group differences, such as Russian and male dominance in chess. *Psychological Science* 7:46–51. [NC]

Charness, N., Krampe, R. Th. & Mayr, U. (1996) The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In: *The road to excellence: The acquisition of expert performance in the arts and sciences,* ed. K. A. Ericsson. Erlbaum. [NC, aMJAH]

Chase, W. G. & Ericsson, K. A. (1981) Skilled memory. In: *Cognitive skills and their acquisition,* ed. J. R. Anderson. Erlbaum. [aMJAH]

Chase, W. G. & Simon, H. A. (1973) Perception in chess. *Cognitive Psychology* 4:55–81. [NC]

Chi, M. T. H. & Ceci, S. J. (1987) Content knowledge: Its role, representation, and restructuring in memory development. *Advances in Child Development* 20:91–142. [aMJAH]

Chorney, M. J., Chorney, K., Seese, N., Owen, M. J., Daniels, J., McGuffin, P., Thompson, L. A., Detterman, D. K., Benbow, C. P., Lubinski, D., Eley, T. C. & Plomin, R. (in press) A quantitative trait locus (QTL) associated with cognitive ability in children. *Psychological Science.* [RP]

Clark, M. M. (1976) *Young fluent readers.* Heinemann Educational Books. [JF]

Collins, J. W. (1974) *My seven chess prodigies.* Simon & Schuster. [DHF]

Columbo, J. (1993) *Infant cognition: Predicting later intellectual functioning.* Sage. [JF, aMJAH]

Coon, H. & Carey, G. (1989) Genetic and environmental determinants of musical ability in twins. *Behavior Genetics* 19:183–93. [aMJAH, EW]

Csikszentmihalyi, M., Rathunde, K. & Whalen, S. (1993) *Talented teenagers: The roots of success and failure.* Cambridge University Press. [MC, rMJAH]

Dark, V. J. & Benbow, C. P. (1990) Enhanced problem translation and short-term memory: Components of mathematical talent. *Journal of Educational Psychology* 82:420–29. [aMJAH]

Dark, V. J. & Benbow, C. P. (1991) The differential enhancement of working memory with mathematical versus verbal precocity. *Journal of Educational Psychology* 83:48–60. [aMJAH]

Davidson, J. W., Howe, M. J. A., Moore, D. G. & Sloboda, J. A. (1996) The role of parental influences in the development of musical performance. *British Journal of Developmental Psychology* 14:399–412. [aMJAH]

Davies, J. B. (1994) Seeds of a false consciousness. *The Psychologist* 7:355–56. [aMJAH]

Davis, J. O., Phelps, J. A. & Bracha, H. S. (1995) Prenatal development of monozygotic twins and concordance for schizophrenia. *Schizophrenia Bulletin* 21:357–66. [rMJAH]

Davis, M. (1994) Folk music psychology. *The Psychologist* 7:537. [aMJAH]

Detterman, D. K. (1993) Discussion. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrille. Wiley. [aMJAH]

Devlin, B., Daniels, M. & Roeder, K. (1997) The heritability of IQ. *Nature* 388:468–71. [rMJAH, RP]

Dudink, A. (1994) Birth date and sporting success. *Nature* 368:592. [JS]

Dweck, C. S. (1986) Motivational processes affecting learning. *American Psychologist* 41:1040–48. [aMJAH]

Eisenberger, R. (1992) Learned industriousness. *Psychological Review* 99:248–67. [RE]

Eisenberger, R. & Armeli, S. (1997) Can salient reward increase creative performance without reducing intrinsic creative interest? *Journal of Personality and Social Psychology* 72:652–63. [RE]

Eisenberger, R. & Cameron, J. (1996) Detrimental effects of reward: Reality or myth? *American Psychologist* 51:1153–66. [RE]

Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B. & Traub, E. (1995) Increased cortical representation of the fingers of the left hand in string players. *Science* 270:305–07. [arMJAH]

Ericsson, K. A. (1990) Peak performance and age: An examination of peak performance in sports. In: *Successful aging: Perspectives from the behavioral sciences,* ed. P. B. Baltes & M. M. Baltes. Cambridge University Press. [aMJAH]

Ericsson, K. A. & Charness, N. (1994) Expert performance: Its structure and acquisition. *American Psychologist* 49:725–47. [NC, KAE, aMJAH]

(1995) Abilities: Evidence for talent or characteristics acquired through engagement in relevant activities. *American Psychologist* 50:803–04. [NC, DKD, KAE, aMJAH]

Ericsson, K. A. & Crutcher, R. J. (1988) The nature of exceptional performance. In: *Life- span development and behavior, vol. 10,* ed. P. B. Baltes, D. L. Featherman & R. M. Lerner. Erlbaum. [aMJAH, JS]

Ericsson, K. A. & Faivre, I. A. (1988) What's exceptional about exceptional abilities? In: *The exceptional brain,* ed. L. K. Obler & D. Fein. Guilford Press. [aMJAH]

