Psychological Review
1999, Vol. 106, No. 3, 435–457

0033-295X/99/$3.00

Talent and Its Development: An Emergenic and Epigenetic Model

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Although superior performance in games, sports, science, and the arts is often ascribed to talent, the hypothesized phenomenon may not be fully understood unless it is conceived as a multidimensional and multiplicative developmental process. This point is elaborated in the form of a 2-part emergenic–epigenetic model. The emergenic part treats domain specificity, profile heterogeneity, cross-sectional distributions and predictability, familial heritability, and domain complexity. The epigenetic part treats early versus late bloomers, early signs, cross-sectional distribution across the life span, talent loss and shifts in talent domain, and longitudinal predictability. Besides explaining the available cross-sectional and longitudinal data, the resulting model has critical implications for how best to investigate the development of exceptional performance in all talent domains.

Among the oldest and most persistent debates in the behavioral sciences is that concerning the relative importance of genetic endowment and environmental experience in the development of the human individual. Indeed, Francis Galton (1874) first explicitly labeled this problem *the nature–nurture issue* well over a century ago. This controversy has had many manifestations, but among the most hotly contested involves the closely related phenomena of genius and talent. At one extreme is the position that exceptional ability of any kind has a powerful inherited component. This view was expressed in John Dryden's (1693/1885, p. 60) famous remark that "genius must be born, and never can be taught." Galton himself was an early scientific advocate of this point of view. In his 1869 book *Hereditary Genius* Galton documented the existence of extensive family pedigrees for achievement domains as diverse as politics and religion, science and music, and competitive wrestling and rowing. At the other extreme are those who affirm that environmental factors, especially arduous education and training, deserve the credit for the emergence of talent and genius. For example, Sir Joshua Reynolds (1769–1790/1966, p. 37) once advised students at the Royal Academy of Arts:

> You must have no dependence on your own genius. If you have great talents, industry will improve them; if you have but moderate abilities, industry will supply their deficiency. Nothing is denied to well directed labour: nothing is to be obtained without it. Not to enter into metaphysical discussions on the nature or essence of genius, I will venture to assert, that assiduity unabated by difficulty, and a disposition eagerly directed to the object of its pursuit, will produce effects similar to those which some call the result of *natural powers*.

Pablo Sarasate, the violin virtuoso and composer, voiced a similar viewpoint more humorously after a critic hailed him as a genius: "A genius! For thirty-seven years I've practiced fourteen hours a day, and now they call me a genius!" (quoted in *Compton's Reference Collection CD ROM,* 1996).

In recent years, psychologists have increasingly favored this nurture account over the nature explanation. In the first place, investigations have unearthed a huge inventory of familial, educational, and sociocultural environments that apparently contribute to development in a wide range of talent domains (for reviews, see Simonton, 1987, 1997b). Even more significant is the contemporary research that demonstrates the supreme role that laborious preparation plays in the development of so-called talent (Bloom, 1985; Ericsson, 1996b; Hayes, 1989; Simonton, 1991b). Especially crucial is the role of what Ericsson and his colleagues have labeled *deliberate practice* (Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Römer, 1993). It has been shown that individual differences in performance in a wide diversity of talent domains can be largely attributed to the number of hours devoted to the direct acquisition of the necessary knowledge and skill. This demonstration is reinforced by the often weak and inconsistent evidence on behalf of inborn talent (Ericsson, 1996a; Ericsson & Lehmann, 1996; Howe, Davidson, & Sloboda, 1998). Some investigators have even suggested that the notion of talent or innate genius may be pure myth (e.g., Howe, Davidson, & Sloboda, 1998).

Needless to say, this question has much more than purely academic interest. The greatest creators, leaders, athletes, performers, and other exceptional achievers almost invariably find themselves honored with monuments, medals, awards, prizes, applause, and other forms of widespread and very often enduring acclaim (Galton, 1869; Simonton, 1991c, 1998a, 1998c). Hence, exceptional performance in most talent domains patently constitutes a culturally valued behavior. Furthermore, the notion that some people are born with more talent than others is firmly ingrained in everyday psychology. Talent is also frequently evoked as an explanatory principle by parents, teachers, and researchers and practitioners in the field of gifted education (Colangelo & Davis, 1997; Winner, 1996). So the resolution of this issue goes well beyond the abstract nature–nurture debate. Educational systems, and especially gifted-education programs, must be adjusted according to the facts of the case. Certainly programs dedicated to the early identification of talented children would lack scientific (and even

I thank Niels Waller and Ellen Winner for their useful comments on drafts of this article.

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moral) justification if the phenomenon of giftedness could be totally explained in terms of nurture rather than nature (see Howe et al., 1998). Such practical implications render all the more urgent a scientific resolution of this long-term controversy. The answer must ultimately decide whether psychological science will make any practical contributions to the conversion of potential talent to actual achievement.

As someone who has devoted more than a quarter century to discovering the environmental factors behind talent development, my professional inclination is to assign more weight to nurture than to nature (e.g., Simonton, 1984b, 1998d). Nonetheless, the talent hypothesis must receive a fair and thorough scientific evaluation. It remains possible that a consequential proportion of the variance in exceptional performance is explicable in terms of innate capacities. Therefore, for both theoretical and practical reasons, it is incumbent on psychologists to estimate that proportion as accurately as possible. Yet a precise evaluation of the contribution of such genetic factors is highly contingent on how talent is conceived to operate during the course of development. It is on this score that previous research may have failed. That is, talent may be a much more complicated process than assumed in most investigations. By working with overly simplistic conceptions of talent, investigators might have looked for evidence by methods that necessarily underestimated its significance. Hence, my purpose here is to present what might constitute a more realistic, but thus more complicated, model of talent and its development (cf. Simonton, 1998b).

I begin by defining exactly what the term *talent* is taken to mean throughout this article. Given that definition, I then develop a more complex theoretical model of talent. Once this model has been sufficiently elaborated, it will be subjected to an extensive empirical evaluation, including a detailed discussion of what psychologists must do to assess talent in specific domains of exceptional performance.

Talent Definition

According to the *American Heritage Electronic Dictionary* (1992), the primary definition of *talent* is "a marked innate ability," where *innate* means "possessed at birth; inborn" and *inborn* means "possessed by an organism at birth . . . inherited or hereditary." This accepted usage needs only modest elaboration to provide the foundation for the present theoretical model. In particular, *talent* is here defined as "any innate capacity that enables an individual to display exceptionally high performance in a domain that requires special skills and training." Such talent domains may include activities as diverse as entrepreneurial leadership, artistic creativity, Olympic sports, competitive chess, and concert performance. In contrast, having the ability to wiggle your ears would not be considered a talent by this restrictive definition, because highly specialized instruction and practice are probably not critical to the manifestation of this behavior. Two features of this definition deserve special emphasis:

1. Deliberate practice and other forms of expertise acquisition are assumed rather than dismissed. Although there exist occasional anecdotes about "untrained talents" emerging *de novo*—like the rather casual manner in which Paul Robeson launched his illustrious singing career—such instances are probably too infrequent and poorly documented to count as serious scientific data (Howe et al., 1998). Besides, the most useful definition of *talent* is that which applies to the largest number of individual cases and to the greatest variety of talent domains. By those criteria, considerable training, coaching, and practice must be presupposed.

2. According to this definition, talent is necessarily innate. The capacity is considered to be innate when it consists of one or more components that feature substantial or nontrivial heritability coefficients. It is significant that the innate capacity is said to comprise all attributes that directly or indirectly facilitate extraordinary performance in a qualifying domain. These attributes may entail cognitive abilities and styles, motives and needs, personality traits and profiles, and interests or values. It does not matter what the endowed attributes are, so long as they enhance performance in the domain. By the same token, it is deemed irrelevant whatever may be the precise manner in which the traits contribute to the enhancement. The contribution may involve either the acquisition of a domain-relevant expertise or the overt manifestation of that acquired expertise.

To illustrate the former possibility, one study of 120 classical composers found that the most eminent composers (a) had less formal music training before taking up composition and (b) had less compositional practice before they began to make lasting contributions to the classical repertoire (Simonton, 1991b). This result implies that the greatest composers could master the materials and techniques of their talent domain at a faster rate than their less distinguished colleagues (see also Simonton, 1991a). Such precocious acquisition parallels the common conception of innate intellectual ability as supporting the accelerated mastery of knowledge and skills (e.g., Jensen, 1992). Although it is customary to think of such phenomena as entailing cognitive abilities, accelerated expertise acquisition could just as well ensue from dispositional attributes, such as unusual energy and special interests, which maintain the intensity and focus of the required learning and practice (see, e.g., Cox, 1926; Csikszentmihalyi, Rathunde, & Whalen, 1993; Winner, 1996).

By contrast, some attributes may operate later in talent development by directly affecting performance rather than expertise acquisition. That is, some aspiring talents may suffer from personal handicaps that prevent them from doing as well as they might during practice sessions. For example, some athletes and performers can suffer from the frustrating liability that they too often choke under pressure or experience stage fright no matter how well they have practiced a given maneuver, routine, or presentation (Baumeister, 1984). If this involuntary disruption of performance arises from an overly reactive sympathetic nervous system, and if that emotional responsiveness has a sufficiently large heritability coefficient, then this would also count as part of the innate capacity required by the adopted definition (for the heritability of emotional excitability see, e.g., Bouchard, 1994; Bouchard, Lykken, McGue, Segal, & Tellegen, 1990). Apropos of such possibilities, the Canadian golfer Moe Norman has been identified as someone whose distinctive temperament and attitude may intervene at the performance level in a talent domain (see Starkes, Deakin, Allard, Hodges, & Hayes, 1996). Despite his becoming a phenomenally skilled golfer by means of a prodigious amount of deliberate practice, his personality seems to "lack what it takes" to make it equally big in the world of competitive sports.

Admittedly, probably not all psychologists would accept the foregoing definition without qualifications. On the one hand, some investigators may think that the current definition is too narrow, for it is conceivable that a talent might be innate without being genetic. Specifically, various prenatal influences can shape personal characteristics independent of genetic effects (e.g., Phelps, Davis, & Schartz, 1997). A highly relevant example is the "Geschwind hypothesis" that testosterone levels in the intrauterine environment may determine early brain development and thereby affect the emergence of certain talents (McManus & Bryden, 1991; see, e.g., Benbow, 1986). Nevertheless, not only does this conjecture remain highly controversial, but in addition the proposed developmental phenomenon would apply to only a restricted subset of domains (e.g., mathematics). Hence, the definition selected here has the asset of maximum applicability. Besides, the existence of nongenetic innate capacities would in most instances serve only to strengthen the main thesis of this article, which is to document the heterogeneous and intricate nature of talent.

On the other hand, some researchers may believe that the chosen definition is too broad: Genetic factors that facilitate performance are lumped together with those that accelerate acquisition, and there exists no explicit provision that the genetic factors be highly specific to the talent domain (cf. Howe et al., 1998; Winner, 1996). Yet I maintain that an inclusive definition remains closest to the common meaning of the term. What really matters is whether there exists some innate endowment that enhances exceptional performance, not the exact nature of that endowment or how it especially operates. If otherwise, then psychologists would be obliged to embrace a cumbersome fourfold typology of potential genetic influences—specific versus general factors that directly affect performance in a talent domain and specific versus general factors that primarily affect expertise acquisition within that domain. Complicating matters all the more is the fact that there exist degrees of specificity and generality (i.e., the variable number of domains to which endowed traits are pertinent). Height, for instance, is relevant for political leadership just as it is for certain sports (Simonton, 1994). In addition, there certainly exist factors that may operate at both acquisition and performance levels, but in varying amounts, depending on the domain (e.g., the ability to sustain focused attention on a single task). It is accordingly far more theoretically elegant to posit that "having a talent" for superior attainment within a domain is simply an integrated function of traits that might fall within one or more of these four classes of genetic factors. The detailed partitioning of these various influences then becomes a useful problem left for research into the basis of particular talents (see the Empirical Evaluation section for more discussion).

Model Formulation

The above definition provides the basis for a two-part model of talent. The first part describes individual differences, whereas the second part examines how these individual differences develop across the formative years of a person's life.

Emergenic Individual Differences

The model begins by assuming that endowed capacity consists of multiple components. In line with the definition given above, these components entail all physical, physiological, cognitive, and dispositional traits that facilitate the manifestation of superior expertise in a talent domain. Although most of these components might be somewhat domain specific (e.g., hand size for virtuoso pianists), some undetermined number may be rather generic (e.g., general intelligence, or "Spearman's *g*"; Spearman, 1927). Whatever the details, the k components that define the domain can be designated $C_1, C_2, C_3, \ldots C_j, \ldots C_k$. Let us also assume that each component is assessed on a ratio scale, with a true zero point that represents the complete absence of that trait (i.e., $C_j \geq 0$). To simplify the derivations, these components are presumed to be uncorrelated, that is, $cov\ (C_j, C_l) = 0$ for all $j \neq l$ (where *cov* indicates the covariance operator). Later I examine what happens if one alters these and other simplifying assumptions (see the Conceptual Elaboration section).

