Psychological Bulletin
1988, Vol. 104, No. 2, 251–267

0033-2909/88/$00.75

Age and Outstanding Achievement: What Do We Know After a Century of Research?

Dean Keith Simonton
University of California, Davis

This article examines, in four sections, the substantial literature on the longitudinal connection between personal age and outstanding achievement in domains of creativity and leadership. First, the key empirical findings are surveyed, with special focus on the typical age curve and its variations across disciplines, the association between precocity, longevity, and production rate, and the linkage between quantity and quality of output over the course of a career. Second, the central methodological issues are outlined, such as the compositional fallacy and differential competition, in order to appraise the relative presence of fact and artifact in the reported results. Third, the more important theoretical interpretations of the longitudinal data are presented and then evaluated for explanatory and predictive power. Fourth and last, central empirical, methodological, and theoretical considerations lead to a set of critical questions on which future research should likely concentrate.

For centuries, thinkers have speculated about the association between a person's age and exceptional accomplishment: Is there an optimal age for a person to make a lasting contribution to human culture or society? When during the life span can we expect an individual to be most prolific or influential? It comes as no surprise, then, that one of the oldest topics in life span developmental psychology is the relation between age and achievement. Perhaps the earliest investigation into this matter may be found in Beard's (1874) *Legal Responsibility in Old Age.* Yet research did not really attain notable proportions until Harvey C. Lehman devoted around three decades to the subject. Most of his principal findings are summarized in his 1953 book, *Age and Achievement* (Lehman, 1953a; see also Lehman, 1962). Among his numerous results was the tendency for achievement, however gauged and no matter what the endeavor, to be a curvilinear, single-peak function of age. This central conclusion provoked some controversy, led largely by Wayne Dennis (e.g., Dennis, 1954d, 1956a, 1958, 1966) but reinforced by sociologists as well (e.g., S. Cole, 1979; Zuckerman & Merton, 1972). Although interest in this subject waned for a decade or so, and Lehman's contributions suffered some neglect and misunderstanding (Romanuik & Romanuik, 1981), psychologists have once again been drawn to this critical issue (see, e.g., Horner, Rushton, & Vernon, 1986; Kogan, 1973; Mumford, 1984). Part of this change may be due to the expansion of inquiries in life span developmental psychology, a growth symbolized as well as encouraged by the advent of a new journal, *Psychology and Aging.* In addition, a huge population of adults, the products of the postwar "baby boom," are now reaching middle age. This demographic reality underlines the importance of learning what we can expect as this large block moves into older adulthood. In any case, it seems that a review of the literature is both timely and necessary to focus subsequent research on the same body of key empirical, methodological, and theoretical issues.

I begin by outlining the central empirical results, with an emphasis on those findings that have been most strongly and consistently replicated over the past century or so. The next section briefly discusses some of the more critical methodological issues that confront researchers in this area, in order to tease out fact from artifact. Then I describe the principal theoretical interpretations, both extrinsic and intrinsic, of the longitudinal data. This review, finally, closes with a brief attempt to direct the attention of investigators to what I view to be the crucial questions if our knowledge is to advance from purely inquisitive empiricism to theoretical comprehension.

Empirical Results

Here we adopt the product-centered approach, that is, our focus is on real-life achievements rather than performance on abstract psychometric measures (cf. Kogan, 1973; McClelland, 1973). Given this restriction, studies of the functional relation between age and achievement can be roughly grouped into two primary categories. On the one hand, achievement may take the form of noteworthy creativity, in which case the goal is to assess how productivity changes over the life span. Such inquiries focus on individual accomplishment in such endeavors as science, philosophy, literature, music, and the visual arts. On the other hand, contributions may be in the guise of leadership, requiring that the investigator examine the ages at which a person is most likely to exert influence over others, especially by occupying significant positions of power, whether political, military, economic, or religious. Although we can argue that creativity and leadership are two facets of the same fundamental phenomenon, exceptional personal influence, I will follow tradition by treating these two routes separately (cf. Simonton, 1984b, 1985a).[1]

Correspondence concerning this article should be addressed to Dean Keith Simonton, Department of Psychology, University of California, Davis, Davis, California 95616.

[1] Actually, Lehman (1953a) devoted considerable attention to a third category of exceptional achiever, namely, those involved in popular cul-

Creativity

Ever since Lehman (1953a), life span developmental studies of creative achievement have centered on three core topics: (a) the age curve that specifies how creative output varies over the course of a career, (b) the connection between productive precocity, longevity, and rate of output, and (c) the relation between quantity and quality of output (i.e., between "productivity" and "creativity").

Age curves. One empirical generalization appears to be fairly secure: If one plots creative output as a function of age, productivity tends to rise fairly rapidly to a definite peak and thereafter decline gradually until output is about half the rate at the peak (see, e.g., S. Cole, 1979; Dennis, 1956b, 1966; Lehman, 1953a; but see Diamond, 1986). In crude terms, if one tabulates the number of contributions (e.g., publications, paintings, compositions) per time unit, the resulting longitudinal fluctuations may be described by an inverted backward-J curve (Simonton, 1977a). Expressed more mathematically, productive output, say $p(t)$, over a career tends to be roughly approximated by a second-order polynomial of the form

$$p(t) = b_1 + b_2 t + b_3 t^2, \qquad (1)$$

where the *b*s are unstandardized regression coefficients obtained by regressing productivity at time t on linear and quadratic functions of t (see, e.g., Bayer & Dutton, 1977; Horner et al., 1986; Simonton, 1977a, 1980c). Typically, b_1, or the intercept term, will be zero or slightly positive, b_2 will be positive or zero, and b_3 will invariably be negative. In applying this equation, the independent variable, t, is not chronological age but rather career or professional age, where $t = 0$ at the onset of the career (see Bayer & Dutton, 1977; Lyons, 1968). However, in practice, chronological age is often used in lieu of career age, a substitution justified by their high correlation (e.g., $r = .87$, according to Bayer & Dutton, 1977).

By taking the first derivative of Equation 1, setting it equal to zero, and solving for t, one can easily show that the peak is expected to appear at one half of the ratio of the third and second regression coefficients (i.e., at $t = -b_2/2b_3$). However, it must be emphasized that the equation presented above is merely a first approximation, and it becomes particularly inadequate should we attempt to extrapolate to extreme age ranges. Specifically, beyond a certain value of t, the predicted level of productivity becomes negative, a meaningless outcome if output is gauged by single contributions or items.[2] Instead, the curve tends to approach the zero productivity rate more or less asymptotically, a tendency that implies that a third-order polynomial in time may fit the data more precisely (Simonton, 1984a). The addition of further terms would also serve to remove another fault of a simple quadratic, namely, that it implies that the pre- and postpeak slopes are roughly equal, which is seldom true in fact (cf. Diemer, 1974). Nevertheless, over most ranges of career ages, Equation 1 provides a close enough fit that the addition of a cubic term (t^3) rarely yields a significant increment to the explained variance (Simonton, 1977a, 1984a; cf. Bayer & Dutton, 1977; Simonton, in press).

Independent of the proper mathematical specification, two necessary qualifications must still be imposed on the empirical generalization just given. In the first place, the location of the peak, as well as the magnitude of the postpeak decline, tends to vary depending on the domain of creative achievement. At one extreme, some fields are characterized by relatively early peaks, usually around the early 30s or even late 20s in chronological units, with somewhat steep descents thereafter, so that the output rate becomes less than one-quarter the maximum. This agewise pattern apparently holds for such endeavors as lyric poetry, pure mathematics, and theoretical physics, for example (Adams, 1946; Dennis, 1966; Lehman, 1953a; Moulin, 1955; Roe, 1972b; Simonton, 1975a; Van Heeringen & Dijkwel, 1987). At the contrary extreme, the typical trends in other endeavors may display a leisurely rise to a comparatively late peak, in the late 40s or even 50s chronologically, with a minimal if not largely absent drop-off afterward. This more elongated curve holds for such domains as novel writing, history, philosophy, medicine, and general scholarship, for instance (Adams, 1946; Richard A. Davis, 1987; Dennis, 1966; Lehman, 1953a; Simonton, 1975a). Of course, many disciplines exhibit age curves somewhat between these two outer limits, with a maximum output rate around chronological age 40 and a notable yet moderate decline thereafter (see, e.g., Fulton & Trow, 1974; Hermann, 1988; McDowell, 1982; Zhao & Jiang, 1986). Output in the last years appears at about half the rate observed in the peak years. Productive contributions in psychology, as an example, tend to adopt this temporal pattern (Horner et al., 1986; Lehman, 1953b; Over, 1982a, 1982b; Zusne, 1976).

It must be stressed that these interdisciplinary contrasts do not appear to be arbitrary but instead have been shown to be invariant across different cultures and distinct historical periods (Lehman, 1962). As a case in point, the gap between the expected peaks for poets and prose authors has been found in every major literary tradition throughout the world and for both living and dead languages (Simonton, 1975a). Indeed, because an earlier productive optimum means that a writer can die younger without loss to his or her ultimate reputation, poets exhibit a life expectancy, across the globe and through history, about a half dozen years less than prose writers do (Simonton, 1975a). This cross-cultural and transhistorical invariance strongly suggests that the age curves reflect underlying psychological universals rather than arbitrary sociocultural determinants. In other words, the age functions for productivity may result from intrinsic information-processing requirements rather than extrinsic pressures due to age stereotypes about older contributors, a point that we shall return to in the theoretical section (see also Bayer & Dutton, 1977).

The second qualification has to do with the occurrence of a single-peak longitudinal function, for some investigators have indicated the appearance of a more complex age curve with two separate peaks. Such double-peak curves are of two types. Most common, perhaps, is the emergence of a secondary upswing in

ture, such as sports and entertainment, who could be styled "celebrities" rather than creators or leaders (cf. Simonton, 1986b). Because the empirical research here is less extensive, and because the pertinent developmental variables are probably different, this type of distinction will not be examined in this review.