Ericsson, K. A. & Kintsch, W. (1995) Long-term working memory. *Psychological Review* 102(2):211–45. [KAE]

Ericsson, K. A., Krampe, R. Th. & Heizman, S. (1993a) Can we create gifted people? In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [aMJAH]

Ericsson, K. A., Krampe, R. Th. & Tesch-Römer, C. (1993b) The role of deliberate practice in the acquisition of expert performance. *Psychological Review* 100:363- 406. [KAE, aMJAH, JS, WS, SET]

Ericsson, K. A. & Lehmann, A. C. (1996) Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annual Review of Psychology* 47:273- 305. [NC, aMJAH]

Ericsson, K. A. & Polson, P. G. (1988) An experimental analysis of a memory skill for dinner-orders. *Journal of Experimental Psychology: Learning, Memory and Cognition* 14:305–16. [aMJAH]

Ericsson, K. A., Tesch-Römer, C. & Krampe, R. Th. (1990) The role of practice and motivation in the acquisition of expert-level performance in real life. In: *Encouraging the development of exceptional abilities and talents,* ed. M. J. A. Howe. British Psychological Society. [aMJAH]

Eysenck, H. J. (1995) *Genius: The natural history of creativity.* Cambridge University Press. [aMJAH]

Eysenck, H. J. & Barrett, P. T. (1993) Brain research related to giftedness. In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH]

Feld, S. (1984) Sound structure as a social structure. *Ethnomusicology* 28:383–409. [aMJAH]

Feldman, D. H. (1980) *Beyond universals in cognitive development.* Ablex. [aMJAH]

(1988) Creativity: Dreams, insights, and transformations. In: *The nature of creativity,* ed. R. J. Sternberg. Cambridge University Press. [aMJAH]

Feldman, D. H. & Goldsmith, L. (1986/1991) *Nature's gambit: Child prodigies and the development of human potential.* Basic Books/Teachers College Press. [DHF, JF, aMJAH]

Ferguson, G. A. (1954) On learning and human ability. *Canadian Journal of Psychology* 8:95–112. [SHI]

(1956) On transfer and the abilities of man. *Canadian Journal of Psychology* 10:121–31. [rMJAH, SHI]

Flynn, J. R. (1984) The mean IQ of Americans: Massive gains 1932 to 1978. *Psychological Bulletin* 95:29–51. [RJSter]

(1987) Massive IQ gains in 14 nations: What IQ tests really measure. *Psychological Bulletin* 101:171–91. [RJSter]

Folstein, S. & Rutter, M. (1977) Infantile autism: A genetic study of 21 twin pairs. *Journal of Child Psychology and Psychiatry* 18:297–321. [SB-C]

Ford, D. H. & Lerner, R. M. (1992) *Developmental systems theory.* Sage. [SET]