Now the potential level of talent is some integrative function of the k components. One obvious possibility is to conceive the composite talent as a simple weighted linear sum of the contributing components. Such a summation procedure would be consistent with the general linear model that figures so prominently in the psychological sciences. The predicted value of the dependent variable in a multiple regression is taken as a weighted sum of the independent variables, whereas each component in a principal-components analysis is defined by a weighted sum of the items (Loehlin, 1992b). Although such linear additive models seem so natural and simple, I argue that a weighted multiplicative model may often better accommodate the genuine complexities of the phenomenon in many talent domains. That is, let us posit that

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

where P_j is the potential talent for the ith individual, C_{ij} is the ith individual's score on component j ($i = 1, 2, 3, \ldots N$), and w_j is the weight given to the jth component ($w_j > 0$). Observe that the component weights did not insert the index for case number, for, according to theory, these weights are dictated by the specific requirements for accomplished performance in a given talent domain. The symbol Π specifies that the components are multiplied together, which requires that the weights w_j function as exponents (rather than as factors, which occurs in the additive model).[1] The specific magnitudes of the weights depend on the variances of the components and, most critically, on the nature of the talent domain. The domain-contingent specification of the weights reflects the fact that even very similar talents probably do not require the exact same mix of underlying facilitative traits. For example, excellent motor coordination is far more important for music performance than it is for music composition, just as height is more critical for basketball than it is for ping-pong. Likewise, a generic component such as Spearman's *g* would presumably have more

[1] Introducing weights as factors in a multiplicative model will not work because of the commutative law of multiplication, which states that the value of a product is not changed when the order of the terms is changed. It may also be worth reminding readers that for any $C_{ij} > 0$, $C_{ij}^0 = 1$ and $C_{ij}^1 = C_{ij}$, but that 0^0 is undefined. It is for the latter reason that the weights must be nonzero and positive if the components are allowed to have zero values.

influence for highly intellectual talents, such as chess, than for less intellectualized talents, such as boxing (Gottfredson, 1997).

In part, a multiplicative model may often be chosen over an additive one in order to recognize a fundamental reality. If someone has absolutely no capacity in just one of the essential components, then that person cannot possibly display any talent potential. In different terms, the absence of a single required component can exert veto power over the expression of the composite characteristic. To offer an extreme but uncontroversial case, an individual who is completely color blind cannot possibility exhibit any talent outside the domain of monochromatic visual art. The multiplicative model is also more consistent with current conceptions of creativity, genius, and outstanding achievement (see, e.g., Allison, 1980; Eysenck, 1995; Jensen, 1996; Lykken, McGue, Tellegen, & Bouchard, 1992; Shockley, 1957; Sternberg & Lubart, 1995; Walberg, Haertel, Pascarella, Junker, & Boulanger, 1981). Of these several applications, it is the emergenic model of Lykken (1982, 1998) that has the most relevance here.

The concept of emergenesis was inspired by certain peculiar research findings in the behavior genetic study of twins. Because monozygotic twins inherit identical genotypes, such twins tend to be extremely similar on both physical and psychological attributes. Dizygotic twins, by comparison, are no more similar genetically than are regular full siblings. Nonetheless, such fraternal twins share enough genes that they should exhibit a certain amount of similarity on a great many characteristics. Even so, for some traits monozygotic twins are *too* similar relative to dizygotic twins. That is, a physical or psychological attribute that shows no heritability in fraternal twins and other siblings might display remarkably high heritability for identical twins. This will happen when the trait in question requires the simultaneous presence of several separate traits, each of which is inherited independently. If one monozygotic twin inherits the entire collection, its twin will obviously do so as well. But it should be extremely unlikely that two siblings originating from different zygotes would inherit all the requisite traits together. In general, an individual-difference variable is emergenic when it consists of multiple genetic components, all of which must be inherited for the main character to appear at all. The confluence of these diverse but well-defined traits is what underlies a new, more comprehensive, emergent trait. Because emergenic attributes are configurational, the genotypic whole is greater than the mere sum of its genetic parts. The paradoxical upshot is that a characteristic can be highly inheritable and yet exhibit little or no tendency toward familial inheritance.

Lykken (1982) stated that such emergenesis may help explain the emergence of exceptional talents. For instance, he applied the concept to explain the astonishing mathematical talent of Karl Friedrich Gauss, a genius whose ability had no anticipation among his progenitors nor any residual among his progeny. Newton, Shakespeare, Michelangelo, and Beethoven offer comparable illustrations (Simonton, 1994). Lykken (1998) also used this explanatory principle to explain why the great Triple Crown race horse Secretariat was unable to sire offspring with comparable success. These same researchers have also speculated that physical attractiveness may entail a special configuration of inherited features that make this characteristic emergenic—a significant contingency insofar as some achievement domains, such as acting, telecasting, and modeling, may include "good looks" among the essential components. Later I review the behavior genetic evidence that some extremely consequential talents may have an emergenic foundation (see the section, Empirical Evaluation).

This emergenic model defined by Equation 1 has six major implications for comprehending individual differences in talent. These concern (a) the domain specificity of talent, (b) the heterogeneity of component profiles within a talent domain, (c) the skewed frequency distribution of talent magnitude, (d) the attenuated predictability of talent, (e) the low familial inheritability of talent, and (f) the variable complexity of talent domains.

Domain Specificity of Talent

Instead of a single highly specialized component that determines performance in a talent domain, the model substitutes a multiplicative composite of separate components, each component with its own distinctive weight. In that more complicated sense, an individual's talent potential P_i remains domain specific. The weights define a highly specialized profile of genetic attributes required for success in a particular domain. A gifted child may be a highly talented musician, but very poor at arithmetic, assuming that the weight for arithmetic ability is zero. Beethoven provides a prime example: an exalted musical talent with virtually no mathematical ability and only passable skill in the verbal domain.

On the other hand, the domain specificity of the weighted multiplicative composite P_i does *not* imply that *all* of the k components making up the trait configuration will themselves be domain specific. On the contrary, a great many components with nonzero weights may have relevance for two or more talent domains, and some may even be pertinent for all areas of achievement. Besides Spearman's g, these generic contributors to talent might include energy, enthusiasm, persistence, independence, and ego strength (see, e.g., Cox, 1926; Csikszentmihalyi et al., 1993; Galton, 1869; Simonton, 1991d). There might even occur domainless talents that consist of nothing other than these generic traits. Such genetic talent might then be channeled by idiosyncratic life experiences toward the development of exceptional expertise within a specialized domain. Such a process would fit Samuel Johnson's (1781, p. 5) assertion that "the true Genius is a mind of large general powers, accidentally determined to some particular direction" (but see Achter, Lubinski, & Benbow, 1996). If persons score high enough on all of the participating components, they might even attain distinction solely for their immense generic potential alone. Someone like Marilyn Vos Savant, who has quite successfully capitalized on her possession of the world's highest recorded IQ according to the *Guinness Book of Records* (McFarlan, 1989), might offer an example.

These possibilities aside, the crucial point is this: The specificity of a talent may often reside not in any highly specialized component but rather in the specific weighted multiplicative integration of the contributing innate components.

Heterogeneity of Component Profiles Within a Talent Domain

Although talent potential (P_i) is domain specific in terms of the component weights (the *w*s), it by no means constitutes a homogeneous dimension in a population of individuals exhibiting equally high levels of the talent under scrutiny. This pervasive heterogeneity arises because P_i was assumed to consist of multiple components that enter into trade-off relationships by means of the hypothesized multiplicative function. Stated more formally, even though there may exist two individuals, 1 and 2, such that $P_1 = P_2$, that does *not* imply that $C_{1j} = C_{2j}$ for all j, or even for most j. So long as neither person is lacking an essential component, the trait profiles on the k components may diverge appreciably—so much so that they may look like rather different talents. One piano prodigy may have a better rhythmic sense, another a superior feel for melodic line, but their overall talent—as judged by performance in piano competitions—may be indistinguishable.

Some of the conceivable variation in component profiles is displayed in Table 1. This shows a hypothetical case of five children with equivalent talent scores ($P_i = 100$) but with highly disparate scores on the three contributing components (all $w_j = 1$). Only the first child exhibits more or less equal scores on all three components, whereas the remaining four exhibit various types of inequalities. The fifth child has virtually all of his or her talent concentrated on the first component. It should be obvious that the number of permissible component profiles among equally talented children is essentially infinite.

The same heterogeneity holds for the absolutely untalented. Because it takes only one $C_{ij} = 0$ for $P_i = 0$, and because any number of components may take zero values, there are many different pathways that result in the failure to exhibit talent. Specifically, there exist $2^k - 1$ alternative routes to the lack of talent. With just 10 prerequisites, there will appear 1,023 distinct ways of failing to display talent. Even with only three essential components in a talent domain, there will be seven different varieties of the untalented. These seven possibilities are shown in Table 2. Notice that if at least one component is absent, the remaining components can have any values whatsoever, immensely increasing the available diversity of trait profiles.

Thus, neither the talented nor the untalented must necessarily reveal characteristic trait profiles according to the emergenic model. Even in a relatively simple domain where $k = 10$—the talent equivalent of a decathlon—the number of ways of winning and losing are truly unlimited.

Skewed Frequency Distribution of Talent Magnitude

According to the model, exceptional talent should be extremely rare. This fits most dictionary definitions of the concept, which emphasize the rarity of the attribute (e.g., *American Heritage Electronic Dictionary,* 1992). It is a quality that many lack and only a few can claim to have to a high degree. The reasons for this inequitable distribution of talent are twofold:

1. There may exist a large proportion of children in a given population for whom $P_i = 0$ simply because these children have at least one essential component such that $C_{ij} = 0$. These children are, strictly speaking, untalented for all domains that require those specific abilities, motives, interests, or values. A child who has absolutely no capacity for self-discipline and hard work may be unsuited to any achievement domain that presumes extensive and intensive deliberate practice (Bloom, 1985; Cox, 1926; Galton, 1869; Simonton, 1994).

2. Under a multiplicative model of talent, the predicted probability distribution of P_i across any sufficiently large N must be highly skewed right. The vast majority of the cases will be clumped in the lower end of the distribution, within 1 *SD* below the mean. Only a minority will enjoy above-average scores. And a tiny elite will occupy the long upper tail that stretches out a dozen or more standard deviations above the mean (see Simonton, 1988b, Figure 4.1, p. 66). For example, if all the component traits are normally distributed, their product will exhibit a *lognormal* distribution (Aitchison & Brown, 1957). But it does not really matter how the component scores are distributed to obtain this result. Even if their cross-sectional distributions feature a rectilinear distribution, the distribution of potential talent will be highly skewed.

The predicted rarity of talent may be illustrated by a simple demonstration published many years ago (Burt, 1943). Suppose that there exist just two factors underlying a particular behavior. These factors are assumed to be measured on the same 5-point ratio scale, including the zero point (i.e., 0, 1, 2, 3, 4). In addition, the scores on the two factors are assumed to be distributed according to the binomial law; that is, the frequencies are set to be proportional to 1, 4, 6, 4, 1. In percentages, these proportions become 6.25, 25.00, 37.50, 25.00, and 6.25. This distribution is the discrete approximation to the continuous normal distribution. Although the distribution for the two components is accordingly symmetric, their product will not be. In particular, rescaling the multiplicative score to the same five categories of the components, the percentages become 49.60, 36.00, 10.90, 3.10, and 0.40. Almost exactly half of the children would fall in the lowest group, and 12% would have no talent whatsoever. In contrast, less than 0.5% would boast the highest possible talent potential. Obviously, unlike the bell-shaped curve of the two participating

Table 1
Hypothetical Three-Component Profiles for Five Children With Equivalently High Potential Talent

	Component scores (k = 3)			
Child (i)	C_{i1}	C_{i2}	C_{i3}	P_i
1	5	5	4	100
2	50	2	1	100
3	2	2	25	100
4	1	20	5	100
5	100	1	1	100

Note. The component weights are all assumed to be equal such that $w_j = 1$ for all j. P_i = potential talent; w_j = component weight.

Table 2
Hypothetical Three-Component Profiles for Seven Children With Zero Potential Talent

	Component scores (k = 3)			
Child (i)	C_{i1}	C_{i2}	C_{i3}	P_i
1	0	60	10	0
2	5	0	50	0
3	20	20	0	0
4	0	0	1	0
5	100	0	0	0
6	0	30	0	0
7	0	0	0	0

Note. The component weights are all assumed to be equal such that $w_j = 1$ for all j. P_i = potential talent; w_j = component weight.

factors, their multiplicative combination is very much skewed right. The highest levels of talent will be as extreme as they are rare.