[2] By using the quadratic formula, $p(t) = 0$ when $t = [-b_2 \pm (b_2^2 - 4b_1b_3)^{1/2}]/2b_3$, and $p(t) < 0$ whenever t is extrapolated beyond this interval.

creative output roughly around retirement age, if not later (see, e.g., Robert A. Davis, 1954; Eagly, 1974; Haefele, 1962, pp. 235–236, 295). This resurgence in the 60s and even 80s is not always apparent, and even when it is present, it is without exception far smaller than the regular maximum observed toward the middle of the career. This contrasts with the other situation in which a bimodal productivity distribution is witnessed, with two age peaks of approximately equal magnitude (see, e.g., Abt, 1983; Bayer & Dutton, 1977; Blackburn, Behymer, & Hall, 1978; Dennis, 1966, Diemer, 1974; Pelz & Andrews, 1976; Roe, 1972b; Stern, 1978). The slump between the two optima in this saddle-shaped age curve most frequently occurs sometime in the early or middle 40s in chronological age. Nonetheless, even though the two peaks are conspicuous, the valley between them is much less prominent, and hence it is often more accurate to talk of a "mesa" rather than two peaks. Indeed, speaking in more general terms, true double-peak functions would require fourth-order polynomials to fully account for the longitudinal fluctuations in output. Yet when higher-order terms are added to Equation 1, and especially when t^4 is inserted, these additions seldom enhance our predictive power over what can be realized via the second-order polynomial in time (Simonton, 1977a, 1984a). Thus, on empirical grounds a single-peak function still provides the most stable summary of the observed data. Moreover, certain methodological considerations, to be treated later, imply that some tabulations with double optima may be more artifactual than real.

When due regard is given to interdisciplinary shifts in the age curve, and when any subsidiary peaks or valleys are simply ignored, a single-peak function such as that given by Equation 1 accounts for a respectable percentage of the total agewise variance in productivity. The specific proportion of variance explained naturally depends on both the type of data studied and the form of the function defining the age trend. For data that are aggregated across hundreds of separate creative individuals, single-peak functions, such as the quadratic polynomial, may explicate nearly 100% of the variance (Simonton, 1984a). In contrast, when the goal is to predict individual time series (i.e., single careers), so that random shocks and measurement errors cannot cancel out through aggregation, the amount of variance accounted for may drop to one-third or lower still (Horner et al., 1986; cf. McCrae, Arenberg, & Costa, 1987; Simonton, 1977a, 1986d, in press). Also, more complex mathematical functions, including some to be discussed later, are prone to handle more precisely the longitudinal fluctuations than are more simple functions, such as Equation 1. This superiority is especially evident when the career lengths are sufficiently extended so as to reveal the more asymptotic, concave-upward decline in the last years.

Precocity, longevity, and output rate. Individual differences in lifetime output are substantial (Simonton, 1984b, chap. 5; 1988b, chap. 4). So skewed is the cross-sectional distribution of total contributions that a small percentage of the workers in any given domain is responsible for the bulk of the work. Generally, the top 10% of the most prolific elite can be credited with around 50% of all contributions, whereas the bottom 50% of the least productive workers can claim only 15% of the total work, and the most productive contributor is usually about 100 times more prolific than the least (Dennis, 1954b, 1955; also see Lotka, 1926; Price, 1963, chap. 2). Now from a purely logical perspective, there are three distinct ways of achieving an impressive lifetime output that enables a creator to dominate an artistic or scientific enterprise. First, the individual may exhibit exceptional precocity, beginning contributions at an uncommonly early age. Second, the individual may attain a notable lifetime total by producing until quite late in life, and thereby display productive longevity. Third, the individual may boast phenomenal output rates throughout a career, without regard to the career's onset and termination. These three components are mathematically distinct and so may have almost any arbitrary correlation whatsoever with each other, whether positive, negative, or zero, without altering their respective contributions to total productivity. In precise terms, it is clear that $O = R(L - P)$, where O is lifetime output, R is the mean rate of output throughout the career, L is the age at which the career ended (longevity), and P is the age at which the career began (precocity). The correlations among these three variables may adopt a wide range of arbitrary values without violating this identity. For example, the difference $L - P$, which defines the length of a career, may be more or less constant, mandating that lifetime output results largely from the average output rate R, given that those who begin earlier, end earlier, and those who begin later, end later. Or output rates may be more or less constant, forcing the final score to be a function solely of precocity and longevity, either singly or in conjunction. In short, R, L, and P, or output rate, longevity, and precocity, comprise largely orthogonal components of O, the gauge of total contributions.

When we turn to actual empirical data, we can observe two points. First, as might be expected, precocity, longevity, and output rate are each strongly associated with final lifetime output, that is, those who generate the most contributions at the end of a career also tend to have begun their careers at earlier ages, ended their careers at later ages, and produced at extraordinary rates throughout their careers (e.g., Albert, 1975; Blackburn et al., 1978; Bloom, 1963; Clemente, 1973; S. Cole, 1979; Richard A. Davis, 1987; Dennis, 1954a, 1954b; Helson & Crutchfield, 1970; Lehman, 1953a; Over, 1982a, 1982b; Raskin, 1936; Roe, 1965, 1972a, 1972b; Segal, Busse, & Mansfield, 1980; R. J. Simon, 1974; Simonton, 1977c; Zhao & Jiang, 1986). Second, these three components are conspicuously linked with each other: Those who are precocious also tend to display longevity, and both precocity and longevity are positively associated with high output rates per age unit (Blackburn et al., 1978; Dennis, 1954a, 1954b, 1956b; Horner et al., 1986; Lehman, 1953a, 1958; Lyons, 1968; Roe, 1952; Simonton, 1977c; Zuckerman, 1977). The relation between longevity and precocity becomes particularly evident when care is first taken to control for the impact of differential life span (Dennis, 1954b). Because those who are very prolific at a precocious age can afford to die young and still end up with a respectable lifetime output, a negative relation emerges between precocity and life span, necessitating that careers be equalized on life span before the correlation coefficients are calculated (Simonton, 1977c; Zhao & Jiang, 1986).

While specifying the associations among the three components of lifetime output, we have seemingly neglected the expected peak productive age. Those creators who make the most contributions tend to start early, end late, and produce at above-average rates, but are the anticipated career peaks unchanged, earlier, or later in comparison to what is seen for their less pro-

lific colleagues? Addressing this question properly requires that we first investigate the relation between quantity and quality, both within and across careers.

Quantity and quality. Lehman (1953a) devoted three entire chapters in his book to analyzing the correlation between quality and quantity of output over the course of a career. Does it make any difference to the outcome if we tabulate the whole output of creative persons rather than restrict our attention to the most important, even landmark, works? Expressed differently, are the age curves identical for creativity, or quality of output, as for productivity, or quantity of output? Resolution of this substantive issue is of immense methodological and theoretical significance. On the methodological side, if the age curves vary according to the criterion adopted for gauging output per time unit, then our estimates of the peak productive period of a career are necessarily contingent on the standards imposed on the contributions before their inclusion in the tabulations. Such a state of affairs would instill the results with some degree of arbitrariness and would make comparisons across separate creative disciplines quite precarious without first finding a way to standardize the merit of the contributions. On the theoretical side, should it be proven that the age curves are affected by the relative weight of quality versus quantity, then distinct explanations have to be evoked for creativity versus productivity. One process cannot then be said to be responsible for both age curves, or at least a different set of variables may be involved that only partly overlap.

When Lehman (1953a) compared tabulations of superior contributions in a wide range of creative activities against those for works of lesser merit, he concluded that the age curves obtained were indeed contingent on the quality criterion utilized in constructing the counts. For the most part, the peak productive age tended to stay relatively stable, only the peak was far more pronounced when only exceptional works were tabulated (see also Lehman, 1958, 1966a). In contrast, when the standards of excellence were loosened, the age curves flattened out appreciably, and the postpeak decline was much less conspicuous. This generalization was largely replicated by Dennis (1966), who was highly critical of Lehman's proclivity for counting just major contributions to the exclusion of total output of achieving individuals. By building age curves for longitudinal changes in productive quantity, without regard for supposed quality, Dennis could show that the function was far less dramatic. In particular, the drop-off in output in the final decades was at worst merely gradual and at best virtually nonexistent, especially in the more scholarly disciplines. It would seem, then, that the relation between age and outstanding creative achievement very much hinges on how strictly we impose the requirement that a prospective contribution be outstanding.

Before we accept this last conclusion, however, we must recognize that a fundamental methodological defect intrudes on the bulk of the research. Rather than scrutinize the connection between quantity and quality within single careers, most investigators have compiled aggregate counts across numerous careers. This procedure alone invited the compositional fallacy to be discussed later in this review. Moreover, seldom are the compilations based on the same samples of creators, but instead, the superior contributions are taken from more selective samples of creative individuals than are the lesser-merit contributions, rendering the contrasts highly suspect. Clearly, to assess fairly and accurately the timewise linkage between productivity and creativity, the distributions of major and minor works must each be drawn from the same set of producers. And the association between quantity and quality must be estimated using a cross-sectional time series design that, in effect, determines the within-career trends before summarizing them across careers (cf. Simonton, 1977b).