Fowler, W. (1981) Case studies of cognitive precocity: The role of exogenous and

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

endogenous stimulation in early mental development. *Journal of Applied Developmental Psychology* 2:319–67. [aMJAH, WS]
Fox, P. W., Hershberger, S. L. & Bouchard, T. J., Jr. (1996) Genetic and environmental contributions to the acquisition of a motor skill. *Nature* 384:356–58. [PBB, RP, DCR]
Freeman, J. (1990) The intellectually gifted adolescent. In: *Encouraging the development of exceptional skills and talents,* ed. M. J. A. Howe. British Psychological Society. [aMJAH]
(1991) *Gifted children growing up.* Heinemann Educational; Cassell. [JF]
(1995) Children's talent in fine-art and music: Optimisers and obstructions. In: *Art & Fact; Learning effects of arts education,* ed. J. Ensink. Netherlands Institute for Art Education. [JF]
Gagné, F. (1993) Constructs and models pertaining to exceptional human abilities. In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH, WS]
Gardner, H. (1983/84) *Frames of mind: A theory of multiple intelligences.* Basic Books (1983 edition); Heinemann (1984 edition). [NC, LGH, aMJAH]
(1993a) Early giftedness and later achievement. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [DHF, aMJAH]
(1993b) *Multiple intelligence: The theory in practice.* Basic Books. [aMJAH]
(1995) Why would anyone become an expert? *American Psychologist* 50:802–03. [aMJAH]
Gazzaniga, M. S. (1985) *The social brain: Discovering the networks of the mind.* Basic Books. [aMJAH]
Geddes, B. W. & Stevenson, R. J. (1997) Explicit learning of a dynamic system with a non-salient pattern. *The Quarterly Journal of Experimental Psychology* 50A(4): [RJStev]
Geschwind, N. & Behan, P. (1982) Left-handedness: Associations with immune disease, migraine, and developmental learning disorders. *Proceedings of the National Academy of Science* 79:5097–100. [aMJAH]
Geschwind, N. & Galaburda, A. (1985) Cerebral lateralization: Biological mechanisms, associations, and pathology: A hypothesis and a program for research. *Archives of Neurology* 42:428–59. [DHF]
Gillberg, C. (1991) Clinical and neurobiological aspects of Asperger syndrome in six family studies. In: *Autism and Asperger syndrome,* ed. U. Frith. Cambridge University Press. [SB-C]
Goldsmith, G. (1990) The timing of talent: The facilitation of early prodigious achievement. In: *Encouraging the development of exceptional skills and talents,* ed. M. J. A. Howe. British Psychological Society. [aMJAH]
Goode, S., Rutter, M. & Howlin, P. (1994) A twenty-year follow-up of children with autism. In: *13th biennial meeting of the International Society for the Study of Behavioral Development.* Amsterdam, The Netherlands. [MR]
Gross, M. U. M. (1993a) Nurturing the talents of exceptionally gifted individuals. In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH]
(1993b) *Exceptionally gifted children.* Routledge. [JF, aMJAH]
Gustin, W. C. (1985) The development of exceptional research mathematicians. In: *Developing talent in young people,* ed. B. S. Bloom. Ballantine. [aMJAH]
Haber, R. N. (1979) Twenty years of haunting eidetic imagery: Where's the ghost? *Behavioral and Brain Sciences* 2:583–94. [aMJAH]
Haber, R. N. & Haber, L. R. (1988) The characteristics of eidetic imagery. In: *The exceptional brain,* ed. L. K. Obler & D. Fein. Guilford Press. [aMJAH]
Hargreaves, D. J. (1986) *The developmental psychology of music.* Cambridge University Press. [aMJAH]
(1994) Musical education for all. *The Psychologist* 7:357–58. [aMJAH]
Haskins, R. (1989) Beyond metaphor: The efficacy of early childhood education. *American Psychologist* 44:274–82. [FG]
Hatano, G. & Inagaki, K. (in press) Cultural contexts of schooling revisited. In: *Global prospects for education: Development, psychology, and schooling,* ed. S. Paris & H. Wellman. American Psychological Association. [GH]
Hayes, J. R. (1981) *The complete problem solver.* Franklin Institute Press. [aMJAH]
(1989) Cognitive processes in creativity. In: *Handbook of creativity,* ed. A. J. Glover, R. R. Ronning & C. R. Reynolds. Plenum. [RWW]
Heavey, L. (1997) Memory in the calendar calculating savant. Ph. D. dissertation, University of London. [MR]
Heckhausen, H. (1987) Causal attribution patterns for achievement outcomes: Individual differences, possible types, and their origins. In: *Metacognition, motivation, and understanding,* ed. F. E. Weinert & R. H. Kluwe. Erlbaum. [CT-R]
Heller, K. A. (1993) Scientific ability. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [aMJAH]
Heller, K. A., Mönks, F. J. & Passow, A. H., eds. (1993) *International handbook of research and development of giftedness and talent.* Pergamon. [WS]
Helsen, W., Starkes, J. L. & Hodges, N. J. (in press) Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology.* [JS]
Helsen, W., Starkes, J. L. & Van Winckle, J. (1997) Birth dates to excellence and dropout in soccer (submitted). [JS]
Hendrikson, A. E. & Hendrikson, D. E. (1980) The biological basis for individual differences in intelligence. *Personality and Individual Differences* 1:3–33. [aMJAH]
Hepper, P. G. (1991) An examination of fetal learning before and after birth. *Irish Journal of Psychology* 12:95–107. [aMJAH]
Hollingworth, L. S. (1942) *Children above IQ 180: Origin and development.* World Books. [aMJAH]
Horgan, D. D. & Morgan, D. (1990) Chess expertise in children. *Applied Cognitive Psychology* 4:109–28. [WS]
Horn, J. L. (1986) Intellectual ability concepts. In: *Advances in the psychology of human intelligence, vol. 3,* ed. R. J. Sternberg. Erlbaum. [aMJAH]
Howald, H. (1982) Training-induced morphological and functional changes in skeletal muscle. *International Journal of Sports Medicine* 3:1–12. [aMJAH]
Howe, M. J. A. (1975) *Learning in infants and young children.* Macmillan. [aMJAH]
(1980) *The psychology of human learning.* Harper & Row. [aMJAH]
(1982) Biographical information and the development of outstanding individuals. *American Psychologist* 37:1071–81. [aMJAH]
(1988a) Intelligence as an explanation. *British Journal of Psychology* 79:349–60. [aMJAH]
(1988b) The hazards of using correlational evidence as a means of identifying the causes of individual ability differences: A rejoinder to Sternberg and a reply to Miles. *British Journal of Psychology* 79:539–45. [aMJAH]
(1989a) *Fragments of genius: The strange feats of idiot savants.* Routledge. [aMJAH]
(1989b) The strange achievements of idiot savants. In: *Psychology survey 7,* ed. A. M. Colman & J. G. Beaumont. British Psychological Society/Routledge. [aMJAH]
(1989c) Separate skills or general intelligence: The autonomy of human abilities. *British Journal of Educational Psychology* 59:351–60. [aMJAH]
(1990a) *The origins of exceptional abilities.* Blackwell. [aMJAH]
(1990b) Does intelligence exist? *The Psychologist* 3:490–93. [aMJAH]
(1990c) Gifts, talents, and natural abilities: An explanatory mythology? *Educational and Child Psychology* 7:52–54. [aMJAH]
(1993) The early lives of child prodigies. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [aMJAH]
(1995) What can we learn from the lives of geniuses? In: *Actualizing talent: A lifelong challenge,* ed. J. Freeman, P. Span & H. Wagner. Cassell. [aMJAH]
(1996a) The childhood and early lives of geniuses: Combining psychological and biographical evidence. In: *The road to excellence: The acquisition of expert performance in the arts and sciences,* ed. K. A. Ericsson. Erlbaum. [aMJAH]
(1996b) Concepts of ability. In: *Human abilities: Their nature and measurement,* ed. I. Dennis & P. Tapsfield. Erlbaum. [aMJAH]
(1997a) Beyond psychobiography: Towards more effective syntheses of psychology and biography. *British Journal of Psychology* 88:235–48. [aMJAH]
(1997b) *IQ in question: The truth about intelligence.* Sage. [rMJAH]
Howe, M. J. A., Davidson, J. W., Moore, D. G. & Sloboda, J. A. (1995) Are there early childhood signs of musical ability? *Psychology of Music* 23:162–76. [aMJAH]
Howe, M. J. A. & Sloboda, J. A. (1991a) Young musicians' accounts of significant influences in their early lives: 1. The family and the musical background. *British Journal of Music Education* 8:39–52. [aMJAH]
(1991b) Young musicians' accounts of significant influences in their early lives: 2. Teachers, practising and performing. *British Journal of Music Education* 8:53–63. [aMJAH]
(1991c) Early signs of talents and special interests in the lives of young musicians. *European Journal of High Ability* 2:102–11. [aMJAH]
Howe, M. J. A. & Smith, J. (1988) Calendar calculating in "idiot savants": How do they do it? *British Journal of Psychology* 79:371–86. [arMJAH]
Humphreys, L. G., Lubinski, D. & Yao, G. (1993) Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. *Journal of Applied Psychology* 78:250–61. [aMJAH]
Irvine, S. H. & Berry, J. W. (1988) The abilities of mankind: A revaluation. In: *Human abilities in cultural context, Part I,* ed. S. H. Irvine & J. W. Berry. Cambridge University Press. [SHI]
Jackson, N. E. (1988) Precocious reading ability; what does it mean? *Gifted Child Quarterly* 32:200–04. [JF]
Johnson, G. (1991) Magnificent obsession. *The New York Times Book Review,* July 21, p. 12. [RE]