Attenuated Predictability of Talent

It is crucial to recognize that the previous implication is unique to a multiplicative model. If one used the alternative, additive formulation, one would not predict a large proportion of untalented people. The latter outcome would require a large number of people for whom $C_{ij} = 0$ for every component, an unlikely possibility in comparison to the requirement that only one $C_{ij} = 0$. Likewise, the skewed distribution is required of a multiplicative model but must be contrived in an additive model. In general, the sum of normally distributed traits will also be normally distributed—indeed, usually even more so than its components. For example, the distribution of scores on an ability test with a random mixture of items of varying difficulty will be normal. In any case, these distinctive features of the multiplicative model have a critical methodological consequence: The correlation between P_j and any particular C_{ij} across a sample of size N will be noticeably reduced. This prediction of attenuation arises from three sources:

1. Many of those children with at least one $C_{ij} = 0$, and hence $P_i = 0$, may have extremely high scores on one or more of the remaining $k - 1$ components. This possibility is indicated in Table 2, where the untalented can be shown to have drastically variable component profiles. This would fill any data set with cases where the expected proportional relationship between an investigated component and the composite talent will be violated. In other words, there will be many instances where a child who scores very highly on a particular component will nonetheless be counted among those with no talent.

2. Even among those for whom $P_i > 0$ because $C_{ij} > 0$ for all j, the nonlinear and nonadditive trade-off relationships among the several components would again work to undermine the empirical component–talent correlations. As is apparent from inspection of Table 1, many children might have similar levels of talent potential but rather disparate scores on the participating components. This heterogeneity, then, lowers the predictability of talent using component scores.

3. Because the distribution of talent would be far more skewed than the distribution of the talent components, the expected correlations will be reduced. Even a multiple regression analysis will not circumvent this problem, because the linear composite will most likely have a roughly normal distribution. The repercussion would then be a large number of residual outliers in the extreme upper tail of the distribution. These outliers are youths with talent so exceptional that they cannot be adequately explained by a linear, additive model.

The above predictive failure would emerge even if all relevant variables were incorporated into the regression equation and all were measured with perfect reliabilities. The only route to explaining 100% of the variance is to fit an explicitly multiplicative model, a rather rare statistical practice in the behavioral sciences.[2]

Low Familial Inheritability of Talent

A second methodological implication of the multiplicative model also has critical conceptual implications. Contrary to what Galton (1869) and others have tried to demonstrate (e.g., Bramwell, 1948; Simonton, 1983), exceptional talent would not necessarily be expected to exhibit genetically based family pedigrees. Because talent has been conceived as an emergenic trait, it would appear only sporadically, if at all, in family lines. Most strikingly, this result would hold even if all of the k components had heritability coefficients of unity. Even under such an unlikely circumstance, it may take an extreme stroke of luck for all siblings in a family to inherit all necessary traits. Only if the talent can be found in both paternal and maternal lines for several generations would such an outcome seem at all likely. The extensive pedigree of the Bach family could possibly represent one of these rare instances, for J. S. Bach came from a very long line of musical talents (Galton, 1869). There was even a high degree of assortative mating on that trait, as intimated in Bach's *Anna Magdalena Notebook,* written explicitly for his musically gifted second wife.

Nevertheless, for reasons to be discussed later, the pedigree method does not provide the most conclusive approach to testing this particular implication of the model. A better method would be to utilize twins. Monozygotic twins should exhibit highly correlated talents, whereas dizygotic twins should exhibit talents no more correlated than seen in unrelated individuals (or in regular siblings). To underline the unusual nature of this pattern, it must be recalled that a commonplace method for estimating heritabilities is to compare the difference between the intraclass correlations for monozygotic and dizygotic twins. The specific formula is $h^2 = 2(r_{mz} - r_{dz})$, where h^2 is the heritability coefficient, r_{mz} is the intraclass correlation for monozygotic twins, and r_{dz} is the intraclass correlation for dizygotic twins (Falconer & Mackay, 1996). Clearly, this formula must routinely yield implausibly high estimates in instances of emergenic traits, for then $h^2 \approx 2\, r_{mz}$. Indeed, heritability estimates can exceed unity even in large samples! This reflects the fact that this formula assumes additive genetic variance, in contrast to emergenic inheritance. The intraclass correlation for dizygotic twins would otherwise depart appreciably from zero and thus considerably lower the difference $r_{mz} - r_{dz}$. In this latter instance, family members will be more similar in their talents.

Variable Complexity of Talent Domains

It is now opportune to make explicit a significant feature of the model defined by Equation 1. I have left open the value of k, the parameter that indicates the number of innate components essential for performance in a talent domain. It seems reasonable to postulate that this parameter varies from domain to domain. Some domains are complex, with rather large ks, whereas others are simple, with quite small ks. Given this interdomain variability, one can then inquire regarding the consequences of increasing the number of components defining a talent domain. The repercus-

[2] An alternative would be to take logarithms of both dependent and independent variables, which would make the equation linear. That is, a logarithmic transformation of Equation 1 would yield the following linear and additive regression model: $\log P_i = \Sigma\, w_j \log C_{ij}$. Still, strictly speaking, this solution would work only for a sample of talented individuals for whom all component scores (and hence the composite score) exceed zero, because the logarithm of zero is undefined (but see Allison, 1980, for other estimation options).

sions essentially repeat most of the implications already discussed but allot them much greater emphasis. On average, as k increases for a domain: (a) component profiles become even more heterogeneous for both talented and untalented individuals with respect to the domain; (b) the frequency distributions of talent magnitude become more skewed, and the proportion of untalented individuals increases; (c) talent becomes increasingly less predictable from either the components separately or from some linear, additive composite of those components (and there appear extreme outliers on the upper end of the distribution); and (d) the familial heritability of the talent declines, as accomplishment in the domain becomes increasingly emergenic and the odds of inheriting the entire configuration ever more small.

To illustrate, let us examine two contrasting cases. At one end is a domain with $k = 1$. An instance might be intellectual giftedness exclusively defined by an intelligence test that loads most heavily on Spearman's g (Stanley, 1997). Terman's (1925) gifted children, for example, were identified as "geniuses" according to their performance on the Stanford–Binet IQ test, which measures mostly general intelligence. Clearly such a talent has no latitude for heterogeneity. To the extent that the test measures a single latent variable, there will be but one path to a high score: getting all or most of the questions right. Furthermore, the distribution of such talent is very closely normal (Burt, 1963; Galton, 1869), and there exists virtually no person who can be said to exhibit no talent at all (i.e., zero intelligence). At the same time, the talent is highly predictable, because the talent and its latent component are synonymous (within the limits of measurement error). Finally, as is well known, general intelligence exhibits an exceptionally high degree of familial inheritance, perhaps the greatest of all major psychological attributes (Plomin, Owen, & McGuffin, 1994; Plomin & Petrill, 1997). It is not an emergenic trait.

At the other extreme is some talent domain where k is rather large. Opera composition, architecture, and choreography may all provide examples, but take choreography for the illustration. Although Gardner (1993) assigned Martha Graham to the kinesthetic intelligence, it is reasonable to assume that she, and other successful choreographers, requires more than just that form of intellectual capacity. At the very minimum, choreography demands capacities in spatial–visual and musical thinking. Sound interpersonal skills are probably just as important in dealing with a dance company, and perhaps even some modicum of mathematical ability may be useful in the early years, before the company can hire its own business director and accountant. It is also not unlikely that some intrapersonal intelligence might facilitate the ability to introduce emotional depth into particular choreographic interpretations. Hence, perhaps a talented choreographer needs tolerable scores on most or all of Gardner's (1983, 1998) several intelligences. Moreover, who knows what special muscular, skeletal, and physiological attributes are necessary to pursue the dancing career that is invariably the essential first step to that of choreography? Whatever the details, the multiplicative model leads us to expect that individuals displaying a choreographic talent would be highly heterogeneous. The talent would be very rare, with many untalented (even among dancers) and with a mere handful of persons boasting the lion's share of the total available talent. Last, choreographic talent would not be easily predicted even from component traits, and the talent itself would exhibit a strongly emergenic form of inheritance.

To make some of the above assertions more concrete, I conducted a Monte Carlo simulation of potential talent in domains that differ regarding the number of components. Specifically, each component score was based on a 5-point (0–4) scale, randomly generated under a binomial distribution ($p = .5$). Ten scores were produced for 10,000 cases. Because of the sample size, these randomly generated component scores were practically uncorrelated ($-.02 < rs < .03$). The component weights for the multiplicative models were always set equal to unity (i.e., $w_j = 1$ for all j). Similarly, the additive models were each defined as the simple, unit-weighted sum of the k components. There was no stochastic component introduced into either set of models, so that talent potential was a deterministic function of the components (e.g., the simulated scores for the multiplicative model were defined exactly according to Equation 1).[3] Table 3 presents the relevant univariate and multiple regression statistics for ks of 1, 5, and 10, and for both additive and multiplicative models.

With respect to univariate statistics, it is clear that the multiplicative model generates ever more extreme distributions as k increases. The means and standard deviations greatly enlarge even though both statistics were divided by k to facilitate comparisons. Skewness and kurtosis dramatically expand as well, indicating that the distribution becomes increasingly skewed right (positive skewness) and leptokurtic (positive kurtosis). Stated less abstractly, the cases become even more bunched toward the lowest possible scores, with only a small proportion of cases exhibiting astronomically high scores. It is telling that the percentage of individuals having no talent goes from approximately 6% to 47%, or nearly half. Likewise, the maximum z score (the mean-deviation score divided by the standard deviation) increases substantially, so that in the 10-component situation the most talented individual is 32 *SD* above the mean! This contrasts greatly with the additive model, where the utterly untalented cannot appear in a hypothetical population even this large, unless k is very small. This complete absence of the totally untalented under an additive model reflects the fact that the probability of having all $C_{ij} = 0$ for a given i is 0.625^k, which yields the tiniest of odds even for $k = 5$. Note, finally, that the additive model displays no tendency for the statistics to get more extreme, with the very modest exception of the maximum z score. In fact, *SD/k* and kurtosis actually tend to shrink as k increases.

The multiple regression results show what happens when the potential talent scores (P) are regressed onto the k component scores across the 10,000 simulated individuals. The statistics are tautological for the additive model: 100% of the variance is ex-

[3] Because I am dealing with talent rather than expertise or performance, it is reasonable to omit a stochastic term. Innate ability should be totally determined by the genetic components. Nonetheless, the introduction of a stochastic or error term would appreciably affect the inferences only if two unlikely conditions hold simultaneously: (a) the error variance were extremely large relative to the variance of the multiplicative term and (b) the stochastic term entered in an additive rather than a multiplicative fashion. The first condition would imply that the genotype has a minor role in determining innate capacity, whereas the second condition would imply that all nongenetic factors underlying innate ability contribute in a radically different way than do the genetic factors. If either of these conditions fails to hold, then the central implications of the Monte Carlo simulation emerge unscathed.

Table 3
Monte Carlo Simulation of Talent: Additive and Multiplicative Models for Three Hypothetical Domains

Statistic	Additive model $k = 1$	Additive model $k = 5$	Additive model $k = 10$	Multiplicative model $k = 1$	Multiplicative model $k = 5$	Multiplicative model $k = 10$
Univariate						
M/k	2.01	2.00	2.00	2.01	6.43	106.93
SD/k	1.00	0.45	0.32	1.00	9.06	320.06
Skewness	0.02	−0.02	0.02	0.02	3.04	10.69
Kurtosis	−0.50	−0.13	−0.07	−0.50	14.41	207.32
$\% P_i = 0$	5.84	0.00	0.00	5.84	26.79	46.94
Maximum z score	1.99	3.56	3.76	1.99	10.60	32.47
Multiple regression						
Average β_{Pj}	1.00	0.44	0.31	1.00	0.35	0.17
$R^2_{P.123\ldots k}$	1.00	1.00	1.00	1.00	0.61	0.29
Maximum studentized residual	0	0	0	0	12.67	38.75

Note. $N = 10{,}000$. Component scores were based on a 5-point (0–4) scale, randomly generated under a binomial distribution ($p = .5$). Results for $k = 1$ must be identical under both models, but the statistics are duplicated anyway to assist comparisons within each model. The components' weights are set equal to unity for both models (i.e., $w_j = 1$ for all j). w_j = component weight.

plained, and the residual scores are zero. The standardized partial regression coefficients, β_{Pj} (for P regressed onto component C_j), closely approximate the maximum possible size for the number of variables in the equation (i.e., for equally weighted components $\beta_{Pj}{}^2 \rightarrow r_{Pj}{}^2$ and $r_{Pj}{}^2 \rightarrow 1/k$ as $N \rightarrow \infty$). By comparison, the standardized coefficients for the multiplicative model are noticeably smaller, especially under the 10-component condition. The proportion of variance explained in potential talent is considerably smaller as well. Just as telling is the fact that the maximum studentized residual becomes quite large as the number of components increases. A studentized residual of around 13 is remarkable enough, so one three times larger still is even more so.