When such precautions are taken, very different results emerge (Simonton, 1977a, 1984b, chap. 6, 1985b, 1988b, chap. 4). First, if one calculates the age curves separately for major and minor works within careers, the resulting functions are basically identical. Both follow the same second-order polynomial (as seen in Equation 1), with roughly equal parameters. Second, if the overall age trend is removed from the within-career tabulations of both quantity and quality, minor and major contributions still fluctuate together. Those periods in a creator's life that see the most masterpieces also witness the greatest number of easily forgotten productions, on the average. Another way of saying the same thing is to note that the "quality ratio," or the proportion of major products to total output per age unit, tends to fluctuate randomly over the course of any career. The quality ratio neither increases nor decreases with age nor does it assume some curvilinear form. These outcomes are valid for both artistic (e.g., Simonton, 1977a) and scientific (e.g., Simonton, 1985b) modes of creative contribution (see also Alpaugh, Renner, & Birren, 1976, p. 28). What these two results signify is that if we select the contribution rather than the age period as the unit of analysis, then age becomes irrelevant to determining the success of a particular contribution. For instance, the number of citations received by a single scientific article is not contingent upon the age of the researcher (Oromaner, 1977).

The longitudinal linkage between quantity and quality can be subsumed under the more general "constant-probability-of-success model" of creative output (Simonton, 1977a, 1984b, 1985b, 1988b, chap. 4). According to this hypothesis, creativity is a probabilistic consequence of productivity, a relationship that holds both within and across careers. Within single careers, the count of major works per age period will be a positive function of total works generated each period, yielding a quality ratio that exhibits no systematic developmental trends. And across careers, those individual creators who are the most productive will also tend, on the average, to be the most creative: Individual variation in quantity is positively associated with variation in quality. There is abundant evidence for the application of the constant-probability-of-success model to cross-sectional contrasts in quantity and quality of output (Richard A. Davis, 1987; Simonton, 1984b, chap. 6; 1985b, 1988b, chap. 4). In the sciences, for example, the reputation of a nineteenth-century scientist in the twentieth century, as judged by entries in standard reference works, is positively correlated with the total number of publications that can be claimed (Dennis, 1954a; Simonton, 1981a; see also Dennis, 1954c). Similarly, the number of citations a scientist receives, which is a key indicator of achievement, is a positive function of total publications (Crandall, 1978; Richard A. Davis, 1987; Myers, 1970; Rushton, 1984), and total productivity even correlates positively with the citations earned by a scientist's three best publications (J. R. Cole & S. Cole, 1973, chap. 4). Needless to say, the correlations between quantity and quality are far from perfect for either longitudinal or cross-sectional data. The coefficients for

within-career fluctuations are typically in the .20s to .50s (after partialling out age trends), whereas the coefficients for across-career variations are usually somewhere between the .50s and .70s (Simonton, 1988b, chap. 4). We are thus speaking of a statistical rather than a deterministic connection. Even so, the association is neither zero nor negative but consistently positive.

The constant-probability-of-success model has an important implication for helping us understand the relation between total lifetime output and the location of the peak age for creative achievement within a single career (Simonton, 1987a, 1988b, chap. 4). Because total lifetime output is positively related to total creative contributions and hence to ultimate eminence, and given that a creator's most distinguished work will appear in those career periods when productivity is highest, the peak age for creative impact should not vary as a function of either the success of the particular contribution or the final fame of the creator. Considerable empirical evidence indeed demonstrates the stability of the career peak (Simonton, 1987a). In the sciences, for instance, the correlation between the eminence of psychologists and the age at which they contribute their most influential work is almost exactly zero (Zusne, 1976; see also Lehman, 1966b; cf. Horner et al., 1986). And in the arts, such as literary and musical creativity, the age at which a masterpiece is generated is largely independent of the magnitude of the achievement (Simonton, 1975a, 1977a, 1977c). Thus, even though an impressive lifetime output of works, and subsequent distinction, is tied to precocity, longevity, and production rate, the expected age optimum for quantity and quality of contribution is dependent solely on the particular form of creative expression (also see Raskin, 1936).

Leadership

Unlike the research on creative achievement, investigations on the life span development of exceptional leadership have been far more sporadic and inconclusive. The overwhelming majority of empirical studies examined the ages at which individuals are most likely to occupy recognized positions of leadership. Lehman's (1953a, chap. 11) work is typical: He surveyed an impressive diversity of leader activities, whether political, military, economic, or religious, and carefully tabulated the usual age upon entering the role (see also Oleszek, 1969; Sorokin, 1925, 1926). Seldom are performance measures used to determine how well a leader succeeded in the position so occupied. For instance, Lehman (1953a) gave the ages at which generals were most prone to have fought major battles without even gauging the impact, if any, of age upon victory or defeat! The closest Lehman came to assessing the real consequence of age for outstanding leadership was his comparison of victorious and defeated candidates for the U.S. presidency; although the modal age for winners and losers is about the same, somewhere in the mid 50s, losers display more variation and thus have a higher likelihood of being either much younger or much older than the apparent optimal age for garnering votes from the American electorate (see also Simonton, 1987d, chap. 2). Even if it has been suggested that this same age period represents an optimum for demonstrating successful presidential leadership (Murphy, 1984), empirical data fail to support this conjecture. Age at inauguration simply bears no connection with presidential performance, no matter how the latter is assessed (Simonton, 1981b, 1985c, 1986e, 1986f, 1987d).

One persistent obstacle to detecting the connection between age and leadership is that most individuals fill positions of power for relatively brief spans of time. In contrast to the creative individual, whose career may span decades, leaders rarely rule for more than a decade. Presidents of the United States, for instance, serve 8 years at most, and the sole exception, Franklin Roosevelt, still served only a dozen years, a career length just a bit better than the average for a sample of 696 classical composers (Simonton, 1977c). As a consequence, leaders infrequently occupy the same office long enough to enable us to estimate age curves like those determined for creators. The curve will just be too flat over the short age intervals available. To be sure, we do have an abundance of leaders who served in office at quite varying ages—Alexander the Great began his conquests at age 22, whereas Louis XIV launched the War of the Spanish Succession at age 63—and this cross-sectional variation may hint at the underlying age curve if the variance injected by longitudinal changes is massive enough to pierce through variance resulting from individual differences. As a case in point, in an investigation of victory on the battlefield, the age of the general was negatively associated with his willingness to take the military offensive, which disposition is a major predictor of tactical success (Simonton, 1980a; cf. Vroom & Pahl, 1971). In addition, those generals who come closest to the age of 45 years have higher odds of displaying superior military competence and experience. As suggestive as these findings are, longitudinal and cross-sectional variance is partly confounded, for few military figures have careers long enough that we can trace victories and defeats over decades. Fewer than a score years separate Napoleon's first military accomplishment from his loss at Waterloo (Simonton, 1979b).

An alternative route around this methodological impasse is to concentrate attention on those leaders who managed to serve long years in office. Particularly revealing are hereditary monarchs from the era of absolute monarchy, for in such cases a ruler could assume the throne as a mere teenager and continue to govern until an octogenarian. Moreover, absolute monarchs were granted more power over events than were medieval rulers and modern constitutional monarchs, presidents, or prime ministers, thus rendering it more probable that life span developmental changes will be reflected in overt acts of leadership. Lastly, a long rule means an abundance of events from which we can construct performance indicators (Simonton, 1984d). To illustrate these potential assets, an inquiry was made into the careers of 25 European kings and queens from over a dozen nations—such as Queen Elizabeth I, Frederick the Great, Ivan the Terrible, and Suleiman the Magnificent—that found that most objective performance indicators either decline with age or else exhibit a curvilinear inverted-U function that maximized at the 42nd year of life, this latter curve holding for some measures of military and diplomatic success (Simonton, 1984c). What made this study sensitive to longitudinal changes was the fact that none of the sampled leaders ruled fewer than 36 years, and the average reign length was 43 years, giving career durations more comparable to those found in the research on distinguished creativity.

The two inquiries just cited, one of military generals and the other of hereditary monarchs, both suggest that leadership may

peak in the early 40s. The correspondence between this peak age and that found for creativity implies that a certain overlap exists between these two modes of achievement: Effective leadership may require some problem-solving capacity, and influential creativity may demand skill at persuasiveness (see, e.g., Alker, 1981; Simonton, 1984b, 1985a, 1987a). This congruence, even if only approximate, should make us wonder whether or not the interdisciplinary contrasts in the age curves noted in creative endeavors have counterparts in realms of leadership. The evidence addressing this question is only indirect at best. Lehman (1953a, chap. 11) made extensive comparisons between leaders in new versus established churches concerning when the leaders assumed high office or position, and he found support for Granville Stanley Hall's (1922, p. 420) assertion, in his classic *Senescence: The Last Half of Life,* that "men in their prime conceived the great religions, the old made them prevail." Thus did Jesus of Nazareth end his ministry at an age less than half that of the typical Roman Catholic pope upon accession.

An analogous age gap appears between revolutionaries and leaders of long-established political institutions. Although as many as half of the notable revolutionaries were younger than 35 (Rejai & Phillips, 1979), very few of the world's political leaders attained power before age 40 (Blondel, 1980). Indeed, just as poets can die younger than prose writers and still achieve a durable reputation (Simonton, 1975a), so the predominant youthfulness of revolutionaries betrays itself in a lower life expectancy. In the Cox (1926) sample of 301 geniuses, who had an overall life span mean of 66 years, the revolutionaries averaged only 51 years, not one living to be 80 and more than 44% dying prior to age 50. These figures contrast dramatically with the statesmen in Cox's sample who operated under more status quo conditions; their life expectancy was 70, only about 5% lived fewer than 50 years, and fully 30% survived to their 80th birthday. Furthermore, these results are enlarged by the finding that as political institutions mature, the age of their leaders increases as well (Lehman, 1953a, chap. 17). In the United States, for example, members of the House of Representatives and the Senate, House speakers, cabinet officers, Supreme Court justices, ambassadors, and army commanders have all gotten older and older since the nation's founding, trends that cannot be explained by corresponding enhancements in general life expectancy (see also Simonton, 1985c, 1987d, chap. 4). Indeed, transhistorical data have consistently shown that the mean life span has not significantly changed over the centuries but rather has stayed close to around 65 years (see, e.g., Simonton, 1975a, 1977c; Zhao & Jiang, 1986), a figure close to the "three-score years and ten" said by Solon to be the normal term of a human life way back in ancient Greece.