Jolliffe, T. & Baron-Cohen, S. (1997) Are people with autism or Asperger's syndrome faster than normal on the Embedded Figures Task? *Journal of Child Psychology and Psychiatry* 38:527–34. [SB-C]

Kalinowski, A. G. (1985) The development of Olympic swimmers. In: *Developing talent in young people,* ed. B. S. Bloom. Ballantine. [aMJAH]

Kanigel, R. (1991) *The man who knew infinity: A life of the genius Ramanujan.* Scribner. [RE]

Kearins, J. M. (1981) The visual spatial memory in Australian Aboriginal children of desert regions. *Cognitive Psychology* 13:434–60. [aMJAH]

Keating, D. P. (1984) The emperor's new clothes: The "new look" in intelligence research. In: *Advances in human intelligence, vol. 2,* ed. R. J. Sternberg. Erlbaum. [aMJAH]

Kliegl, R. & Baltes, P. B. (1987) Theory-guided analysis of mechanisms of development and aging mechanisms through testing-the-limits and research on expertise. In: *Cognitive functioning and social structure over the life course,* ed. C. Schooler & K. W. Schaie. Ablex. [PBB]

Kliegl, R., Smith, J. & Baltes, P. B. (1989) Testing the limits and the study of age differences in cognitive plasticity of mnemonic skill. *Developmental Psychology* 25:247–56. [aMJAH]

(1990) On the locus and process of magnification of age differences during mnemonic training. *Developmental Psychology* 26:894–904. [PBB]

Kliegl, R., Smith, J., Heckhausen, J. & Baltes, P. B. (1987) Mnemonic training for the acquisition of skilled digit memory. *Cognition and Instruction* 4:203–23. [PBB]

Kolata, G. (1987) Remembering a magical genius. *Science* 236:1519. [AHZ]

Krampe, R. Th. (1994) *Maintaining excellence: Cognitive-motor performance in pianists differing in age and skill levels.* Max-Planck-Institut für Bildungsforschung. [aMJAH]

Krampe, R. Th. & Ericsson, K. A. (1996) Maintaining excellence: Cognitive motor performance in pianists differing in age and skill level. *Journal of Experimental Psychology: General* 125:331–60. [aMJAH]

Krogius, N. (1976) *Psychology in chess.* RHM Press. [aMJAH]

Landon, H. C. R. (1956) The concertos: (2) Their musical origin and development. In: *The Mozart companion,* ed. H. C. R. Landon & D. Mitchell. W. W. Norton. [RWW]