Needless to say, there is no theoretical or empirical reason why k cannot exceed 10. For really complex domains—such as opera composition, architecture, and choreography—all of the prominent trends shown in Table 3 would become exaggerated all the more. This can be illustrated by increasing the maximum k by just 50%, or $k = 15$. The distribution now features a skewness of 27.95 and a maximum z score of 57.41; more than 61% of the population would exhibit no talent. The R^2 shrinks by more than half, to .12, so that only 12% of the variance is now predicted by a linear, additive model. Furthermore, the average β_{Pj} (and hence r_{Pj}) falls to .09, which is far smaller than the .26 expected under the additive model. Last, the maximum studentized residual grows to 74.79. Exceptional talent in a 15-component domain would be rare and elusive indeed.

Taken in sum, the weighted multiplicative model guides us to a rather more complicated understanding of how talent might operate among children, adolescents, and adults. As will become evident later, sufficient data can be marshaled in support of this model that it can be said to enjoy empirical plausibility as well.

Epigenetic Development

The individual-differences model, for all its potential utility, remains too simplistic. The central deficiency is its static nature. Talent is implicitly conceived as a completely realized attribute bestowed at birth, or even at the moment of conception. Each infant inherits a distinctive component profile, which then persists throughout the life span. This view seems uncomfortably to echo the outdated preformationist doctrine in which the fertilized egg was a homunculus, a miniature version of the adult human being. This static conception of talent is plainly wrong. Talent development must instead entail some form of epigenesis. That is, starting with a relatively undifferentiated state, the various traits slowly appear and differentiate over time. After all, the diverse components that constitute a talent must ultimately depend on underlying neurological, muscular, skeletal, and physiological structures (Obler & Fein, 1988). These structures are not prewired at birth but rather emerge gradually during the course of long-term interactions between the internally developing organism and appropriate environmental stimulation (Bronfenbrenner & Ceci, 1994; Elman et al., 1996). Furthermore, because these diverse substrates have their own distinct epigenetic trajectories, the development of a talent must represent a highly dynamic process. Infancy, childhood, adolescence, and even adulthood will see the latent components undergoing various transformations. Two crucial features of this hypothesized developmental process must be highlighted.

1. The various innate components that make up a talent can often develop more or less independently of each other. To some reasonable extent, components have a modular character (Fodor, 1985; Pinker, 1997). As a repercussion, the growth of various structures and functions can be governed by their own epigenetic rules.

2. To a very large extent, these epigenetic programs are subject to individual differences. A child might exhibit accelerated development on one component while displaying retarded or arrested development on another. Talent development can thus entail a highly idiosyncratic process.

The reality of these two aspects is demonstrated by the extreme diversity of developmental pathways actually observed. The occurrence of autistic savants, for instance, provides ample evidence for the possibility that some components might develop at rates totally at variance with other components (Howe, 1989). A child might have arithmetic, musical, or artistic skills that few adults can match, and yet be well behind his or her age group on even the most basic abilities needed for survival in the world (e.g., the well-known case of Nadia, as reported in Selfe, 1977). Asynchronous development is also apparent in many child prodigies, albeit the discrepancies are less dramatic (Radford, 1990). It is also commonplace to speak of early bloomers and late bloomers in implicit acknowledgment that developmental patterns can vary tremendously from person to person (e.g., Busse & Mansfield, 1981).

Therefore, the next step in the evolution of a more sophisticated model is to incorporate these complexities. I start by making explicit that the components are not static entities but rather develop over the course of infancy, childhood, adolescence, and adulthood. That is, each component is some function of time, so that $C_{ij}(t) = f_{ij}(t)$, where t represents age in years ($t \geq 0$). By appending two indices, i and j, to the epigenetic function, I am making explicit that the developmental trajectories may not be identical across all individuals. Consequently, Equation 1 must now be changed to

$$P_i(t) = \prod_{j=1}^{k} C_{ij}(t)^{w_j}, \tag{2}$$

to reflect the age dependence of composite talent. The question naturally arises what the age functions are for the various components. Let us posit that the development of every component adopts the linear form

$$\begin{aligned} C_{ij}(t) &= 0, \text{ if } t < s_{ij}, \\ &= a_{ij} + b_{ij}t, \text{ if } s_{ij} \leq t < e_{ij}, \text{ and} \\ &= a_{ij} + b_{ij}e_{ij}, \text{ if } t \geq e_{ij}. \end{aligned} \tag{3}$$

Here s_{ij} is the age at which development of component C_{ij} first starts (or "kicks in") for individual i, whereas e_{ij} is the age at which development of component C_{ij} ends for individual i. The remaining two parameters, a_{ij} and b_{ij}, are simply the coefficients of the linear equation (intercept and slope, respectively) that define how scores on the given component change between s_{ij} and e_{ij}. Normally, $a_{ij} = 0$, except when development commences with a substantial jump start. On the other hand, most often $b_{ij} > 0$ to capture the positive growth trajectory for a particular trait (but see the later discussion of talent loss).

The linear functions described by Equation 3 can closely approximate various nonlinear developmental trajectories, including the logarithmic, logistic, and power functions. For example, the correlation between age and the logarithm of age for $0 < t < 20$ is .93, and the correlation between age and the square root of age over the same interval is .99. Equation 3 can even precisely duplicate other developmental trends. In particular, if one makes the intercept $a_{ij} = e_{ij}$ and $b_{ij} = 0$, one obtains a step function where the component instantaneously reaches its maximum value when the component fires up at $t = s_{ij}$. Thus, the equations can accommodate, if necessary, any quantum leaps or qualitative jumps in the emergence of a genetically endowed trait. This epigenetic pattern might be most apt for what might happen for certain components at the onset of puberty, when many talents can undergo a rapid transformation in either a positive or a negative direction (see, e.g., Bamberger, 1986; Csikszentmihalyi et al., 1993). Most critically, even if the true developmental function for a particular component cannot be duplicated or approximated by the linear representation, it makes no difference for the theoretical implications anyway. All of the inferences drawn below really assume only that component values *change* with maturation. It would actually enhance the theoretical argument if one were to hypothesize more complex longitudinal trends. For instance, higher order polynomial developmental functions might account for the sporadic appearance of bursts and slumps, such as witnessed in the rather unsteady development of creative potential (Runco & Charles, 1997).

In light of these considerations, the formulation given in Equation 3 is used solely for the sake of argument. Despite any simplifications, linear epigenetic functions suffice to reveal the richer complexity of talent development. Specifically, this elaborated model contributes to our comprehension of (a) the occurrence of early and late bloomers, (b) the potential absence of early talent indicators, (c) the age-dependent cross-sectional distribution of talent, (d) the possibility of talent loss, (e) the possible age dependence of a youth's optimal talent domain, and (f) the increased obstacles to the prediction of talent.

Occurrence of Early and Late Bloomers

One now has a formal means of representing the contrasting developmental trajectories of early and late bloomers. On the one hand, an early-blooming talent is a child for whom s_{ij} is small even for the most late-maturing component for the given talent domain (e.g., $s_{ij} < 5$ for all j). In other words, the child prodigy in a domain is someone who "gets it all together early." On the other hand, a late bloomer is someone for whom one or more components will not begin developmental growth until much later, such as adolescence or even older. More formally, for the latter class of talents there may exist at least one $s_{ij} > 13$, or some even later figure. Admittedly, these formulations are not all that profound. But one is thereby led to a more subtle aspect of the developmental divergence: There is basically only one way of becoming an early bloomer, because all components must show precocious development; but there are k ways of being a late bloomer in a talent domain. Whichever talent component is the last to mature defines the particular manner in which a particular youth was "held back." This is the first of several instances where superficially similar talents—in this case late bloomers whose talents blossomed at the same time—may have fundamentally distinct epigenetic histories. Another illustration of this crucial possibility immediately follows.

Potential Absence of Early Talent Indicators

It would be of immense practical value if there were signs that occurred in the earliest years that would reliably predict the later emergence of full-blown talent. These signs could then be used for early identification of gifted children for special programs and instruction within a domain (e.g., Stanley, 1997). If it requires a decade of intensive training and practice to acquire world-class competence in a talent domain, then an early start may be highly advantageous. Although investigators have often suggested the occurrence of early signs, such as early interest in singing for the musically talented, empirical research has not always succeeded in finding truly dependable indicators of later talent (Sloboda, 1996; Winner, 1996).

Yet according to the emergenic and epigenetic model, the existence of such precursor components is by no means essential for the operation of talent. To consider the most extreme case, one might conceive s_{ij} as being a random variable across both components and individuals. That is, the onset of development for any requisite trait may occur at any time for any component for any person. If so, then there will be k alternative ways to commence the development of a particular talent. Any one of the k components may have the smallest starting age and thus be the first to launch talent growth. To be sure, one might argue that certain components must invariably occur before others. There might exist some a priori ordering to at least a subset of the components owing to the temporal sequence in the development of the supporting biological structures. Yet unless this epigenetic ordering applies to all k components, one would still not predict the appearance of a reliable early indicator. For instance, suppose that all even-numbered components must appear in strict order and that all odd-numbered components might do the same. In music performance, the first series might represent the development of auditory discrimination, and the second the growth of manual dexterity. Then whether talent development began with an odd- or an even-numbered component (C_{i1} or C_{i2}) would still be subject to unpredictable individual differences. Two teenagers with precisely the same talent potential might have begun their talent development very differently a decade earlier, one with the first component of the even-numbered sequence, the other with that of the odd-numbered sequence.

I must stress that the model does *not* predict that there exists *no* precursor trait for *any* talent domain. The model maintains only that the existence of such early indicators is not mandated for talent to exist as a genetic behavioral phenomenon. Therefore, the empirical absence of consistent signs cannot be taken as evidence against individual differences in domain-specific talents (cf. Howe et al., 1998).

Age-Dependent Cross-Sectional Distribution of Talent

In line with the preceding remarks, the cross-sectional distribution of talent should vary with age t. At very young ages (e.g., $t < 10$), $C_{ij}(t) = 0$ for a large proportion of the population. Indeed, these untalented individuals may constitute the overwhelming majority. Thus, the probability distribution of potential talent P_i will be highly skewed, with a modal score of $P_i = 0$. As t increases, the number of zero scores will decrease, and hence the number of potential talents will increase. However, the distribution will always be highly skewed, owing to the multiplicative nature of the model. In fact, the variance of the cross-sectional distribution will increase as a cohort of youth matures. The larger the number of components that define the talent, the faster the rate at which this variation expands with age.

Possibility of Talent Loss

Early bloomers and late bloomers do not exhaust the range of talent trajectories according to the current model. Once-promising youth can also fail to realize their initial potential (Albert, 1996). Sometimes this results from certain quirks in cognitive development, such as the so-called "mid-life crisis" that sometimes obstructs the maturation of music talent (Bamberger, 1986). At other times, the youth experiences some sort of "burnout" because of social–emotional obstacles and distractions (Csikszentmihalyi et al., 1993). One oft-cited example in the domain of mathematical giftedness is William James Sidis (Montour, 1977). This child prodigy entered Harvard University at age 11 and as a freshman delivered an impressive talk before the Harvard Mathematics Club. But he soon dropped out of school, sank into eccentric obscurity, and eventually ended up as a human calculating machine in the precomputer era.

No doubt many of these episodes in the history of child prodigies were the upshot of adverse environmental events and circumstances of various kinds. Robert Schumann's early ambition to become a piano prodigy was dashed by an injury to one of his fingers, for example. Nonetheless, according to the present model, such talent loss can just as well result from genetically controlled development. More precisely, the theory would lead us to define two distinct forms of talent loss: relative and absolute.

Relative talent loss. This would occur when $P_i(t)$ continues to increase with age t, but a particular talent's potential does not increase as rapidly in comparison to other members of his or her cohort who are working within the same talent domain. For instance, it might hold that $P_1(t) < P_2(t)$ for $t < 10$, but $P_1(t) > P_2$ for $t > 10$, so that at age 10 the two youths switch their rank ordering (holding environmental factors constant). Loss in rank is extremely critical in domains where only individuals who are best or near-best have any chance of earning fame and fortune. In prestigious piano competitions, only the first-place winner can have reasonable expectations of securing lucrative recording contracts and concert tours. The faint praise "fourth place" or even "runner-up" sells neither compact disks nor concert tickets. Likewise, in Olympic sports only the top three receive medals, and usually only the gold medalist can expect to be actively courted by companies seeking product endorsements. Theoretically, such relative talent loss is said to take place when a youth begins developing the relevant talent components at an early age, but the rate of growth of those components is slower than in others who begin later yet who exhibit faster rates of growth. For example, comparing Individual 1 with Individual 2 in terms of the linear growth function given by Equation 3, one may find that $s_{1j} \leq s_{2j}$ for all j, but that $b_{1j} < b_{2j}$ for all j as well (where $a_{1j} = a_{2j} = 0$, again for all j). Thus, even though the first child gets a head start, the second can soon catch up with and then surpass the first. The late bloomer overtakes the early bloomer.