Even granting that the linkage between age and exceptional leadership often parallels that observed between age and noteworthy creativity, the possible congruences have not been fully unearthed. For one thing, the associations among precocity, longevity, and output rate that are so conspicuous in creative activities have yet to be completely documented in leadership domains, despite some suggestive data regarding military and legislative behaviors (Simonton, 1984b, 1984d). Additionally, no empirical study to date has discovered the leadership analogue of the probabilistic association between quantity and quality of output in creative vocations, even though, once more, what little data exist are not inconsistent with this relationship (Simonton, 1980a, 1984b, 1984d). More research is obviously necessary before the impact of age on phenomenal leadership has been assayed with the same precision and comprehensiveness that has been seen in the literature on distinguished creativity.[3]

Methodological Issues

Anyone who demonstrates, as Lehman (1953a) did, an age decrement in achievement is likely to provoke controversy. After all, aging is a phenomenon easy enough to become defensive about, and such defensiveness is especially probable among those of us who are already past the putative age peak for our particular field of endeavor (cf. R. J. Simon, 1974). It is not surprising, then, that Lehman, unlike any other researcher in this area, became subject to a whole host of criticisms focusing on whether or not achievement exhibits a negative slope in the latter part of a career (e.g., S. Cole, 1979; Dennis, 1954d, 1956a, 1956b, 1958, 1966; Zuckerman & Merton, 1972). Some of these supposed difficulties were picky and impertinent, such as the objection raised by Dennis (1956a, 1958) to the age units selected for aggregating achievements, yet others are too serious to be ignored with impunity and hence are just as germane to today's research as to that of 30 years ago. These still-persistent problems concern the measurement and the tabulation of achievement (cf. Kogan, 1973; Romanuik & Romanuik, 1981).

What Counts as an Achievement?

Lehman (1953a) usually tabulated his age curves not from the total output of each individual career but rather from the truly notable contributions. That is, the achievements counted in each age period had to be cited in standard reference works, such as histories and chronologies, as landmark or history-making products or events. Dennis (1956a) maintained that the postpeak decline would be much less substantial once an individual's entire corpus was counted. He backed up his argument empirically by tabulating the total contributions by hundreds of individuals working in over a dozen disciplines, often finding negligible decreases (except in the arts) (Dennis, 1966). In short, quality output may trail off in the later years of a career, but quantity output exhibits a more optimistic agewise trend. Given that the quality assessments are predicated on subjective judgments, whereas the quantity measures are based on objective behaviors (e.g., completed paintings, published papers), the latter may be more indicative of true changes over the life span (see also Bullough, Bullough, & Mauro, 1978; Dennis, 1954d, 1956b). Dennis (1954d, 1956a) was particularly skeptical of the historian's evaluations because of changes in the competition as a person's career progresses. In most disciplines, the membership has been expanding, and often exponentially (Price, 1963, chap. 1; Simonton, 1975b; Taagepera & Colby, 1979). As a con-

[3] The literature on the relation between age and leadership in more everyday situations has yielded less than consistent results, with correlations ranging from −.32 to .71 and averaging around .21 (Bass, 1981, p. 47). Nonetheless, besides the restriction to less momentous forms of leadership, these studies often are heterogeneous as to the nature of the subject pools (e.g., children versus adults and academic versus business settings) and seldom look for curvilinear functions.

sequence, as an individual ages, he or she must face ever more competitors for the limited space that posterity can allot to describing important events (Dennis, 1958). Such differential competition across the life span then inserts an artifactual loss in apparent accomplishments with age.

Though convincing on first blush, these arguments against Lehman's empirical conclusions fail for the following four reasons:

1. Various investigators have introduced controls for differential competition across the life span without any substantial impact on the outcome. These corrections may be indirect, such as partialling out time trends (e.g., Diemer, 1974; Simonton, 1975a, 1980b), or direct, such as actually tabulating the number of competing individuals or products (e.g., Simonton, 1977a, 1980c), but the upshot is more or less the same (see also Lehman, 1960). Increased competition may indeed depress the odds of recording an achievement in the last decades of life, yet not by enough to account for the age peak and subsequent decline. Moreover, the same substantive conclusions obtain even when we inspect age curves in endeavors in which the number of participants has been on the decline (Simonton, 1975a, 1983, 1986d). Lastly, there is some question as to whether or not the authors of archival sources really do discriminate against the more recent products of older achievers (Simonton, in press), for the exponential growth in the number of competitors is often more than compensated for by a "discounting effect," such that more recent work is often discussed at the expense of earlier work (see, e.g., Abt, 1983; Simonton, 1975b, 1976a, 1976b, 1985b; Taagepera & Colby, 1979).

2. To the extent that the constant-probability-of-success model holds for longitudinal data, the contrast between notable and total contributions is a false one. Specifically, if the number of major achievements in any age period is a probabilistic function of the number of entire attempts, then the former can serve perfectly well as an indicator of the latter. As noted earlier, most previous comparisons between major and minor contributions over the career failed to examine the interconnection for the same sample of achievers and achievements, nor did earlier investigations use the proper longitudinal design. When suitable precautions are taken, major and minor contributions change together over time, and the proportion of major to total output fluctuates randomly (Simonton, 1977a, 1984b, chap. 6, 1985b, 1988b, chap. 4).

3. It is possible to gauge outstanding achievement without resorting to the subjective judgments of those scholars who compile the histories and chronologies of past accomplishments. In the case of leadership, for instance, we can examine undisputed battlefield victories and still obtain age-decrement effects (Simonton, 1980a). For creativity, the value of products can sometimes be assessed by objective content analytical procedures (Simonton, 1984b, chap. 7). For example, totally computerized content analyses of 15,618 themes from the classical repertoire provided an index of melodic originality based strictly on transition probabilities (Simonton, 1984e). This utterly objective measure was nonetheless a curvilinear, inverted backward-J function of age (Simonton, 1980b, 1980c). Longitudinal measures of scientific achievement based on the *Science Citation Index* also evince declines in the later years, especially after due provision is made for the decay in citation rates (see, e.g., S. Cole, 1979; Diamond, 1986; Simonton, 1984b, chap. 6; Van Heeringen & Dijkwel, 1987).

4. Insofar as our current needs are concerned, the charge that the age curves for major achievements may not be equivalent to those for total output is simply irrelevant. If the substantive interest is in the bearing that age has on outstanding accomplishment, then we have no other recourse than to rely on measures that emphasize quality over quantity. The stance taken here is that both creativity and leadership represent sociopsychological phenomena rather than purely psychological, even intrapsychic, events (cf. Kogan, 1973). Naturally, in the realm of leadership there is almost no debate on this proposition, for to define someone as a leader sans followers is prima facie absurd. Yet creativity, it can be argued, is equally a guise of leadership, an act of intellectual or aesthetic persuasion (Simonton, 1987a, 1988b). To label a poem creative that lacks appreciators, or a theory creative that boasts no adherents, is to remove the term from the domain of interpersonal and sociocultural pertinence. Recent definitions of creativity have in fact turned toward a more social conception of what creativity entails (e.g., Amabile, 1982, 1983; Sternberg, 1985). Achievement is very much an attribution made by others that results in a product or a person acquiring the label that designates creativity or leadership (see, e.g., Simonton, 1986c). Hence, if a conflict does appear between indicators of quality and those of quantity, we must side with the former. And, needless to say, if the constant-probability-of-success model is correct, no real disparity exists anyway.

In conclusion, the criticisms leveled against Lehman's manner of operationalizing outstanding achievement do not suffice to undermine the chief inferences concerning the age curves. Lehman (1960, 1962) himself ably responded to his critics on this issue, as well as on the problem discussed next.[4]

How Should Achievements Be Counted?

One persistent danger threatening much research on the age-achievement function is what has been styled the "compositional fallacy" (cf. Riley, Johnson, & Foner, 1972, pp. 81–82). Analogous to the notorious ecological fallacy that plagues demographic studies (see, e.g., Robinson, 1950), this artifact occurs when individual attributes are aggregated in such a way that observed relationships among the variables reflect the manner of aggregation more than the actual correlations occurring at the individual level of analysis. One common form of this methodological confounding in life span developmental psychology is the inference of age effects from solely cross-sectional

[4] Lehman's critics do not appear willing to acknowledge his responses to their criticisms, producing an illusion in the literature that the critiques were much more devastating than they were in fact. It is more than a mere curiosity that many of his detractors refer only to Lehman's (1953a) book plus Dennis's (1954d, 1956a, 1958) negative reviews without referring to Lehman's (1956, 1960) replies, even when printed back to back with Dennis' comments; nor do his critics cite the many articles that Lehman published since 1953 (especially Lehman, 1958, 1962, 1963, 1966a, and 1966b); this omission occurs despite a willingness to mention Dennis' (1966) final thrust at Lehman's findings (see, e.g., Cole, 1979; Zuckerman & Merton, 1972). Lehman could not respond to the latter, for he died in August 1965 (Lehman, 1966a).

data. As is well known, it is hazardous in the extreme to infer developmental changes by taking measures all at one point in time on a sample of individuals varying in age; cohort effects may account for all observed age contrasts (Baltes, Cornelius, & Nesselroade, 1979; Romanuik & Romanuik, 1981). This problem is especially urgent in the study of achievement, given how a large body of research suggests that generational fluctuations in observed creativity or leadership occur because of the impact of the political, social, and cultural milieu on the developing individual (Simonton, 1984b, chap. 3, 1987b, 1988b, chap. 5).