Lang, G. (1994) String fever. *Town & Country,* April, 86–91, 123. [FG]

Lecanuet, J. P. (1995) Prenatal auditory experience. In: *Perception and cognition of music,* ed. I. Deliege & J. A. Sloboda. Erlbaum. [aMJAH]

Le Couteur, A., Bailey, A., Goode, S., Pickles, A., Robertson, S., Gottesman, I. & Rutter, M. (1996) A broader phenotype of autism: The clinical spectrum in twins. *Journal of Child Psychology and Psychiatry* 37:785–801. [SB-C]

Lehmann, A. C. (1997) Acquisition of expertise in music: Efficiency of deliberate practice as a moderating variable in accounting for sub-expert performance. In: *Perception and cognition of music,* ed. J. A. Sloboda & I. Deliege. Erlbaum. [aMJAH, SET]

Lehmann, A. C. & Ericsson, K. A. (in press) The historical development of domains of expertise: Performance standards and innovations in music. In: *Genius and the mind: Studies of creativity and temperament in the historical record,* ed. A. Steptoe. Oxford University Press. [ACL]

Lewis, D. (1976) Observations on route finding and spatial orientation among the Aboriginal peoples of the western desert region of central Australia. *Oceania* 46:349–82. [aMJAH]

Lewis, M. & Michalson, L. (1985) The gifted infant. In: *The psychology of gifted children: Perspectives on development and education,* ed. J. Freeman. Wiley. [JF]

Lindenberger, U. & Baltes, P. B. (1995) Testing-the-limits and experimental simulation: Two methods to explicate the role of learning in development. *Human Development* 38:349–60. [PBB]

Lykken, D. (in press) The genetics of genius. In: *Genius and the mind,* ed. A. Steptoe. Oxford University Press. [aMJAH]

Lynn, R., Wilson, G. R. & Gault, A. (1989) Simple musical tests as measures of Spearman's *g. Personality and Individual Differences* 10:25–28. [DKD]

Manturzewska, M. (1986) Musical talent in the light of biographical research. In: *Musikalische Begabung finden und förden.* Bosse. [aMJAH]

(1990) A biographical study of the life-span development of professional musicians. *Psychology of Music* 18:112–39. [aMJAH]

Marshall, C. (1982) Towards a comparative aesthetics of music. In: *Cross cultural perspectives in music,* ed. R. Falck & T. Rice. University of Toronto Press. [aMJAH]

Marshall, R. L. (1991) *Mozart speaks.* Schirmer Books. [DHF]

Matarazzo, J. D. (1972) *Wechsler's measurement and appraisal of adult intelligence.* The Williams & Wilkins Company. [DKD]

McCall, R. B. & Carriger, M. S. (1993) A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development* 64:57–79. [DCR]

McCarthy, G. & Donchin, E. (1981) A metric for thought: A comparison of P300 latency and reaction time. *Science* 211:77–79. [aMJAH]

McClearn, G. E., Johansson, B., Berg, S., Pedersen, N. L., Ahem, F., Petrill, S. A. & Plomin, R. (1997) Substantial genetic influence on cognitive abilities in twins 80 or more years old. *Science* 276:1560–63. [RP]

McGue, M. (1997) The democracy of the genes. *Nature* 388:417–18. [RP]

McLeish, J. & Higgs, G. (1982) Musical ability and mental subnormality: An experimental investigation. *British Journal of Educational Psychology* 52:370–73. [DKD]

Mead, M. (1975) *Growing up in New Guinea.* Morrow. [aMJAH]

Merriam, A. P. (1967) *The ethnomusicology of the flathead Indians.* Aldine. [aMJAH]

Messenger, J. (1958) Esthetic talent. *Basic College Quarterly* 4:20–24. [aMJAH]

Messer, D. J. (1993) Mastery, attention, IQ, and parent-infant social interaction. In: *Mastery motivation in early childhood: Development measures and social processes,* ed. D. J. Messer. Routledge. [JF]

Miller, L. K. (1989) *Musical savants: Exceptional skill in the mentally retarded.* Erlbaum. [aMJAH]

Miller, K. & Gelman, R. (1983) The child's representation of number: A multidimensional scaling analysis. *Child Development* 54:1470–79. [aMJAH]

Monsaas, J. (1985) Learning to be a world-class tennis player. In: *Developing talent in young people,* ed. B. S. Bloom. Ballantine. [aMJAH]

Nettelbeck, T. & Young, R. (1996) Intelligence and the savant syndrome: Is the whole greater than the sum of the fragments? *Intelligence* 22:49–68. [DCR]

Newell, A. (1990) *Unified theories of cognition.* Harvard University Press. [NC]

Newell, A. & Rosenbloom, P. S. (1981) Mechanisms of skill acquisition and the power law of practice. In: *Cognitive skills and their acquisition,* ed. J. R. Anderson. Erlbaum. [NC]

Ng, E. & Bereiter, C. (1995) Three levels of goal orientation in learning. In: *Goal-driven learning,* ed. A. Ram & D. B. Leake. MIT Press. [RJStev]