Absolute talent loss. This would take place when the actual value of the potential talent for a particular youth declines after a particular age. More formally speaking, the slope of the developmental trajectory is no longer positive monotonic (i.e., at some age t the first derivative becomes negative, or $dP_i/dt < 0$). This can occur when at least one essential component rapidly declines after a certain age, lowering the multiplicative composite score for $P_j(t)$. For instance, a certain acceptable degree of mental health is probably mandatory for the manifestation of certain talents, such as sports (e.g., Eysenck, Nias, & Cox, 1982). There are many cases of ever-growing mental illness eventually undermining talent. One real case became famous in the movie *Shine,* which tells the story of David Helfgott, a once-phenomenal piano virtuoso. Such epigenetic destruction of talent may be accommodated by only a slight alteration in the linear equations given earlier. Specifically, one might posit that for some components the trajectory is described as follows:

$$C_{ij} = a_{ij}, \text{ if } t < s_{ij},$$

$$= a_{ij} - b_{ij}t, \text{ if } s_{ij} \leq t < e_{ij}, \text{ and}$$

$$= 0, \text{ if } t \geq e_{ij}. \quad (4)$$

Here a_{ij} represents the initial, acceptable level of component j ($a_{ij} > 0$), s_{ij} the age at which the deterioration starts, and e_{ij} the age when it reaches a level of sufficient incapacity that the multiplicative product becomes zero, that is, $P_i(t) = 0$ for all $t \geq e_{ij}$. Because many detrimental developmental trends may not begin until puberty or even early adulthood (Plomin, 1986), this process can thus account for the tragic loss of talent in the later years. However, the loss does not have to be complete and may even involve nothing more than a slow decline into mediocrity. Of course, some detrimental effects may set in earlier and thereby prevent a once-promising child from fully realizing his or her early potential. A potential case is attention deficit hyperactivity disorder, which is under partial genetic control (Tannock, 1998). Although this syndrome would likely interfere with efficient training, its detrimental effects usually appear early in development and therefore could account for talent loss only in children who had already exhibited precocity in a domain that requires intense concentration and practice, such as music performance.

Whatever the specific instances, the crucial point is this: (a) The innate capacities that compose a talent must include innate incapacities as well and (b) insofar as the latter may require years to unfold, then longitudinal changes in talent potential $P_i(t)$ are not confined to a positive monotonic trend.

Possible Age Dependence of a Youth's Optimal Talent Domain

Among the valuable implications of the individual-differences model is that the talent evident in a given domain is heterogeneous rather than homogeneous; two youths may have the same overall talent potential without having equivalent scores on the contributing components. When one turns to the longitudinal model, this heterogeneity becomes even more prominent—not only across individuals but also within the developmental history of a single person. That timewise heterogeneity results from the fact that even under the very simple linear model of developmental trajectories there are numerous parameters that may freely vary. The age of onset (s_{ij}) and termination (e_{ij}), the intercepts (a_{ij}) and slopes (b_{ij}) of the linear functions—these may all adopt a wide variety of values. Accordingly, a youth's talent potential is not a stable innate trait but rather is constantly transforming during the maturation process. A teenager will not have the same talent in comparison to a child, nor will an adult necessarily contain the same innate constitution as a teenager. Solely if all the epigenetic parameters are equal across all components would one anticipate longitudinal stability in talent. Not only may talent be lost, as noted in the previous section, but in addition one talent may metamorphose into another talent. This developmental event would occur whenever there exists some adjacent talent domain in which the distinctive multiplicative function would yield a higher talent potential score for the same component profile. That is, there may exist some closely related domain that assigned different weights to roughly the same set of components. In formal terms, there may exist another domain such that

$$P_i(t)^* = \prod_{j=1}^{k} C_{ij}(t)^{w_j^*}, \quad (5)$$

where, in general, w_j^*/w_j, for most or even all k components. It therefore may happen that at a certain age the talent potential for the second domain exceeds that for the first; that is, $P_j(t)^* > P_j(t)$ for some t greater than a certain value. At this crossover age, the developing youth can best optimize continued growth by switching domains. This is actually a fairly commonplace developmental event. In music, for example, an instrumentalist may switch to composition, or a would-be composer may become a conductor or a teacher. Specific illustrations are found among the child prodigies studied by Feldman and Goldsmith (1986), only one of whom displayed any talent stability (see also Csikszentmihalyi et al., 1993; Getzels & Csikszentmihalyi, 1976). Presumably in many of these instances the individuals are still "following their talents" but, because talent development is a dynamic rather than static process, the optimal talent domain may transform with maturation.

Increased Obstacles to the Prediction of Talent

I have already pointed out how the cross-sectional heterogeneity of the individual-difference model must render it far more difficult to predict talent. The allowable diversity of component profiles within the same talent domain lowers the potential utility of various predictor variables. Now that I have replaced the static conception of talent growth with a more dynamic viewpoint, the difficulties confronting prediction become all the more paramount. According to an epigenetic model, talent is not a fixed quality endowed at birth in some preformationist fashion. On the contrary, talent may bloom early or late. Talent may come and go, both absolutely and relatively. Not only may the composition of a given talent change as a person ages, but the optimal talent domain may change as well. Hence, the developmental pathways that talents may follow in the pursuit of their innate potential are incredibly varied. Moreover, as the talent domain becomes more complex (i.e., the larger is k), the available developmental routes to any given talent—or lack of talent—become almost infinite. Only in the case of monozygotic twins, who inherit identical epigenetic programs, would one ever predict equivalent developmental trajectories in the emergence of a given talent.

Conceptual Elaboration

In the above presentation, the emergenic–epigenetic model was deliberately kept as simple as possible. So what happens if certain key simplifying assumptions are removed? To address this issue, I examine three matters: (a) the ratio scaling of the talent components, (b) the postulate of uncorrelated components, and (c) the integration of the k components using a multiplicative rather than an additive function.[4]

Component Scaling

The original weighted multiplicative model operated under the assumption that each innate trait could be assessed along a ratio scale. It is this feature that provides a true zero point that enables the inference that there can exist the literal absence of talent in a particular child. Although this assumption may seem arbitrary, it can be argued that it enjoys plausibility from the standpoint of genetics. Essentially, the model is assuming that all components are quantitative traits that are inherited under a polygenic-additive process (Lykken et al., 1992). For example, a given trait may be based on a dozen genes, each inherited independently and each making roughly equal contributions to the expression of the trait. Children who inherit all dozen genes have the maximum score on the innate attribute, whereas those who inherit not one of the genes will fail to exhibit the corresponding trait in even the smallest degree.

The genetic plausibility notwithstanding, I can relax this assumption various ways without affecting the central implications of the model (see also Lykken et al., 1992). Consider the following two complications:

1. Some of the components may be qualitative traits that are either present or absent. Such discrete attributes are usually decided by a single gene. The corresponding components could then have only zero–one values. Because these traits would still possess the possibility of a zero value, they would still exert veto power over the development of talents in which these components participate. The sole major change in the model would be that people who possessed such traits would not display variation among themselves on the all-or-nothing components. Thus, these discrete traits could not enter into multiplicative trade-off relationships with other traits. But as long there exist two or more truly quantitative components, the implications of the model still stand.

2. Some of the components may be quantitative, but without true zero points. A clear-cut example is intelligence. Although a child with a hypothetical "0 IQ" would certainly not have any chance of becoming a great mathematician or a champion golfer, that claim must be considered trivial. Most discussion of talent development operates under the implicit assumption that one is dealing with children who are intelligent enough to acquire skills and pursue careers. One way of handling this second complication is simply to assert that some components may always have values greater than zero. Such components would not be able to exert veto power over the manifestation of a talent, but they would still figure prominently in the trade-off relationships of the multiplicative model, and they would still yield the skewed distributions of talent. Hence, as long as there yet remain other zero-valued (discrete or quantitative) traits, the derived implications remain unchanged.

Another possible solution is to posit that certain components operate by means of specific threshold functions (Lykken et al., 1992; Simonton, 1994). To illustrate, one formal model predicted that the probability of exerting leadership over group members becomes nonzero only when the leader's intelligence exceeds that of the average group member (Simonton, 1985). Thus, even though intelligence may have a nonzero minimum, the operation of a threshold means that contribution of intelligence to leadership ceases below a certain level—in effect providing a zero point. To be specific, suppose that the first component, C_{i1}, is general intelligence. Then let Θ_1 represent the minimum level of Spearman's g required to achieve exceptional performance in a domain (e.g., whatever would be equivalent to an IQ of, say, 100). Then the component would be defined as follows:

$$C_{i1} = 0, \text{ if } g_i \leq \Theta_1,$$
$$= g_i - \Theta_1, \text{ if } g_i > \Theta_1, \quad (6)$$

where g_i is the ith person's innate intelligence. Under Equation 6, the first component would constitute a ratio scale.

It is interesting that empirical research on creativity has also suggested the existence of thresholds that define the minimal intelligence required for the demonstration of creative behavior (Barron & Harrington, 1981; Simonton, 1994). So threshold functions may mediate the participation of many components in the multiplicative definition of many talents. As is evident from Equation 6, however, components that operated by means of such mechanisms would have consequences indistinguishable from those obtained by the postulated ratio scales (for further discussion, see Lykken et al., 1992).

Probably many genuine talents are a mixture of a great many different component types. Some components may be qualitative and thus have the capacity to veto the expression of talent without ever having the capacity to participate in multiplicative trade-offs. Other components will be quantitative, but without a true zero point, and hence can enter into trade-offs without exerting any veto power. Still other components—such as simple polygenic-additive ratio scales or the more complex threshold functions—will have both veto and trade-off functions. Such a rich soup of innate traits would nevertheless produce the same implications derived from the simpler version of the emergenic model.

Component Correlations

Another assumption concerns the relationships among the components. To avoid cluttering the discussion, the k components were said to be uncorrelated. This would be the expected outcome in the classic Mendelian situation where none of the components shared any genes and all relevant genes underwent random assortment during reproduction (i.e., no constraints because of chromosomal linkage). If this postulate still seems too restrictive, it is easy to make a methodological adjustment. For instance, it may be that there actually exist m correlated variables that underlie a given talent, where $m > k$. One can then use principal-components analysis to reduce these m variables to k orthogonal components. Discussion of the individual-difference and longitudinal models may then proceed as before.

Even if this maneuver is considered as a mere methodological legerdemain, the repercussions of correlated components are by no means severe. All of the central inferences drawn from the models

[4] I will not even consider the possibility that some of the components feature curvilinear relations with talent potential (e.g., the roughly inverted-U connection between intelligence and leadership predicted in Simonton, 1985). Such complexities would simply reinforce all the more the main thesis of this article.

would persist with minimal, if any, modification. Indeed, in many important instances the conclusions become accentuated. For instance, it is a well-known psychometric property of additive models that the variance of a linear composite increases as the correlations among the items increase (Nunnally, 1978). This variance increase is even more conspicuous in multiplicative models, and hence the expected cross-sectional distribution of potential talent would become ever more skewed.[5]

Probably the only major qualification introduced by the intrusion of correlated components concerns the heterogeneity of the talent profiles. If the intercorrelations are extremely large, there will be little latitude for trade-off relationships among the components, because the traits will be strongly constrained to covary. Yet if the components really did correlate highly enough to severely constrain individual differences in trait profiles, one would then have to question whether the components represent distinct entities in the first place. Rather, the components likely hold many genes in common. The true component count would accordingly be some number less than the nominal k. The necessity of performing a principal-components analysis might then become paramount.

Multiplicative Functions

Equations 1 and 2 incorporate a critical mathematical feature: The components combine through multiplication rather than through addition. It is this facet of the model that gives ratio-scaled components their veto power, rendering each a sine qua non of talent development. Although I justified this mathematical assumption in the theory of emergenesis, I ought to inquire what would happen if one relaxed this requirement. Consider the following, more inclusive equation:

$$P_i(t) = a\prod_{j=1}^{k} C_{ij}(t)^{w_j} + \sum_{j=1}^{k} b_j C_{ij}(t), \qquad (7)$$

where $a \geq 0$ and $b_j \geq 0$. Note that thus far I have been working with the special case of Equation 7, in which $a = 1$ and $b_j = 0$ for all j; such constitutes the pure multiplicative model. On the other hand, the pure additive model is given by the parameters $a = 0$ and $b_j > 0$ for the k components. When $b_j = 1$ for all j, in fact, one obtains the linear model that generated the scores in the Monte Carlo simulation shown in Table 3.