Fortunately, although some investigators have relied heavily on cross-sectional designs (e.g., Bayer & Dutton, 1977), a respectable proportion of the investigations from Lehman (1953a) on have employed some variety of longitudinal or cross-sequential procedure (e.g., Simonton, 1977a; Horner et al., 1986). Even so, the introduction of measurements over time does not all by itself remove the worry that a compositional fallacy might intrude into the analysis (cf. Van Heeringen & Dijkwel, 1987). Lehman (1953a) has been repeatedly accused of making this fundamental error (e.g., Dennis, 1956a; Zuckerman & Merton, 1972). The potential spuriousness arises from the fact that much of the time Lehman would sum contributions across individuals within each age period (usually 5 years in length). For those age periods in which all potential contributors are alive, this procedure offers no difficulty, yet in the final periods, after many potential achievers have passed away, an interpretative mistake of the highest order may ensue. To take the extreme case, there might be no decline whatsoever in the last decades of the typical career, yet a decrease may emerge in the data aggregated across persons because of the ever-diminishing collection of individuals yet alive each consecutive age period. The consequence would be an aggregated age curve that is characteristic of not a single person in the sample! Lehman's critics maintain that this compositional fallacy renders his empirical generalizations quite suspect (e.g., Alpaugh et al., 1976; Riley et al., 1972, pp. 605–607).

Numerous methods exist for getting around this potential liability. Dennis (1966) confined his sample to octogenarians before tabulating the number of contributions per age decade; this avoids one source of erroneous conclusions only by introducing another, namely, obtaining an unrepresentative sample by excluding those individuals who fail to pass the restrictive test regarding life span. For example, among the endeavors Dennis investigated was music, yet in Cox's (1926) study, around 28% died before attaining the half-century mark, and not one reached 80. Of what worth is a tabulation of achievements that categorically excludes some of the world's most noteworthy achievers? Lehman's (1953a) own solutions are far superior: To check out the impact of differential life span, he would (a) offer the curves for the number of survivors alongside the curves for tabulated achievements (showing that the former dropped off far more slowly than the latter), (b) stratify the tabulations according to life span (indicating the same curves across strata), or (c) perform a straightforward arithmetic correction to give the longitudinal counts in proportion to the number of potential achievers per age period (see also Lehman, 1958, 1963). Yet another solution, favored by the current reviewer, is to exploit a cross-sectional time series design (cf. Simonton, 1977b). Here, age functions are estimated across and within careers, with the cross-sectional variance first extirpated. One asset of this particular statistical framework is that it allows the age functions to be estimated in the context of many control variables, such as competition, physical illness, and social reward (see, e.g., Simonton, 1977a, 1985b). Still another possible approach is to take the single creative product or leadership act as the unit of an analysis, a line of attack that has been pursued for such endeavors as music, drama, and war (see, e.g., Simonton, 1980b, 1983, 1986a, 1986d, in press).

Whatever the specific precautions taken, once the intrusion of the compositional fallacy has been denied, the empirical results discussed earlier in this review yet persist, albeit the decline may not be so pronounced as it sometimes looks in many published data. The location of the age peak is singularly immune from this consideration, and for good cause (Lehman, 1962). The number of individuals who died before they would be expected to reach their peak age for achievement is quite small (Zhao & Jiang, 1986; cf. Bullough et al., 1978). Only 11% of Cox's (1926) sample failed to attain the 50th year, which comes about a decade after the expected peak for most activities. To be sure, poets die young, yet their age optimum is correspondingly younger. And even if the peak age for leadership sometimes occurs after the 50th year, the life expectancy of leaders is older in rough proportion.

Although the concern of most researchers has been on how the compositional fallacy may introduce an artifactual decline, it is clear that it may impede accurate inferences in other ways as well. Most notably, those studies mentioned earlier that claim to have divulged saddle-shaped age functions may actually have failed to segregate distinctive achievement domains that harbor discrepant peaks (Simonton, 1984a). For example, if achievement in pure mathematics peaks at an earlier age than that in applied mathematics, then aggregating across both types of contributions will perforce generate a double-peak age curve (cf. Dennis, 1966). Hence, the errors of aggregation can be very pervasive.

Theoretical Perspectives

Granting that the chief empirical results are not merely methodological artifacts, what do the data tell us about human achievement? More specifically, what theories or models enable us to explain the main findings? In broad terms, explanations can be grouped according to whether they evoke variables extrinsic or intrinsic to the process of achievement.

Extrinsic Factors

Lehman (1953a) was an empiricist at heart and displayed no genuine desire to frame hypotheses about the results he reported. Indeed, it was only at the urging and encouragement of Edwin G. Boring and Lewis M. Terman that he consented to add the final chapter summarizing and interpreting the gist of the preceding 19 chapters. So, Lehman enumerated 16 possible causes for the early maxima in creative activity over the life span and then listed another 5 reasons why leaders tend to peak at older ages still. The overwhelming majority of these causal factors are plainly extrinsic in nature. The supposition is clearly that the decline in achievement would be minuscule if not totally nonexistent were it not for external conditions that impose

constraints on the individual achiever. A great many of these adverse circumstances concern physical health, and most of what remains concerns personal problems, psychological pathologies, and unfavorable work conditions of various kinds. The closest Lehman comes to espousing an intrinsic foundation for the observed age curves is when he conjectures that motivation may decline with age, that the mind may become even more inflexible on account of negative transfer, and that achievement is primarily driven by the ambition for renown that once obtained removes the original impetus. Nevertheless, all of these explanations, extrinsic and intrinsic alike, are more last-minute, post hoc speculations that Lehman made no effort, then or subsequently, to develop theoretically or to evaluate empirically.

Even so, some empirical research has been conducted that touches on one or more items on Lehman's explanatory list. For example, there is reason to believe that creative productivity may be depressed by (a) declining physical health (Simonton, 1977a), (b) increased parental responsibilities (Hargens, McCann & Reskin, 1978; McDowell, 1982), and (c) expanded administrative duties (Diemer, 1974; Garvey & Tomita, 1972; Jernegan, 1927; Roe, 1972a; Stern, 1978). In addition, sociologists have surmised from somewhat indirect evidence that social rewards may help maintain productivity throughout the career (Allison & Stewart, 1974; S. Cole, 1979). Investigators have also indicated that with age, people may convert from an accommodating adaptive style to a realistic, controlling adaptive style, a shift in life emphasis that can be enlisted to account for the decline in exceptional achievement (Mumford, 1984). No doubt further inquiries will unearth additional variables that impinge on individuals so as to encourage or retard their efforts as notable creators or leaders (see also Romanuik & Romanuik, 1981).[5]

Yet such an inventory of extrinsic causes, no matter how long, must leap over some fairly tall hurdles before the phenomenon is comprehensively explicated. Those who resort to extraneous variables tend to leave many key facets of the age-achievement relation out of the explanatory picture. Perhaps owing to the ego defensiveness mentioned earlier, researchers have become obsessed with the decline in the later years. Nonetheless, a full account must successfully deal with such additional questions as, Why are precocity, longevity, and output rate so highly intercorrelated? Why is quality apparently a probabilistic repercussion of quantity? And why do the age curves vary across domains of achievement in ways both systematic and cross-culturally invariant? Moreover, it is my position that a sound theoretical interpretation would handle individual differences in achievement, not just longitudinal changes within careers (see also Over, 1982a, 1982b). Given these specifications, extrinsic causes do not deal adequately with the observed data.

Take physical health as a case in point. Besides the fact that the age curve survives even after a fair attempt is made to control for this contaminating influence (Simonton, 1977a), it simply cannot carry us very far as an explanatory principle (Simonton, 1984b, chap. 6). Are the correlations among precocity, longevity, and rate of output due to individuals who are healthier earlier also being healthier later and being blessed with better health throughout their careers? This seems unlikely, especially given the negative correlation between precocity and life span mentioned earlier (Simonton, 1977c; Zhao & Jiang, 1986). And how do longitudinal and cross-sectional variations in physical well-being contribute to the connection between quantity and quality? The nexus is not obvious. Also, do certain fields feature younger peaks than do other fields as a result of differences in the amount of physical vigor required? For example, does it require more energy to write a lyric poem than to compose a novel? Finally, despite the fact that extreme illness definitely vitiates achievement, can we really explicate individual differences, including the distinctive elitist distribution of output, in terms of this variable? Darwin and Beethoven suffered from chronic illnesses—the latter even from deafness—without substantial impairment in output. There must have been innumerable lesser lights than they who were gifted with superior health.

The above remarks should not be taken as a denial that extrinsic factors play a significant role. Rather, it is this reviewer's position that these variables operate as random shocks to the system. The key features of the age-achievement relation—the age curves (including consistent contrasts across achievement domains), the quantity-quality association, and the tight binding of precocity, longevity, and output rate—are all the manifestations of factors intrinsic to unusual achievement, the sort of factors inventoried by Lehman and others serving merely to deflect the expected effects from this baseline. Variance will be accounted for by extrinsic variables, but that variance will consist of the residuals left over after first taking into consideration those processes more intimately engaged in generating acts of exceptional achievement.

Intrinsic Factors

Four theoretical perspectives, or models, attribute the observed relationships between age and outstanding contributions to developmental changes involving psychological processes that directly participate in achievement behaviors. These theories span over a hundred years, and they vary immensely in their explanatory scope and predictive accuracy. All suffer from the limitation that they mainly address developmental changes in creative achievement, any relevance to leadership being acquired largely via extrapolation. In chronological order, these interpretations are Beard's (1874) two-factor theory, diverse psychometric accounts (cf. Kogan, 1973), Diamond's (1984) economic model, and Simonton's (1987a, 1988a, 1988b) chance-configuration theory.

Two-factor theory. Beard (1874) was not merely the earliest contributor to the empirical literature on age and achievement but its first theorist as well. According to him, creativity is a function of two underlying factors, enthusiasm and experience. Enthusiasm provides the motivational force behind persistent effort, yet enthusiasm in the absence of the second factor yields just original work. Experience gives the achiever the ability to separate wheat from chaff and to express original ideas in a more intelligible and persistent fashion. Yet experience in the absence of enthusiasm produces merely routine contributions.