O'Connor, N. & Hermelin, B. (1987) Visual and graphic abilities of the idiot savant artist. *Psychological Medicine* 17:79–90. [aMJAH]

O'Neill, S. (1994) Factors influencing children's motivation and achievement during the first year of instrumental music tuition. *Proceedings of the Third International Conference on Music Perception and Cognition.* University of Liege, Belgium. [aMJAH]

Owen, E. & Sweller, J. (1985) What do students learn while solving mathematics problems? *Journal of Educational Psychology* 77:272–84. [RJStev]

Papousek, H. (1995) Musicality and infancy research. In: *Perception and cognition of music,* ed. I. Deliege & J. A. Sloboda. Erlbaum. [aMJAH]

Parncutt, R. (1993) Prenatal experience and the origins of music. In: *Prenatal perception, learning and bonding,* ed. T. Blum. Leonardo. [aMJAH]

Patel, V. L. & Groen, G. J. (1991) The general and specific nature of medical expertise: A critical look. In: *Toward a general theory of expertise,* ed. K. A. Ericsson & J. Smith. Cambridge University Press. [aMJAH]

Perkins, D. N. (1981) *The mind's best work.* Harvard University Press. [aMJAH]

Phillips, D. (1976) An investigation of the relationship between musicality and intelligence. *Psychology of Music* 4(2):16–31. [DKD]

Plomin, R. (1988) The nature and nurture of cognitive abilities. In: *Advances in the psychology of human intelligence,* ed. R. Sternberg. Erlbaum. [aMJAH]

(1994) *Genetics and experience: The interplay between nature and nurture.* Sage. [RP, RJSter]

Plomin, R. & DeFries, J. C. (in press) Genetics of cognitive abilities and disabilities. *Scientific American.* [RP]

Plomin, R., DeFries, J. C., McClearn, G. E. & Rutter, M. (1997) *Behavioral genetics,* 3rd edition. W. H. Freeman. [RP, DCR, MR]

Plomin, R., Owen, M. J. & McGuffin, P. (1994) The genetic basis of complex human behaviors. *Science* 264:1733–39. [RP]

Plomin, R. & Petrill, S. A. (1997) Genetics and intelligence: What's new? *Intelligence* 24:53–77. [RP]

Plomin, R. & Thompson, L. A. (1993) Genetics and high cognitive ability. In: *Ciba Foundation Symposium 178: The origins and development of high ability,* ed. G. R. Bock & K. Ackrill. Wiley. [aMJAH]

Radford, J. (1990) *Child prodigies and exceptional early achievers.* Harvester Wheatsheaf. [aMJAH]

(1994) Variations on a musical theme. *The Psychologist* 7:359–60. [aMJAH]

Renninger, K. A. & Wozniak, R. N. (1985) Effect of interest on attentional shift, recognition and recall in young children. *Developmental Psychology* 21:624–32. [aMJAH]

Revesz, G. (1925) *The psychology of a musical prodigy.* Kegan Paul, Trench & Trubner. [aMJAH]

Rijsdijk, F. V. & Boomsma, D. I. (1997) Genetic mediation of the correlation between peripheral nerve conduction velocity and IQ. *Behavior Genetics* 27:87–98. [DCR]

Rollet, B. (1994) Development of high ability. In: *Competence and responsibility, vol. 2: Proceedings of the Third European Conference of the European*

Council for High Ability, ed. K. A. Heller & E. A. Hany. Hogrefe & Huber. [CT- R]

Rosenblith, J. F. (1992) *In the beginning: Development from conception to age two.* Sage Publications. [JF]

Rosser, P. L. & Randolph, S. M. (1989) Black American infants: The Howard study. In: *The cultural context of infancy. Volume 1: Biology, culture and infant development,* ed. J. K. Nugent, B. M. Lester & T. B. Brazelton. Ablex. [aMJAH]

Rutter, M., Dunn, J., Plomin, R., Simonoff, E., Pickles, A., Maughan, B., Ormel, J., Meyer, J. & Eaves, L. (1997) Integrating nature and nurture: Implications of person-environment correlations and interactions for developmental psychopathology. *Development and Psychopathology* 9:335–64. [MR]

Sacks, O. (1995) *An anthropologist on Mars.* Picador. [aMJAH]

Sattler, J. M. (1988) *Assessment of children,* 2nd edition. J. M. Sattler. [FG]

Scanlan, T. K., Simons, J. P., Carpenter, P. J., Schmidt, G. W. & Keeler, B. (1993) The sport commitment model: Measurement development for the youth-sport domain. *Journal of Sport and Exercise Psychology* 15:16–38. [JS]

Scarr, S. & McCartney, K. (1983) How people make their own environments: A theory of genotype effects. *Child Development* 54:424–35. [AHZ]

Scheibel, A. B. & Paul, L. (1985) On the apparent non-adhesive nature of axospinous dendritic synapses. *Experimental Neurology* 89:279–83. [aMJAH]