Nonetheless, mixed models are also conceivable. Suppose, for example, that $a = b_j = 1$ for all j (and that $k > 1$). Then both multiplicative and additive components will help determine the youth's talent potential. However, because the product of the k variables would exhibit far more variance than the sum of those same variables, the multiplicative contribution will greatly dominate the outcome. This dominance can be easily inferred from the results reported in Table 3. Thus, for $k = 10$, the variance of the multiplicative composite exceeds that of the additive composite by a factor of 10^5. Accordingly, the positive-skewed, leptokurtic distribution would still characterize the expected cross-sectional distribution of talent. In general, the larger is k, the more elitist will be the distribution, even under an equally weighted mixed model. Furthermore, to the extent that the multiplicative term monopolizes the total variance in talent potential, one would still predict the low familial heritability of talent, the reduced predictability of talent, and other critical ramifications of the emergenic model. Indeed, in one instance the consequence would become more severe: Because Equation 7 combines a nonlinear–multiplicative term with a linear–additive term, the statistical prediction of potential talent would be rendered far more problematic (e.g., the equation could not be made linear and additive by means of any straightforward manipulation). In any case, the magnitude of the single a relative to the several b_js would have to be extremely small to invalidate these consequential derivations.

The only noteworthy contrast with previous deductions would be that it would be very rare, if not impossible, for $P_j = 0$ for any individual. Although the multiplicative term always equals zero when only one component is zero, the additive term equals zero only if all components equal zero, a very rare circumstance, as demonstrated in Table 3. Nevertheless, the amount of talent potential individually contributed by the additive components would remain so small relative to that contributed by their collective multiplication that persons at the bottom of the talent distribution would, for all practical purposes, exhibit no potential. Their talent would be so minuscule as to be effectively imperceptible.

It should be apparent that the parameters a and b_j, like k, may vary from one talent domain to another. Hence, besides differentiating domains according to complexity, one can also distinguish them according to the degree to which they would display the properties predicted by the multiplicative function. There might even exist talent domains in which the additive model is perfectly appropriate, obviating the key concerns raised by the emergenic model. This possibility has interesting implications for how researchers should best investigate domain contrasts in the operation of talent, as shall become apparent in the next section.

Empirical Evaluation

So far the emphasis has been on demonstrating how talent might possibly function and develop in a manner much more complicated than is commonly assumed. The goal was theoretical rather than empirical. Yet the scientific value of the emergenic–epigenetic model must ultimately depend on how well it fits the relevant data. No doubt a comprehensive empirical assessment would require a considerable amount of research; the model may be fertile enough to provide the basis for several long-term research programs—probably even one whole career per major talent domain! Fortunately, there already exist published results that lend empirical support to the model. After reviewing that empirical literature, I discuss what steps must be taken in future research to establish the scope and limits of the model's explanatory power.

Current Evidence

The literature accumulated on individual differences, behavior genetics, and exceptional performance is already sufficiently rich to permit a strong a priori case for the operation of innate capac-

[5] The basis for this assertion is that realization that the variance of an additive composite is defined by the sum of 2^k second-order terms (viz., the variances and covariances), whereas the variance of a multiplicative product is defined by a term that has the order $2 \times k$ (i.e., the square of the k components multiplied together). As C_{ij} gets ever larger, the latter quantity will enlarge faster as the components become more highly correlated.

ities in at least some talent domains. Not only do human beings vary tremendously on a vast number of cognitive capacities, motivations, personality traits, interests, and values, but in addition a large proportion of these individual-difference variables feature respectable heritability coefficients (Bouchard et al., 1990; Loehlin, 1992a; Plomin, Owen, & McGuffin, 1994). Even rather complex characteristics have genetic underpinnings, including political attitudes and musical tastes (Tesser, 1993), the amount of time devoted to watching television (Plomin, Corley, DeFries, & Fulker, 1990), job satisfaction and values (Arvey, Bouchard, Segal, & Abraham, 1989; Keller, Bouchard, Arvey, Segal, & Dawis, 1992), dispositional empathy (Davis, Luce, & Kraus, 1994), and religious interests and attitudes (Waller, Kojetin, Bouchard, Lykken, & Tellegen, 1990). These recent findings emerged from highly sophisticated research programs that applied state-of-the-art statistical techniques to both adoption and twin data (including genetically unrelated children raised together and monozygotic twins reared apart).

At the same time, there exists an ample inventory of cognitive, motivational, and dispositional characteristics that differentiate people who attain exceptional levels of performance from those who fail to do so (see, e.g., Cattell & Butcher, 1968; MacKinnon, 1978; Simonton, 1995, in press; Winner, 1996). Accordingly, the minimal requirement for the existence of a bona fide talent is that there be some overlap between the list of inherited traits and the list of predictor variables. In other words, if a given variable displays a respectable validity coefficient in predicting exceptional performance, and if that same variable has a respectable heritability coefficient, then a prima facie case has been made for that variable constituting a talent component according to the model. Instances of such overlap abound for both dispositional and intellectual traits.

Perhaps the most obvious example is general intelligence, or Spearman's *g*. This attribute features one of the largest heritability coefficients of all psychological traits, and the quantitative trait loci associated with gifted-level IQs are now being successfully located at the human chromosome (Chorney et al., 1998). At the same time, general intelligence is indubitably the individual-difference factor most consistently associated with (a) the ability to acquire expertise on complex tasks (Gottfredson, 1997) and (b) the capacity to display high-level performance in such domains as creativity and leadership (Simonton, 1985, 1995, in press). Similar linkages can be found for other psychometric variables, such as tests of special abilities, interests, values, and personality. For example, the instruments that have been used to establish personality profiles for achievers in major talent domains (e.g., Cattell & Butcher, 1968; Eysenck et al., 1982) have also been shown to have significant heritabilities for most of the subscales defining the profiles (e.g., Beer, Arnold, & Loehlin, 1998; Cattell, Schuerger, & Klein, 1982; Eysenck, 1995; Floderus-Myrhed, Pedersen, & Rasmuson, 1980). In general, it would probably be the exception rather than the rule to find an established correlate of attainment in some talent domain that does not feature a nontrivial genetic substrate.

To be sure, neither the heritability nor the validity coefficients are so high that one would expect that genetic endowment would account for a large proportion of the variance in performance. Any single trait might at most account for 1% or 2% of the observed individual differences. Even so, that admission is not tantamount to the assertion that these innate abilities and dispositions can be ignored. On the contrary, the following two extenuating factors must be recognized:

1. Genetic endowment may not have to have a substantial effect size for it to have important consequences. Not only can relatively small effects have impressive practical repercussions (Rosenthal, 1990; Rosenthal & Rubin, 1979), but in addition even momentarily trivial influences can have major results if the effects are cumulative over a long period of time (Abelson, 1985). It is conceivable that talent development constitutes just such a cumulative process in which any small genetic advantage amplifies over the life span into hefty individual differences.

2. The individual characteristics are not what are crucial, but rather their multiplicative combination. To the degree that a talent domain is multidimensional and multiplicative, the validity coefficients of any single component will be attenuated. This was made clear in the earlier Monte Carlo simulation (see Table 3). The impact of innate factors must be correspondingly determined by the emergenic whole rather than the isolated parts. As a consequence, the R^2 for the entire multiplicative prediction may be quite convincing even when the single components have relatively small associations with a talent criterion.

Of course, this second extenuating circumstance assumes that emergenic inheritance can indeed take place, and so it is to the research on this point that I must now turn.

Emergenic Inheritance

Although nonadditive inheritance may be relatively uncommon for simple human attributes, it can equal and even surpass that attributable to additive inheritance when the characteristics are more complex (e.g., Bouchard, 1994). It is significant that there already exists sufficient evidence that many talents may be included in the inventory of complex attributes (Lykken et al., 1992).

Take the case of Social Potency, namely "the self-perceived ability to influence, lead, or dominate others" (Lykken, 1982, p. 370). Monozygotic twins, whether reared apart or together, closely match on this trait; yet dizygotic twins are no more alike than any two people selected randomly from the population. Lykken (1982) noted that this characteristic is thus more than just polygenic; it may also require all the corresponding genes to participate if the trait is to appear at all. In particular, Social Potency "probably depends on some configuration of attractiveness, self-confidence, assertiveness, dominance—whatever the ingredients are of 'charisma' " (p. 370). If one component is lacking, Social Potency cannot emerge as a character trait. Consequently, although dizygotic twins correlate only .07 on this trait, monozygotic twins correlate .67 even when reared apart (Lykken, 1982). Comparable results were found by Gangestad and Simpson (1993) with respect to the closely related dimension of Expressive Control (the genetic portion of the self-monitoring inclination). This factor contains such socially valuable skills as an individual's ability to impress and entertain people, to engage effectively in role playing (e.g., improvisational acting), to mimic other persons, and to practice deception successfully (i.e., to lie with a straight face while looking someone in the eye). Monozygotic twins correlated .76 on this trait, whereas dizygotic twins correlated only .16. Because both Social Potency and Expressive Control are associated with effective leadership, these findings suggest that there exists an emergenic basis for talent in this domain. Expressive Control would also seem a requisite for exceptional performance in entertainment fields.

Research has even found convincing evidence that creative talent may be an emergenic trait (Waller, Bouchard, Lykken, Tellegen, & Blacker, 1993). Using the Creative Personality Scale (Gough, 1979) that had been previously validated on more than 1,700 participants—including eminent architects, mathematicians, research scientists, and other notable creators—Waller et al. obtained an impressive intraclass correlation of .54 for monozygotic twins reared apart. The corresponding correlation for dizygotic twins also reared apart was only −.06, which is not statistically different from zero. This outcome suggests that the more than two dozen descriptors that define this scale must form a unified configuration for creative behavior to appear. These essential components evidently include such diverse cognitive and dispositional characteristics as intelligence, insightfulness, reflectiveness, originality, inventiveness, wide interests, resourcefulness, self-confidence, unconventionality, and individualism. Finally, I should mention an investigation that found comparable results for self-assessed interests and talents in arts and crafts; the intraclass correlations were in this case .63 for monozygotics and .07 for dizygotics (Lykken et al., 1992). Hence, any talent domain in which either creativity or leadership is an essential ingredient would probably feature some proportion of emergenic origins.

The foregoing studies provide direct support for the emergenic model. Yet indirect support also deserves mention. One of the expectations derived from any multiplicative model is that the cross-sectional distribution of the final scores should be highly skewed. Thus, individual differences should be described by log-normal distributions in all domains involving the performance of complex tasks. The prominence of such distributions is empirically incontrovertible. In fact, multiplicative models were first introduced decades ago precisely to explain the distinctive cross-sectional distributions in income and creative productivity (Burt, 1943; Shockley, 1957). Both money-earning power and the output of creative products exhibit extremely asymmetrical distributions, with a small percentage of the population claiming the bulk of the material or intellectual wealth (Dennis, 1955; Lotka, 1926; Price, 1963). To the extent that these disparities reflect underlying differences in entrepreneurial or creative talent, these empirical distributions may be said to lend support to the emergenic model (cf. Simon, 1955; Simonton, 1997a). Indeed, virtually all domains that feature exceptional performance are also characterized by the same positively skewed cross-sectional distribution (Walberg, Strykowski, Rovai, & Hung, 1984). Normal distributions may be the exception rather than the rule in any complex talent domain. Although such consistent patterns do not prove that the underlying causal basis is emergenic, they do imply that whatever the participating factors may be, they must be combined in a nonadditive fashion (see also Eysenck, 1995). Furthermore, one mathematical analysis of longitudinal changes in the highly skewed distribution of scientific output found that these individual differences could be projected back to age 0, implying that there exist "substantial inequalities at birth" (Allison & Stewart, 1974, p. 601). Obviously, these residual inequalities may represent cross-sectional variation in whatever the components are that constitute scientific talent.

When this indirect support is combined with the direct support for emergenic inheritance, a core assumption of the theoretical model can be said to enjoy reasonable empirical plausibility.