[5] On the other hand, this inventory should also include a list of null effects. For example, the functional link between productivity and age may not be affected by such external circumstances as biographical stress (Simonton, 1977a), albeit such stress may directly affect the content of the work produced (Simonton, 1980b, 1987c, in press). Output is evidently also not influenced by the obtaining of academic tenure (Bridgwater, Walsh, & Walkenbach, 1982).

Genuine creativity requires the balanced cooperation of both enthusiasm and experience. Beard postulates, however, that these two essential components display quite distinctive distributions across the life span. Whereas enthusiasm usually peaks early in life and steadily declines thereafter, experience gradually increases as a positive monotonic function of age. The correct equilibrium between the two factors is attained between the ages of 38 and 40, the most common age optima for creative endeavors. Prior to that expected peak, an individual's output would be excessively original, and in the postpeak phase the output would be overly routine. The career floruit in the late 30s thus represents the uniquely balanced juxtaposition of the rhapsodies of youth and the wisdom of maturity.

Beard's theory is not without attractive features. It has certain points of contact, for example, with Galton's (1869) theory of genius, which stresses both intellectual and motivational determinants (see also Alpaugh & Birren, 1977), and with Bartlett's (1958) work on thinking, especially the distinction between original and routine contributions. Moreover, Beard's account, for all its simplicity, can boast a respectable amount of explanatory power. Besides handling the broad form of the age curve, this theory leads to an interpretation of why different endeavors may peak at distinct ages (Simonton, 1984b, chap. 6). The contrast between poetic and prose literature, for instance, can be interpreted as the immediate consequence of the assumption that the two domains demand a different mix of the two factors: poetry, more enthusiasm, and prose, more experience. Indeed, in fields in which expertise may be far more crucial than emotional vigor, most notably in scholarship, we would anticipate little if any decline with age, and such is the case (Dennis, 1956b, 1966). We can even extend Beard's theory to leadership domains. Thus the discrepancy between age peaks for revolutionaries and status quo politicians may again merely mirror disparities in the relative place of excitement and expertise in the two modes of leadership.

These interpretative successes notwithstanding, Beard's theory has major deficiencies, too. For one thing, it might be accused of violating Occam's razor by postulating two age trends in order to explain one age curve (yet we may grant that this is necessary to accommodate interdisciplinary variations). The theory is more conceptual than mathematical and hence leads to no precise predictions that can be subjected to empirical tests. And it makes no attempt to deal with other empirical results, such as the associations among precocity, longevity, and rate of output. Indeed, sometimes Beard's theory has implications that run counter to the data on the phenomenon. As a case in point, one could not derive the constant-probability-of-success model from his theory, because it would predict that the quality ratio should peak in the late 30s. Curiously, the two-factor theory implies that the lower proportion of major to total output expected in the earlier and the later stages of a career would result from different weaknesses, extensive immaturity in the former and lack of inspiration in the latter. Evidence on behalf of this implication is utterly lacking.

Psychometric interpretations. Ever since Galton's (1883) classic efforts, psychologists have struggled to explain and predict individual differences in outstanding achievement in terms of measured (or measurable) abilities. The early work focused on intelligence, defined by the IQ test, as the primary determinant (e.g., Cox, 1926; Terman, 1925), yet in the 1950s and 1960s, investigators turned to creativity as an explanatory variable, and so creativity tests proliferated (e.g., Barron & Welsh, 1952; Guilford, 1967; Mednick, 1962). Given these psychometric instruments, it seems quite natural that life span developmental psychologists would inquire whether or not the age curves correspond to deeper movements in human performance (Kogan, 1973; Romanuik & Romanuik, 1981). Many investigators pinpointed a decline in intellectual power in the later years of life (or at least a drop in "fluid" as opposed to "crystallized" intelligence) (e.g., Horn, 1982), and others reported single-peak functions and negative age slopes for certain creativity measures as well (Alpaugh & Birren, 1977; Alpaugh, Parham, Cole, & Birren, 1982; Bromley, 1956; Cornelius & Caspi, 1987; Eisenman, 1970; McCrae et al., 1987; Ruth & Birren, 1985; cf. Jaquish & Ripple, 1981). Yet the defensiveness noted twice earlier in this essay may have provoked the debate that followed these published results, a controversy about whether the decreases with age were real or simply reflected some pernicious age bias. Some of the issues in this debate were the same recurrent methodological questions that plague life span developmental research, especially the potential artifact introduced by depending on cross-sectional data when inferring longitudinal trends (Kogan, 1973; Romanuik & Romanuik, 1981; Schaie & Strother, 1968).

Nevertheless, we need not settle this controversy here in order to evaluate the theoretical efficacy of the psychometric viewpoint. In the reviewer's mind, this work, though quite interesting and valuable, is simply not germane to the substantive issues at hand (cf. Kogan, 1973). The application of psychometric variables to longitudinal data involved the extrapolation of cross-sectional results to agewise trends. Still, not all central results were carried over. To begin with, even if a minimal level of intelligence is requisite for achievement, beyond a threshold of around IQ 120 (the actual amount varying across fields), intellectual prowess becomes largely irrelevant in predicting individual differences in either creativity or leadership (Simonton, 1985a). The decline in intelligence would therefore have to be huge for notable achievers to be converted to nonentities, and such is not the case. Short of organic disabilities and senility, the reported losses in IQ scores are seldom large enough to plunge numerous individuals below the threshold. The most phenomenal achievers, indeed, have considerable intellect to spare. There is also reason to believe that any such losses are concentrated among those individuals who are not continuously exercising their intellects and thus would not be strongly committed to achievement activities in the first place (cf. Denny, 1982). Finally, at a cross-sectional level, the bell-shaped distribution of intelligence cannot explain the skewed right distribution of productivity (H. A. Simon, 1954).

Matters are worse for the creativity tests, given that considerable doubts exist about whether or not these psychometric measures actually tap the psychological factors behind creative accomplishments (see, e.g., Hocevar, 1981; Hudson, 1966; Kogan & Pankove, 1974; Weisberg, 1986). The validity coefficients, as weighed against adulthood success, are too low to make the scores very binding. Moreover, even if some theorists have defended the distinction between domain-specific and creativity-specific skills (e.g., Amabile, 1983), it appears that creativity in many disciplines is so domain specific as to preclude measurement by the class of generalized proclivities examined in the

typical creativity test (Simonton, 1988b, chap. 7). In fact, any decline in creativity of the test variety may merely divulge an individual's adaptive transformation of generalized skills to capacities more specifically tailored to the needs of his or her specialty. Finally, should we accept the creativity tests on face value, and consider the possibility of a decline with age, we are nevertheless left with the simple problem encountered in the intelligence tests: Any negative slope may simply not be steep enough to have substantive effects (cf. Alpaugh et al., 1982). We should not expect without evidence that psychometric measures explain more variance in longitudinal changes than they can account for in individual differences (see, e.g., McCrae et al., 1987).

Again, these objections do not amount to a criticism of the whole research tradition. It may very well be that longitudinal shifts in cognitive functions have tremendous import for comprehending the aging process, even changes in human problem-solving abilities (see, e.g., Alpaugh et al., 1976; Cornelius & Caspi, 1987). Nonetheless, if the goal is to explain developmental variation in outstanding achievement (those acts that leave a more durable impression on others), we may have to turn to different factors, such as those relating to the information-processing demands behind creativity or leadership.

Economic model. Cross-sectional variations in productivity, especially gender differences, have from time to time been interpreted using the favorite concepts of economic theory: utility functions, investment, human capital, income, and the like (e.g., McDowell, 1982). In essence, this outlook presumes that achievement is a by-product of rational self-interest in which individuals are operating so as to maximize the acquisition of certain specified goods, commonly material ones (viz. income). Diamond (1984) applied such notions to creativity. In particular, he adapted a "simple human capital investment model" to the phenomenon of scientific productivity. Working under the rudimentary assumption that a scientist seeks to maximize the "discounted sum of his income," Diamond derived the prediction that "either the quantity of output or the average quality per article (or both) decline with age" (pp. 194–195). In a subsequent paper, Diamond (1986) tested his model against a sample of scientists and mathematicians, claiming to have found corroborative results: Both the quantity and the quality of research output were a straight negative function of age. This conclusion, naturally, runs counter to the generalizations presented earlier in this essay; most investigators in the past suggest that quantity and quality exhibit single-peak functions.

This empirical discrepancy aside, Diamond's economic model of life cycle human capital investment makes assumptions that many psychologists would find untenable. Numerous psychological theories of creativity posit that this phenomenon is driven by intrinsic rather than extrinsic motives (e.g., Amabile, 1983; Rogers, 1954; Simonton, 1988b), whereas Diamond holds that the motive intrinsic to achievement is fundamentally extrinsic in orientation. In this sense, Diamond's theory is behavioristic, accomplishments serving as operants subject to social reinforcements, but with a cognitive element introduced to permit calculations of cost-benefit ratios. In contrast, those who maintain that the creative process is propelled by intrinsic drives do not deny that extrinsic motives may operate but rather think that such motives are extraneous, even interfering (e.g., Maslow, 1962). At best, the intrinsic drive to order experience has been favored by natural selection, an extrinsic process, so as to become an innate cognitive disposition of the human species (Simonton, 1988b, chap. 1).

Chance-configuration theory. Simonton (1987a, 1988a, 1988b) has recently developed Campbell's (1960) blind-variation and selective-retention model of creative thought into a theoretical system. In a nutshell, the theory states that the creative process begins with the quasi-random permutation of mental elements from which are selected a smaller proportion of stable configurations, such as metaphors, similes, analogies, and models. These chance configurations then undergo transformation into communication configurations by the assignment of appropriate symbols to the initial inarticulate configurations. These communication configurations subsequently become subject to further selection processes on the interpersonal and sociocultural planes (cf. Campbell, 1965). After showing how the postulated psychological processes are consistent with the introspective reports of notable creative individuals (e.g., Poincaré, 1921), Simonton uses the theory to derive a series of more detailed, formal, and often mathematical models that explain and predict key facets of exceptional creative achievement, such as personality traits (cognitive style and motivational disposition), productive output within and across careers (both quantity and quality), developmental antecedents, and the multiples phenomenon (in which two or more scientists independently and often simultaneously make the same discovery).