Schlaug, G., Jäncke, L., Huang, Y. & Steinmetz, H. (1995) *In vivo* evidence of structural brain asymmetry in musicians. *Science* 267:699–701. [aMJAH]

Schneider, W. (1993) Acquiring expertise: Determinants of exceptional performance. In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. [aMJAH, WS]

(1997) The impact of expertise on performance: Illustrations from developmental research on memory and sports. *High Ability Studies* 8:7–18. [WS, EW]

Schneider, W., Bös, K. & Rieder, H. (1993) Leistungsprognose bei jugendlichen Spitzensportlern [Performance prediction in adolescent top tennis players]. In: *Aufmerksamkeit und Energetisierung,* ed. J. Beckmann, H. Strang & E. Hahn. Hogrefe. [WS]

Schulz, R. & Curnow, C. (1988) Peak performance and age among superathletes: Track and field, swimming, baseball, tennis, and golf. *Journal of Gerontology: Psychological Sciences* 43:113–20. [ACL]

Selfe, L. (1977) *Nadia: A case of extraordinary drawing ability in an autistic child.* Academic Press. [aMJAH]

Seligman, M. E., Nolen-Hoeksema, S., Thornton, N. & Thornton, K. M. (1990) Explanatory style as a mechanism of disappointing athletic performance. *Psychological Science* 1:143–46. [CT-R]

Sergent, D. & Roche, S. (1973) Perceptual shifts in the auditory information processing of young children. *Psychology of Music* 1:39–48. [aMJAH]

Shah, A. & Frith, U. (1983) An islet of ability in autism: A research note. *Journal of Child Psychology and Psychiatry* 24:613–20. [SB-C]

Shuter-Dyson, R. & Gabriel, C. (1981) *The psychology of musical ability,* 2nd edition. Methuen. [aMJAH, DKS]

Simon, H. A. & Chase, W. D. (1973) Skill in chess. *American Scientist* 61:394–403. [aMJAH]

Simonton, D. K. (1991) Emergence and realization of genius: The lives and works of 120 classical composers. *Journal of Personality and Social Psychology* 61:829–40. [arMJAH]

(1997) Creative productivity: A predictive and explanatory model of career trajectories and landmarks. *Psychological Review* 104:66–89. [NC]

Slater, A. (1995) Individual differences in infancy and later IQ. *Journal of Child Psychology and Psychiatry* 36:69–112. [aMJAH]

Sloan, K. D. & Sosniak, L. A. (1985) The development of accomplished sculptors. In: *Developing talent in young people,* ed. B. S. Bloom. Ballantine. [aMJAH]

Sloboda, J. A. (1985) *The musical mind.* Clarendon Press. [aMJAH]

(1991) Musical expertise. In: *Toward a general theory of expertise,* ed. K. A. Ericsson & J. Smith. Cambridge University Press. [aMJAH, JS]

(1996) The acquisition of musical performance expertise: Deconstructing the "talent" account of individual differences in musical expressivity. In: *The road to excellence: The acquisition of expert performance in the arts and sciences,* ed. K. A. Ericsson. Erlbaum. [aMJAH]

Sloboda, J. A., Davidson, J. W. & Howe, M. J. A. (1994a) Is everyone musical? *The Psychologist* 7:349–54. [aMJAH]

(1994b) Musicians: Experts, not geniuses. *The Psychologist* 7:363–64. [aMJAH]

Sloboda, J. A., Davidson, J. W., Howe, M. J. A. & Moore, D. G. (1996) The role of practice in the development of performing musicians. *British Journal of Psychology* 87:287–309. [arMJAH, OV, EW]

Sloboda, J. A., Hermelin, B. & O'Connor, N. (1985) An exceptional musical memory. *Music Perception* 3:155–70. [arMJAH]

Sloboda, J. A. & Howe, M. J. A. (1991) Biographical precursors of musical excellence: An interview study. *Psychology of Music* 19:3–21. [aMJAH]

(1992) Transitions in the early musical careers of able young musicians: Choosing instruments and teachers. *Journal of Research in Music Education* 40:283–94. [aMJAH]

Sosniak, L. A. (1985) Learning to be a concert pianist. In: *Developing talent in young people,* ed. B. S. Bloom. Ballantine. [aMJAH, EW]

(1990) The tortoise, the hare, and the development of talent. In: *Encouraging the development of exceptional abilities and talents,* ed. M. J. A. Howe. British Psychological Society. [aMJAH, JS]

Spitz, H. (1986) *The raising of intelligence: A selected history of attempts to raise retarded intelligence.* Erlbaum. [DKD, DCR]

Starkes, J. L. (1987) Skill in field hockey: The nature of the cognitive advantage. *Journal of Sports Psychology* 9:222–30. [JS]

Starkes, J. L., Deakin, J., Allard, F., Hodges, N. & Hayes, A. (1996) Deliberate practice in sports: What is it anyway? In: *The road to excellence: The acquisition of expert performance in the arts and sciences,* ed. K. A. Ericsson. Erlbaum. [aMJAH, JS]