Epigenetic Growth

I have concentrated on the evidence supporting the emergenic portion of the two-part model. This emphasis ensues from the fact that this part may be the more controversial of the two. Nevertheless, ample evidence also exists on behalf of the model's epigenetic segment. Some of the pertinent data were already cited earlier, when I mentioned the research on the asynchronous developmental trajectories of savants and child prodigies. General inquiries into behavior genetics provide the following two additional findings:

1. Just because a trait claims a genetic foundation does not automatically mean that the trait appears all at once. On the contrary, many characteristics, even if under demonstrable genetic control, take years, even decades, to emerge. As an example, intelligence undergoes multiple changes from childhood through adulthood, as various participating genes become activated during the course of intellectual development (Plomin, Fulker, Corley, & DeFries, 1997; Plomin & Petrill, 1997). As a curious consequence of this epigenetic progression, the heritability of IQ actually increases across the life span—even during the adult years, when environmental influences would presumably be maximized! This principle extends to many other individual-difference variables as well, albeit to varying degrees (Bouchard, 1995). It is for this reason that identical twins reared in separate homes tend to become more similar with age, whereas unrelated individuals reared in the same home tend to become more different as they grow older (see Scarr & McCartney, 1983, for interpretation).

2. The epigenetic programs that govern the development of a trait are not necessarily the haphazard repercussion of the influx of environmental events that impinge on the individual's life. On the contrary, behavior genetics has shown that the differential timing of developmental events can often have a genetic component (Bouchard, 1995; Plomin, 1986; Plomin, Owen, & McGuffin, 1994). Specifically, monozygotic twins, in contrast to dizygotic twins, often exhibit highly synchronized onsets, lags, and spurts for both physical and mental growth. For instance, one study found that the synchronies observed from infancy to adolescence averaged around .90 for monozygotic twins but only around .50 for dizygotic twins (Wilson, 1983). This contrast implies that a significant portion of the developmental trajectories is driven by endogenous rather than exogenous factors.

Thus, genetic endowment can help determine individual differences not only in the final manifestation of an attribute but also in the developmental trajectory by which that attribute emerged. These results demonstrate that the epigenetic portion of the model is indeed empirically credible.

Future Research

The foregoing review has shown that the current two-part model of talent already enjoys appreciable factual plausibility. Even so, considerably more research must be conducted before psychologists can estimate the model's explanatory utility and power. Happily, the model has several explicit implications regarding how research should be conducted to assess the model's scientific merit. These fall into four categories: familial inheritance, cross-sectional variation, longitudinal changes, and domain contrasts.

Familial Inheritance

Much more research is necessary on the predicted low familial inheritance of talent. One seemingly straightforward way of accomplishing this task is to use Galton's (1869) pedigree method to determine the extent to which talent runs in family lines (e.g., Bramwell, 1948; Brimhall, 1922, 1923a, 1923b; Simonton, 1983). Nonetheless, this approach is far from ideal, because it is virtually impossible to separate the relative influences of nature and nurture (Simonton, 1984b). For example, there is abundant evidence that exceptional performance can be nurtured by role modeling and mentoring (e.g., Bloom, 1985; Simonton, 1988a, 1992a, 1992b) and that such social learning can be effectively carried out by parents who have interests and expertise in the talent domain (e.g., Davidson, Howe, Moore, & Sloboda, 1996; Schaefer & Anastasi, 1968; Simonton, 1984a, 1992c; Werts & Watley, 1972). Only after these environmental influences are completely stripped away would researchers obtain a more secure estimate of the degree of familial inheritance. At present there exists no acceptable method of making such a correction.

Consequently, a far more powerful approach is to scrutinize samples of twins, the method that inspired the concept of emergenesis in the first place (Lykken, 1982). In particular, researchers need to identify the intellectual and dispositional characteristics that exhibit high intraclass correlations for monozygotic twins but negligible or zero intraclass correlations for dizygotic twins. If those are also personal attributes that are associated with exceptional performance in a recognized talent domain, then they may be added to the inventory of emergenic effects. Better yet, it would be especially powerful to apply this statistical criterion to actual performance measures, as Coon and Carey (1989) attempted to do in the case of musical ability. This method may be much more difficult to execute, but it has the obvious advantage of attacking the question most directly.

Incidentally, it is sometimes erroneously inferred that emergenic inheritance implies that identical twins would be disproportionately represented among individuals who have attained distinction within a talent domain. But emergenesis solely predicts that monozygotic twins would display nearly identical innate capacities. The process does not require that their capacities be higher than those of dizygotic twins or regular siblings. Indeed, because twins often suffer from lowered birth weights, intelligence, and other liabilities, twins of any kind may, if anything, be underrepresented in the population of individuals who have attained distinction within a talent domain (see, e.g., Husén, 1960; Zajonc, 1976). In any case, twin frequencies alone are not informative one way or the other with respect to the emergenic hypothesis.

Cross-Sectional Variation

According to the multiplicative model, talent should be characterized by skewed-right distributions in the total population. As mentioned earlier, there already are ample data showing that performance in a great many talent domains is characterized by lognormal cross-sectional distributions. Even so, these results apply to the phenotypic manifestation of accomplishment within a domain, whereas the model deals with the form of the variation in the underlying genotypes. As a consequence, to make a more convincing case on behalf of the model requires that the cross-sectional distribution be estimated after controlling for environmental effects—especially for individual differences in deliberate practice. There are basically two main ways of accomplishing this methodological desideratum: (a) longitudinal studies in which the effects of nurture are systematically measured or experimentally manipulated during the course of development and (b) retrospective studies in which the effects of nurture are assessed through questionnaires and interviews and then partialed out by means of multiple regression or analysis of covariance. Although the first option is by far the best, most research on talent development uses the latter strategy (cf. Ericsson, 1996b; Subotnik & Arnold, 1994). In any case, the current model predicts that once all due adjustment is made for differential environmental influences, the cross-sectional distribution should still display positive skew and kurtosis. For example, if assessed performance in a given talent domain were regressed onto all pertinent environmental influences, including the amount of deliberate practice, the residual scores (or prediction errors) that result should still exhibit a lognormal distribution.

Three methodological precautions are in order about this distinctive prediction:

1. The suggested test is probably conservative in the sense that it may be biased against the talent hypothesis. To the extent that the level of deliberate practice is itself a function of innate factors, such as interests, persistence, and energy or endurance, then these factors will be incorrectly partialed out. This could be an instance of what is sometimes called statistical "overcontrol" (Darlington, 1990). Empirical tests would suffer less from this problem to the extent that the environmental factors are experimentally manipulated rather than merely observed.

2. Depending on the specific talent domain under investigation, the cross-sectional distribution of residualized scores may be distorted by the type of performance scaling. Thus, in gymnastic events where no competitor can score higher than a "perfect 10," ceiling effects may restrict the variation in the upper tail. Such scaling properties mean that although skewed residuals would strongly support the emergenic model, the absence of the expected skew would disprove the model only when it can be clearly shown that the measures are truly unrestricted at the upper levels of performance.

3. Sampling procedures can affect the predicted distribution as well. The model's prediction applies to a representative sample of the human population, yet in many talent domains the distribution of performance is truncated at the lower end (e.g., when athletes must first pass certain set qualifying times, heights, distances, or scores before they can enter a given competition). When the investigators are thus unable to investigate the form of the entire distribution, they must focus on the shape of the upper tail. Fortunately, the upper tail of a lognormal distribution remains empirically distinguishable from the upper tail of a normal distribution (Simon, 1954; Simonton, 1988b; see also Galton, 1869). The former approaches the zero asymptote far more slowly.

In some domains it may be possible to obtain reasonably reliable and valid measures of the underlying components as well as the desired performance measures. In such cases, the emergenic model can be tested directly by directly comparing the multiplicative model against the additive model. If the former explains more variance than the latter, then that would provide direct evidence for the present theory. Because the supposed innate components would most likely be conceived as latent variables within covariance structure models—which presuppose linear–additive effects and multinormal distributions—special procedures must be introduced to handle the multiplicative hypothesis (Ping, 1996). Moreover, a just evaluation of the multiplicative model presumes that the sample on which the tests are made exhibits sufficient variation on the criterion and predictor variables. Variance truncation lowers the observed correlations and thereby undermines the total predictive power. For instance, investigators have often erroneously concluded that general intelligence has nothing to do with talent whenever their studies were based on highly selected samples (McNemar, 1964; Simonton, 1994).

Longitudinal Changes

Eventually, talent development will not be truly understood without genuine longitudinal studies that are designed and executed with the current model in mind. Such investigations are necessary to address the following three questions:

1. To what extent does innate capacity account for continuity in the acquisition of expertise in a given talent domain? For example, imagine a longitudinal study of music performance in which precise records are kept of the amount of time spent on lessons and practice. Presumably, for any given level of such training there will still appear individual differences in the level of skilled performance. Some students will perform much better than would be expected according to the amount of training, whereas others will perform much worse. The next question is whether this cross-sectional variation is stable across time. According to the current theoretical model, one would predict that these differences should display (a) short-term stability but long-term instability during childhood and (b) both short- and long-term stability in adolescence or adulthood (where short term might be measured in weeks and long term in years). Because of variation in the epigenetic rules for the various talent components, talent should be undergoing a constant transformation in the early years, as different components kick in at different times and grow at unequal rates. Only later, when all components have nearly completed their growth trajectories, would a stable talent materialize; hence arises the model's prediction of a declining contrast between short- and long-term stability over the first couple of decades of talent development.

2. How does the cross-sectional distribution change with the age of a given cohort? The model predicts that the variance should increase over time, as ever more components begin their epigenetic emergence. The proportion of youths potentially capable of successfully mastering a talent domain should also increase with cohort age. Indeed, theoretically, this is what provides the basis for late bloomers. Needless to say, this question assumes adequate control for environmental influences.

3. To what extent are the epigenetic programs that govern talent development under genetic control? According to the theory, genetically unrelated individuals would probably display extremely diversified trajectories in the emergence of their talents. There should appear a mix of early and late bloomers, with appreciable variation in how the various components of a talent appear and grow. In contrast, monozygotic twins who pursue the same talent domain should exhibit highly similar developmental trajectories in acquisition and mastery. Dizygotic twins may be more like unrelated individuals or more like the monozygotic twins, depending on whether the epigenetic rules are acquired through additive or nonadditive inheritance.

The preceding questions require responses that use more mainstream quantitative and nomothetic techniques. Nonetheless, it may also be instructive to perform case study analyses of those rare instances in which monozygotic twins attain distinction in the same domain (e.g., the newspaper advice columnists Ann Landers and Abigail Van Buren; see Pottker & Speziale, 1987). The convergence and divergence in their developmental trajectories may provide insights into the epigenetic foundation of the talent, especially when examined in the context of how genetic capacities unfold over time (see, e.g., Bouchard, 1995). Someday it may even be possible to identify genuine instances of monozygotic twins who have been raised apart who still attained high performance levels in the same talent domain. At present, there exists only intriguing but inconclusive anecdotal evidence about how some monozygotic twins have managed to develop rather similar interests and talents even when they are raised apart in distinct home environments (e.g., Lykken et al., 1992).

Domain Contrasts

The preceding statements must be qualified by one last consideration: Talent development may not operate in the same manner across all domains. For instance, because most talents are presumed to consist of multiple components, domains can be differentiated according to the nature of the components that enter into the genotypic mix. In particular, the components may be distinguished along two dimensions. First, components may be either general or specific. That is, some traits, such as general intelligence, may be pertinent to a vast range of talent domains, whereas other traits, such as height, may be restricted to domains in which this feature would count as an important asset. Second, some components may function primarily in the acquisition phase, whereas other components may have the most impact in the performance phase. Examples were given earlier in this article, when the concept of talent was first defined. The main point is that talent domains may represent collections of genetic traits that have highly heterogeneous functions. One goal of researchers should be to (a) identify the relevant components for various domains, (b) estimate the weights those components are assigned for those domains, (c) compare those weights with those in other domains, and (d) determine the precise manner in which those components facilitate exceptional performance.

An illustration about how this might be done may be drawn from research on creative talents. So far, investigators have accumulated an impressive list of cognitive and dispositional characteristics that are associated with creative performance in a diversity of fields (Simonton, in press). These traits include general intelligence, openness to experience, ego strength, independence, introversion, and a tempered disposition toward mental instability (e.g., Barron, 1969; Eysenck, 1993; McCrae, 1987). These same personal attributes all have sizable heritability coefficients (e.g., Bouchard, 1994; Eysenck, 1995). At the same time, researchers have shown how the relative impact of these attributes depends on the specific domain in which the creative behavior appears. The configuration of inheritable traits that contribute to scientific creativity differs markedly from traits that contribute to artistic creativity, for example (e.g., Cattell & Butcher, 1968; Roe, 1952). Hence, one set of weights may generate a scientific talent, and another set of weights may generate an artistic talent. As an example, general intelligence has a much larger weight for scientists than for artists (e.g., Cox, 1926; Schaefer & Anastasi, 1968; Winner, 1996), whereas mental instability has a much larger weight for artists than for scientists (e.g., Ludwig, 1995; Post, 1994). Finally, research has deciphered some of the specific mechanisms by which these various inheritable factors contribute to creative behavior.