Among these derivations, for example, is the constant-probability-of-success model already discussed; if the permutations are strictly random (i.e., unguided by effective foresight but instead directed by free association), then the probability of a success should be a probabilistic function of the total number of trials, a stochastic association that must hold both across careers (the most influential creators are the most prolific in variations) and within careers (the masterworks are most likely to appear in those segments of a single career in which emerge the largest variety of works). In addition, another model shows that if the number of mental elements available for the chance permutations is normally distributed like intelligence, then the cross-sectional distribution of possible permutations (and hence configurations) will be described by a highly skewed right, elitist distribution as described by the Lotka and Price laws (cf. Dennis, 1954c, 1955; Lotka, 1926; Price, 1963; Shockley, 1957; H. A. Simon, 1954, 1955). And, finally, under the assumptions of the theory, it is possible to subsume the stochastic models of multiple discovery and invention that so successfully handle the central empirical features of the phenomenon, such as the probability distribution of multiple grades (Simonton, 1978, 1979a, 1986g).

Yet the derived model that most concerns us now is that which predicts the longitudinal changes in creative productivity (Simonton, 1984a, 1988b, chap. 4). As the chance-configuration theory has it, creativity at the individual level entails a two-step process. First, a creator begins with a supply of "creative potential" (or mental elements available for chance permutations) that is haphazardly sorted through to generate creative "ideations" (chance configurations). Second, the resulting collection of ideations or "works-in-progress" becomes elaborated into finished products (communication configurations). By making a few simple assumptions about the rates of ideation and elaboration (e.g., that the velocity at which chance configu-

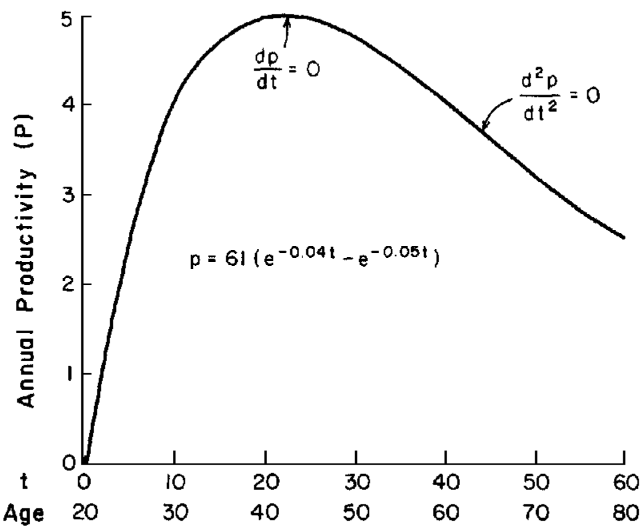

Figure 1. Relation between productivity and career age according to two-step cognitive model under typical parameters (from Simonton, 1984a).

rations emerge is proportional to the existing creative potential at a given career age), then it is possible to specify a system of three linear differential equations that, when solved, leads to the following equation:

$$p(t) = c(e^{-at} - e^{-bt}) \quad (2)$$

Here the level of productivity (the number of contributions) at career age t is a double exponential function in which a is the ideation rate, b is the elaboration rate, and c is equal to $abm/(b - a)$, where m is the creative potential at the outset (i.e., the maximum number of chance configurations the individual is capable of producing in an unlimited life span).[6] Under plausible parameters, Equation 2 yields a single-peak function not unlike the quadratic function given by Equation 1, but with a few refinements in the latter portions of the career. To illustrate, we can take $a = .04$, $b = .05$, and $c = 61$ (or $m = 305$) to get the age curve graphed in Figure 1. Starting with $p(0) = 0$, the predicted contribution rate rises quickly in a decelerating (concave downward) curve to a peak at about career age 22 (or chronological age 42 if $t = 0$ at true age 20). Yet the subsequent decline is broken by an inflection point (at $d^2p/dt^2 = 0$), after which productivity approaches the zero level asymptotically. Thus, Equation 2, unlike Equation 1, generates realistic values for all conceivable career ages. Even the specific features of the predicted age curve, particularly the concave-downward initial segment and the concave-upward last segment, fit the observed data (Simonton, 1984a). On the average, correlations between predicted and observed productivity for a wide range of data sets (e.g., S. Cole, 1979; Dennis, 1966; Lehman, 1953a; Zuckerman, 1977) tend to range in the mid to upper .90s (Simonton, 1984b, 1988b, chap. 4). The function even performs well with individual-level data: The correlation is .87 between predicted scores and the number of patents claimed by Thomas Edison (from Lehman, 1953a, chap. 1).

Naturally, accurate prediction of the data depends on a careful estimation of the two information-processing parameters, a and b, that decide the actual shape of the curve. Both ideation and elaboration rates will be large (fast) in disciplines that feature early peak productive ages and rapid postpeak declines, whereas these same parameters will be small (slow) in those fields in which the peaks are attained only gradually and the postpeak are slopes near zero. For example, if one exploits the longitudinal tabulations of Dennis (1966), one finds that for poets, $a = .04$ and $b = .07$, for novelists, $a = .02$ and $b = .05$, and for historians, $a = .02$ and $b = .03$; likewise, $a = .03$ and $b = .05$ for mathematicians and $a = .02$ and $b = .04$ for geologists (Simonton, 1988b, chap. 4). These contrasts may not seem much, but small shifts in the parameters cause immense movements in the predicted peaks. Given these parameters, the expected optima in career age equivalents are 19, 26, and 40 for poets, novelists, and historians, respectively, and 26 and 35 for mathematicians and geologists, differences of about a full decade or more. In certain respects, the crucial parameter is a, the ideation rate, inasmuch as it registers the speed at which the initial reservoir of creative potential is consumed. The reciprocal of a divided by the natural logarithm of 2 gives the expected creative "half-life" for a given discipline, that is, the career age at which 50% of the starting creative potential has been translated into configurations. Going back to the interdisciplinary comparisons just presented, the creative half-life can range from 17 years for poets to 35 years for novelists, historians, and geologists, with a more middling 23 years for mathematicians. In any event, the two-step cognitive model explains interdisciplinary contrasts between disciplines in terms of the information-processing demands within each discipline.

To account for systematic interdisciplinary variations in the form taken by the age curves, we had to assume that a and b were characteristic of a given endeavor. All achievers within the same field are operating under the same ideation and elaboration rates (cf. Bayer & Dutton, 1977). If one grants this assumption, the constant c, which scales the overall height but not the shape of the curve, is entirely determined by m, the maximum possible lifetime output, the initial creative potential at $t = 0$. This relationship permits the model to explain the covariation among precocity, longevity, and output rate (Simonton, 1984a, 1988b). Given that two individuals reside in the same discipline and begin the chance permutation procedure at the same time, then the higher the starting creative potential, as registered by m, the larger the area under the curve from $t = 0$ onward. Because we are dealing with a stochastic process for generating creative ideas, it necessarily follows that, on the average, the individual with the largest value for m will make the first contribution sooner, continue producing contributions far later in the career, and exhibit much more impressive rates of contribution throughout the career. On the other hand, individual differences in creative potential leave no impact whatsoever on the location of the peak, because its agewise position is affected exclusively

[6] As given, Equation 2 assumes that $a < b$ (i.e., the ideation rate is slower than the elaboration rate). Although this theoretical inequality has a substantive defense (Simonton, 1988b, chap. 4), alternative specifications are allowable. If $a > b$, the difference in parentheses becomes negative, but so does the constant c, and thus $p(t)$ remains positive for all $t \geq 0$. Should $a = b$, solution of the original differential equations (owing to equal roots in the auxiliary equation) yields $p(t) = a^2mte^{-at}$, a formula with fewer parameters but less flexibility in prediction.

by the two information-processing parameters a and b. When this null effect is combined with the constant-probability-of-success model, we end up with the expectation that the most outstanding achievements by the greatest achievers will tend to appear at the same career ages as the best achievements by their less-renowned colleagues (Simonton, 1984a, 1988b, chap. 4). The more famous figures may start earlier and end later, but their optima are in the same career place as those of the far less illustrious. As noted earlier, this special prediction is confirmed by data collected by several independent investigators (see, e.g., Raskin, 1936; Simonton, 1975a; Zusne, 1976; cf. Horner et al., 1986). In addition, this implication suggests that the position of the peak will be dependent on the starting and ending points of a career (assuming no constraints from biological longevity), which indicate career age. Hence, the two-step model subsumes Zusne's (1976) otherwise inexplicable model, which holds that the best work appears at the age which is the harmonic mean of the ages of first and last works, at the same time specifying the circumstances under which Zusne's model would not be valid (see Simonton, 1984a).

The above two-step cognitive model, and the chance-configuration theory from which it is derived, support numerous other implications that we cannot discuss at length here. For example, the theory provides a basis for understanding the operation of "Planck's principle," or the tendency for older achievers within a discipline to be less receptive to new ideas, a speculation of Max Planck (1949, pp. 33–34) that has received empirical documentation both direct (Diamond, 1980; Hull, Tessner, & Diamond, 1978) and indirect (Alpaugh & Birren, 1977; Green, Rich, & Nesman, 1985; Vroom & Pahl, 1971; see also Oromaner, 1981). In addition, the theory specifies some of the extrinsic conditions that are most likely to alter the career course from the idealized curve seen in Figure 1 (Simonton, 1988b, chap. 4). Nevertheless, the discussion thus far should suffice to depict something of the range and precision attempted by the theory and its associated models. At the same time, as with other theoretical schemes in psychology, the chance-configuration theory is not free of flaws. For instance, to obtain solvable differential equations, the usual simplifying assumptions are made that are certainly approximate at best (but, for elaborations, see Simonton, 1988b, chap. 4). Nonetheless, in the last analysis the chance-configuration theory has an asset not enjoyed by rival accounts: It can be tested and proven wrong. The falsifiability of the theory may serve to inspire more inquiries into the connection between age and outstanding achievement.