Sternberg, R. J. (1993) Procedures for identify intellectual potential in the gifted: A perspective on alternative "metaphors of mind." In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH]

(1996) Costs of expertise. In: *The road to excellence,* ed. K. A. Ericsson. Erlbaum. [OV]

Sternberg, R. J. & Grigorenko, E. L., eds. (1997) *Intelligence, heredity, and environment.* Cambridge University Press. [RJSter]

Stevenson, R. J. & Geddes, B. W. (1997) Effects of goal specificity and explanations on instance learning and rule learning. In: *Proceedings of the 19th Annual Conference of the Cognitive Science Society.* Stanford University Press/LEA. [RJStev]

Stevenson, R. J. & Palmer, J. A. (1994) Learning: Principles, processes, and practices. Cassell. [RJStev]

Storfer, M. D. (1990) *Intelligence and giftedness: The contributions of heredity and early environment.* Jossey-Bass. [aMJAH]

Sundet, J. M., Eilertsen, D. E., Tambs, K. & Magnus, P. (1994) No differential heritability of intelligence test scores across ability levels in Norway. *Behavior Genetics* 24:337–39. [DCR]

Super, C. (1976) Environmental effects on motor development: The case of "African infant precocity." *Developmental Medicine and Child Neurology* 18:561–67. [aMJAH]

Takeuchi, A. H. & Hulse, S. H. (1993) Absolute pitch. *Psychological Bulletin* 113:345- 61. [aMJAH]

Tannenbaum, A. J. (1983) *Gifted children: Psychological and educational perspectives.* Macmillan. [WS]

Thompson, L. A. & Plomin, R. (1993) Genetic influence on cognitive ability. In: *International handbook of research and development of giftedness and talent,* ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH]

Torff, B. & Winner, E. (1994) Don't throw out the baby with the bath water. *The Psychologist* 7:361–62. [aMJAH]

Treffert, D. A. (1989) *Extraordinary people.* Harper & Row. [aMJAH]

Trehub, S. E. (1990) The perception of musical patterns by human infants: The provision of similar patterns by their parents. In: *Comparative perception, Vol. 1: Basic mechanisms,* ed. M. A. Berkeley & W. C. Stebbins. Wiley. [aMJAH]

Usher, J. A. & Neisser, U. (1993) Childhood amnesia and the beginnings of memory for four early life events. *Journal of Experimental Psychology: General* 122:155–65. [aMJAH]

Vispoel, W. P. & Austin, J. R. (1993) Constructive response to failure in music: The role of attribution feedback and classroom goal structure. *British Journal of Educational Psychology* 63:110–29. [aMJAH]

Vitouch, O. (1996) Expertise in music, chess, mathematics, . . . : Talent or training? Paper presented at the 5th ECHA Conference, Vienna, Austria. [OV]

Vollmeyer, R., Burns, B. D. & Holyoak, K. J. (1996) The impact of goal specificity on strategy use and the acquisition of problem structure. *Cognitive Science* 20:75–100. [RJStev]

Watson, J. B. (1914) *Behavior. An introduction to comparative psychology.* Holt. [OV]

(1930) *Behaviorism* (Norton edition, 1970). Norton. [RE]

Weisberg, R. W. (in press) Creativity and knowledge: A challenge to theories. In: *Handbook of human creativity,* ed. R. J. Sternberg. Cambridge University Press. [RWW]

Whittlesea, B. W. A. & Dorken, M. D. (1993) Incidentally, things in general are particularly determined: An episodic-processing account of implicit learning. *Journal of Experimental Psychology: General* 122:227–48. [RJStev]

https://doi.org/10.1017/S0140525X98341230 Published online by Cambridge University Press

Willerman, L., Schultz, R., Rutledge, J. N. & Bigler, E. D. (1991) *In vivo* brain size and intelligence. *Intelligence* 15:223–28. [DCR]
Winner, E. (1996a) *Gifted children: Myths and realities.* Basic Books. [EW]
(1996b) The rage to master: The decisive role of talent in the visual arts. In: *The road to excellence: The acquisition of expert performance in the arts and sciences,* ed. K. A. Ericsson. Erlbaum. [DHF, aMJAH, OV]
(1997) Giftedness vs. creativity in the visual arts. *Poetics* 24(6):3349–77. [MC]
Winner, E. & Martino, G. (1993) Giftedness in the visual arts and music. In: International handbook of research and development of giftedness and talent, ed. K. A. Heller, F. J. Mönks & A. H. Passow. Pergamon. [aMJAH]
Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. G. & Karp, S. A. (1962) *Personality through perception.* Harper & Row. [SB-C]
Zi-Xiu, Z. (1985) The psychological development of supernormal children. In: *The psychology of gifted children: Perspectives on development and education,* ed. J. Freeman. Wiley. [JF]
Zohar, A. H. (1990) Mathematical reasoning ability: Its structure and some aspects of its genetic transmission. Ph. D. thesis, Hebrew University of Jerusalem, Israel. [AHZ]