A case in point is the extensive work carried out on psychoticism, a scale of the Eysenck Personality Questionnaire, which is often adopted as a measure of potential mental instability (see Eysenck, 1993, 1995, for more extensive discussion). Psychoticism is associated with certain distinctive cognitive quirks, like latent inhibition and negative priming, that bear the close connections with both psychopathological symptoms (e.g., "allusive" and "overinclusive" thinking) and creative processes, particularly the capacity to generate many divergent responses and unexpected associations (e.g., Eysenck, 1994). At the same time, these information-processing features have been linked to more basic psychoneurological functioning—such as levels of the neurotransmitter dopamine—which then helps to establish the connection between the cognitive processes and the underlying behavior genetics of the trait (Eysenck, 1995). Although much more research is clearly necessary to close all the gaps in our knowledge, there is already sufficient reason for concluding that psychoticism may operate primarily during performance rather than acquisition. That is, this innate disposition helps support the cognitive processes required to transform mere mastery of a domain into the capacity to make highly original contributions to that domain. Without this cognitive inclination, even the most impressive expertise may not transform into true creativity (see also MacKinnon, 1978; Rostan, 1994).

Besides distinguishing the various types and functions of talent components, there is another task that I believe is even more urgent: Researchers should also try to differentiate the diverse types of domains. According to the equations that define the current model, talent domains can be differentiated along two mostly orthogonal dimensions (exactly orthogonal whenever $k > 1$). The first dimension is the complexity of the domain (i.e., k in Equations 1 and 2). Some domains consist of relatively few components (small k), whereas other domains consist of relatively many components (large k). The second dimension is whether the integration of those components is more multiplicative or more additive (i.e., $a = 1$ and $b_j = 0$ or $a = 0$ and $b_j > 0$ in Equation 7). These two dimensions thereby yield a fourfold typology of domains: simple–additive, complex–additive, simple–multiplicative, and complex–multiplicative. Naturally, these four categories represent endpoints on a continuous plane. Not only may the number of components vary as any integer quantity, but in addition the multiplicative and additive functions may have variable influences, including hybrid multiplicative–additive integrations (i.e., both $a = 1$ and $b_j > 0$). Nonetheless, it is instructive to examine how these four types of talent would differ according to the emergenic and epigenetic model. From the standpoint of future empirical reasearch, perhaps the most useful expected contrasts are shown in Table 4 (see also Table 3).

It should be clear that the four types are highly distinct with respect to the various attributes by which psychologists can describe talent domains. In more detail, these contrasts may be grouped into the three categories of inheritance, variation, and development.

Inheritance. Domains best explicated in terms of a multiplicative model will show the pattern typical of emergenic inheritance. There will appear high intraclass correlations for monozygotic twins, but negligible intraclass correlations for dizygotic twins; family pedigrees should be extremely rare (at least, once correction is introduced for social-learning effects). The more complex the domain, the more extreme these expectations become. By comparison, domains in which the innate components are integrated by additive functions will display a high degree of family similarity in the relevant talent. Monozygotic twins will be more similar than dizygotic twins and other siblings, but the latter two groups will show much more family resemblance than any two randomly chosen individuals. Thus, the intraclass correlations will be respectable for all three categories of siblings, and family

Table 4
Fourfold Typology of Talent Domains: Simple Versus Complex and Additive Versus Multiplicative Talents

	Additive model		Multiplicative model	
Domain attribute	Simple	Complex	Simple	Complex
Familial inheritance	Highest	High	Low	Lowest
Cross-sectional distribution	Normal	Normal	Skewed	Extremely skewed
Maximum standardized score	Small	Modest	Large	Extremely large
Proportion untalented	Very small	Extremely small	Very large	Extremely large
Developmental trajectories	Few	Numerous	Few	Numerous
Developmental onset	Childhood	Childhood	Late childhood/ adolescence	Adolescence/ early adulthood

Note. Simple talent domains are those in which the number of genetic components k is small, whereas complex domains are those in which k is large (see Equation 1). The models are described by Equation 7, where $a = 0$ and all $b_j > 0$ for the additive model, and $a = 1$ and all $b_j = 0$ for the multiplicative model.

pedigrees within the talent domain should be fairly large. Complex and simple domains should differ relatively little in these attributes when an additive model is operative. It is possible that some forms of competitive sports and certain types of music performance may be best described by additive talent models. Galton (1869) identified fairly prominent pedigrees for wrestlers and rowers (but without controlling for environmental factors); Coon and Carey (1989) obtained intraclass correlations for musical interests and performance that are most consistent with an additive genetic model (at the same time including environmental effects in their analyses).

Variation. As repeatedly noted, and as demonstrated in the Monte Carlo simulations, talents that operate according to the multiplicative model should display skewed-right and leptokurtic distributions, the degree of departure from normality corresponding to the complexity of the domain. Along with the degree of skewness come expectations regarding the endpoints of the distribution: Multiplicative talent domains should feature a few individuals with extremely high innate capacities and a very large number of individuals who are, for all practical purposes, untalented in the domain. In contrast, domains that best fit an additive model should feature a distribution that closely approximates the normal distribution. The proportion of persons with no talent whatsoever will be minuscule, especially in complex domains. The best talents in the domain will not be placed at the leading edge of an extremely long upper tail but rather will be only a few standard deviations above the mean. To illustrate, the ratings of chess players according to the Elo system exhibit a distribution that is positively skewed to a statistically significant degree, and yet the skew is relatively modest in comparison to what is usually seen in many other talent domains (Charness & Gerchak, 1996; Elo, 1986). This outcome suggests that chess may involve components that are integrated according to an additive model, with only a slight multiplicative contribution at best.[6]

Development. Clearly, the more components that define a given talent domain, the more alternative ways that talent may emerge in childhood, adolescence, and adulthood. Hence, simple domains should display relatively few developmental trajectories, whereas complex domains should display proportionately more. But the type of model separates the talent domains in an orthogonal fashion. All other factors held constant, there should appear major differences among domains in the expected age at which the specified talent first begins to make itself felt in personal development. According to the epigenetic model, the emergence of certain components may begin at variable ages during childhood, adolescence, and even adulthood. For additive models, this longitudinal variability has minimal repercussions. Once any particular component begins to gain strength or influence, then the composite talent will accordingly launch its upward growth. So if any component begins appearing at age t, the talent itself starts to emerge at age t. Thus, the onset of talent development is contingent on whatever component appears first. The circumstance is very different for the multiplicative model. Talent development does not begin until all essential components have begun their upward trajectory. As a consequence, the onset of development for an emergenic talent is determined by whatever component arises last. The greater the number of components that have this veto power, and the more variable the expected onsets of the components, the later talent development will be delayed. It is intriguing, for example, that child prodigies tend to concentrate in a few restricted domains, such as music, mathematics, and chess (Feldman & Goldsmith, 1986; Radford, 1990). Such outcomes imply that these domains may be governed by additive models, perhaps with relatively few essential components. In contrast, it is quite common for great scientists, even Nobel laureates, not to show any special gift for scientific work until their college years (Roe, 1952). This delayed onset may in part correspond to the multidimensional and perhaps even multiplicative nature of scientific creativity (see, e.g., Feist & Gorman, 1998).

Taken in combination, the attributes in Table 4 can help investigators better understand the diverse ways that talent can function in the various domains in which individuals try to attain distinction. In a sense, the detailed patterns exhibited in the table represent a set of theoretical predictions regarding how talents can be differentiated according to the degree to which they are either multidimensional, multiplicative, or both. Moreover, these distinctive domain features might be usefully supplemented by other clues regarding the nature of a talent domain. For instance, it is intriguing to compare these discriminators with the results of the many and varied attempts at computer simulations of human expert performance in intellectual fields. These simulations have been most successful in such domains as mathematics, music, and chess (Boden, 1991; Johnson-Laird, 1993). Indeed, in the last talent domain a computer system has actually attained levels of performance that surpass the most proficient human beings (Newborn, 1996). Other computer simulations, such as those attempting to reproduce literary creativity, have been far less accomplished (e.g., Turner, 1994). These differences are roughly consistent with the patterns observed in these domains according to the fourfold typology, including the precocity of development most often seen. In general, intellectual domains that are simple and additive may be the most easily simulated by computers. By the same token, it seems likely that cognitive domains that have the complex–multiplicative features will be the last to witness computer simulations that are competitive with human world-class performance.

Finally, nothing prevents us from combining the fourfold typology described in Table 4 with the previous specification of how domains may vary according to the types of components that define a talent domain. Thus, two domains may be equally multiplicative and complex but still differ according to whether their respective components are mostly general or specific and whether their components function primarily during acquisition or performance. Whether all 16 distinct pure types are possible is an empirical issue. But at least it is safe to conclude that the model is rich enough to differentiate the myriad ways that talents might actually emerge and operate in the real world. Given the tremendous variety of alternative paths to the demonstration of talent, investigators must take immense care not to impose the same

[6] To make these cross-domain comparisons scientifically precise, the sampling and scaling procedures must be comparable across the separate domains. Sampling can differentially truncate the lower end of the distribution, and dissimilar scaling can differentially shrink the upper tails. In Olympic sports, for example, performance measures might allow comparison of ice skating scores with gymnastic scores, but probably neither could be easily compared with track times. Likewise, the distribution of performance among Olympic athletes in any given event would probably differ substantially from that seen among collegiate or high school athletes.

methodological strategy on all domains. An approach that might be right on target in one domain may be horribly off the mark in another.

Nature and Nurture

The sole aim of this article was to indicate how talent may operate in a far more elaborate manner than commonly assumed by most researchers. At least in a significant subset of achievement domains, talent may be multidimensional, multiplicative, and dynamic rather than unidimensional, additive, and static. Still, the purpose of this article was definitely not to exalt genes over the environment as the primary agent behind exceptional performance in games, sports, science, and the arts. On the contrary, it is extremely likely that environmental factors, including deliberate practice, account for far more variance in performance than does innate capacity in every salient talent domain. Even so, psychology must endeavor to identify all of the significant causal factors behind exceptional performance rather than merely rest content with whatever factor happens to account for the most variance. Accordingly, psychologists should give the concept of talent a scientifically impartial evaluation. Such an assessment demands that investigators make due allowance for the potential niceties of the phenomenon. In the absence of such methodological and theoretical provisions, psychologists may prematurely reject the hypothesis that innate capacities may indeed provide a partial foundation for exceptional performance in at least some talent domains.

But the matter must not rest here. A complete picture of talent and its development demands that the effects of nature be integrated with the effects of nurture. Behavior genetics now takes great care to distinguish between various kinds of genetic (additive and nonadditive) and environmental (shared and nonshared) effects (e.g., Bouchard, 1994), so research on development in talent domains must certainly do the same. However, such partitionings of the variance may eventually have to recognize that nurture may also function by complex nonadditive functions, such as have already been demonstrated for social-learning effects (e.g., Simonton, 1983, 1984a). If the genes are to be given more explanatory power by allowing departures from additive and linear functions, then certainly the same opportunity must be allowed environmental factors. Complicating matters even more is the need to decipher the convoluted ways that nature and nurture may interact during the course of individual development. For example, complete models may eventually have to include both genetic and environmental factors in a single multiplicative function, as was proposed in Eysenck's (1995) recent theory of how creativity-as-trait becomes creativity-as-achievement. More critically, the environment probably determines how the genotype is converted into the phenotype through nonadditive synergistic processes, as detailed in the bioecological model of development proposed by Bronfenbrenner and Ceci (1994). At the same time, it is not unlikely that the genotype can at times exert an influence over the environment in which a youth develops, as frequently argued in behavior genetics (Plomin & Bergeman, 1991; Scarr & McCartney, 1983) and as suggested in some studies of highly gifted children (Feldman & Goldsmith, 1986; Winner, 1996). In fact, according to Darwinian models of talent development, an individual's potential becomes actualized through the evolutionary interaction of innate capacities and "ecological niches" available in family, school, and workplace (e.g., Simonton, 1999; Sulloway, 1996).

In a nutshell, the debate over the place of talent in exceptional performance must be intimately and irrevocably embedded in the broader empirical and theoretical literature on the interplay of genes and environment in the determination of human behavior. It must be remembered that the terms *nature* and *nurture* were first introduced by Galton (1874) in the specific context of a debate over which influence contributed most to talent development (viz., de Candolle, 1873; Galton, 1869; see Hilts, 1975). As Galton recognized over a century ago, talent provides a critical research site for addressing one of the biggest enigmas in the behavioral sciences. Because this question is as practically important as it is theoretically significant, an impartial and sophisticated assessment becomes all the more imperative.

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Received January 20, 1998
Revision received August 28, 1998
Accepted August 28, 1998 ■