Conclusion

Over the past century plus, a large empirical literature has accumulated on the age-achievement relation. Although the consensus is by no means perfect, some agreement has been reached on (a) the most typical shape of the age curve, (b) the variation in the characteristic curve, especially the peak productive age, across fields of achievement, (c) the positive associations among precocity, longevity, and production rate, and (d) the probabilistic nexus between quantity and quality of output within a career; these are listed in rough order of the strength of replication. Further, these life span developmental generalizations persist after introducing the requisite controls for various possible methodological artifacts, such as differential competition and the compositional fallacy. Theoretical interpretations of the empirical findings are quite diverse, many investigators preferring to compile long inventories of extrinsic influences, whereas other researchers venture to propose theories or models that see the age functions as resulting from factors more intrinsic to the achievement process.

Additional empirical, methodological, and theoretical work is clearly desirable, the apparent accumulation of effort notwithstanding. The literature would probably be better served if future researchers concentrated on several critical questions suggested by the results just reported. The following two sets of questions, in particular, deserve considerably more attention.

First, we must learn more about the details of the longitudinal changes in achievement. Thus, is the age curve truly a single-peak function as most theoretical treatments suggest? Or else, can multiple-peaks occur? If so, do these merely represent the extrinsic distortion of an intrinsically single-peak function? And is the onset of the age curve decelerating or accelerating, concave downward or upward? Research that takes care to control for potential artifacts seems to point to a decelerating concave-downward career beginning, and at least one theory specifically predicts as much, but too few studies have tackled this question. If the curve is accelerating, some kind of growth process may turn out to be more appropriate as an interpretation.

Second, more effort should be directed at unearthing the specific way that individual differences in achievement are connected with the central factors involved in longitudinal changes in achievement. What is the relation between lifetime output and the peak age of output, whether gauged by total productivity or by the single best work? Some theories expect that the age optima are a function of the discipline rather than the eminence attained by an individual within that discipline. And several empirical investigations, by means both direct and indirect, endorse this expectation. Even so, more empirical work needs to be done on this substantive issue. Moreover, if the desire is to tie outstanding achievement to scores on specific psychometric measures, whether assessing intelligence or creativity, then this probably should be executed in such a manner that the established cross-sectional relationships reinforce rather than contradict the anticipated longitudinal relationships. For instance, if we wish to attribute any age decrements in achievement to longitudinal changes in performance on intelligence tests, we should expect that such losses do not occur for those achievers who score well above the threshold levels established in cross-sectional research.

The specific relation between age and outstanding achievement is by no means a purely academic issue. Yuasa (1974) argued that by the year 2000 a decline in science in the United States is inevitable because of the shifting age structure of American scientists (see also Oromaner, 1981). More specifically, when the mean age of U.S. scientists attains the 50th year, the United States will soon be replaced by some other nation as the center of scientific activity (Zhao & Jiang, 1985). An analogous "Yuasa phenomenon" may attend achievement in other domains as well. Yet this forecast is predicated on the notion that the slope of the age function is negative after some peak in the late 30s or early 40s. Despite the considerable empirical and theoretical corroboration this postulate possesses, more documentation is necessary before this prognosis of doom (for U.S.

citizens anxious for Nobel prizes) projects full force. It bears repeating that the age structure of American society very much hinges on the baby boomers, and this generation is only about a decade away from the critical age when the United States may witness itself supplanted by some upstart nation. Admittedly, enhanced knowledge may give us no means to reverse inexorable historical trends (cf. Alpaugh et al., 1976), yet we can at least have the consolation of understanding why the locus in outstanding achievement strayed from our own shores (Simonton, 1984b, chap. 10).

References

Abt, H. A. (1983). At what ages do outstanding American astronomers publish their most cited papers? *Publication of the Astronomical Society of the Pacific, 95,* 113–116.

Adams, C. W. (1946). The age at which scientists do their best work. *Isis, 36,* 166–169.

Albert, R. S. (1975). Toward a behavioral definition of genius. *American Psychologist, 30,* 140–151.

Alker, H. A. (1981). Political creativity. In L. Wheeler (Ed.), *Review of Personality and Social Psychology* (Vol. 2, pp. 167–188). Beverly Hills, CA: Sage.

Allison, P. D., & Stewart, J. A. (1974). Productivity differences among scientists: Evidence for accumulative advantage. *American Sociological Review, 39,* 596–606.

Alpaugh, P. K., & Birren, J. E. (1977). Variables affecting creative contributions across the adult life span. *Human Development, 20,* 240–248.

Alpaugh, P. K., Parham, I. A., Cole, K. D., & Birren, J. E. (1982). Creativity in adulthood and old age: An exploratory study. *Educational Gerontology, 8,* 101–116.

Alpaugh, P. K., Renner, V. J., & Birren, J. E. (1976). Age and creativity: Implications for education and teachers. *Educational Gerontology, 1,* 17–40.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology, 43,* 997–1013.

Amabile, T. M. (1983). *The social psychology of creativity.* New York: Springer-Verlag.

Baltes, P. B., Cornelius, S. W., & Nesselroade, J. R. (1979). Cohort effects in developmental psychology. In J. R. Nesselroade & P. B. Baltes (Eds.), *Longitudinal research in the study of behavior and development* (pp. 61–87). New York: Academic Press.

Barron, F., & Welsh, G. S. (1952). Artistic perception as a possible factor in personality style. *Journal of Personality, 33,* 199–203.

Bartlett, F. C. (1958). *Thinking: An experimental and social study.* New York: Basic Books.

Bass, B. M. (1981). *Stogdill's handbook of leadership: A survey of theory and research.* New York: Free Press.

Bayer, A. E., & Dutton, J. E. (1977). Career age and research—Professional activities of academic scientists: Tests of alternative non-linear models and some implications for higher education faculty policies. *Journal of Higher Education, 48,* 259–282.

Beard, G. M. (1874). *Legal responsibility in old age.* New York: Russell Sage Foundation.

Blackburn, R. T., Behymer, C. E., & Hall, D. E. (1978). Correlates of faculty publications. *Sociology of Education, 51,* 132–141.

Blondel, J. (1980). *World leaders: Heads of government in the postwar period.* Beverly Hills, CA: Sage.

Bloom, B. S. (1963). Report on creativity research by the Examiner's Office of the University of Chicago. In C. W. Taylor & F. Barron (Eds.), *Scientific creativity: Its recognition and development* (pp. 251–264). New York: Wiley.

Bridgwater, C. A., Walsh, J. A., & Walkenbach, J. (1982). Pre- and post-tenure productivity trends of academic psychologists. *American Psychologist, 37,* 236–238.

Bromley, D. B. (1956). Some experimental tests of the effect of age on creative intellectual output. *Journal of Gerontology, 11,* 74–82.

Bullough, V., Bullough, B., & Mauro, M. (1978). Age and achievement: A dissenting view. *Gerontologist, 18,* 584–587.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67,* 380–400.

Campbell, D. T. (1965). Variation and selective retention in socio-cultural evolution. In H. R. Barringer, G. I. Blanksten, & R. W. Mack (Eds.), *Social change in developing areas* (pp. 19–49). Cambridge, MA: Schenkman.

Clemente, F. (1973). Early career determinants of research productivity. *American Journal of Sociology, 79,* 409–419.

Cole, J. R., & Cole, S. (1973). *Social stratification in science.* Chicago: University of Chicago Press.

Cole, S. (1979). Age and scientific performance. *American Journal of Sociology, 84,* 958–977.

Cornelius, S. W., & Caspi, A. (1987). Everyday problem solving in adulthood and old age. *Psychology and Aging, 2,* 144–153.

Cox, C. (1926). *The early mental traits of three hundred geniuses.* Stanford, CA: Stanford University Press.

Crandall, R. (1978). The relationship between quantity and quality of publications. *Personality and Social Psychology Bulletin, 4,* 379–380.

Crane, D. (1965). Scientists at major and minor universities: A study of productivity and recognition. *American Sociological Review, 30,* 699–714.

Davis, Richard A. (1987). Creativity in neurological publications. *Neurosurgery, 20,* 652–663.

Davis, Robert A. (1954). Note on age and productive scholarship of a university faculty. *Journal of Applied Psychology, 38,* 318–319.

Dennis, W. (1954a). Bibliographies of eminent scientists. *Scientific Monthly, 79,* 180–183.

Dennis, W. (1954b). Predicting scientific productivity in later decades from records of earlier decades. *Journal of Gerontology, 9,* 465–467.

Dennis, W. (1954c). Productivity among American psychologists. *American Psychologist, 9,* 191–194.

Dennis, W. (1954d). Review of *Age and Achievement. Psychological Bulletin, 51,* 306–308.

Dennis, W. (1955). Variations in productivity among creative workers. *Scientific Monthly, 80,* 277–278.

Dennis, W. (1956a). *Age and Achievement:* A critique. *Journal of Gerontology, 9,* 465–467.

Dennis, W. (1956b). Age and productivity among scientists. *Science, 123,* 724–725.

Dennis, W. (1958). The age decrement in outstanding scientific contributions: Fact or artifact? *American Psychologist, 13,* 457–460.

Dennis, W. (1966). Creative productivity between the ages of 20 and 80 years. *Journal of Gerontology, 21,* 1–8.

Denny, N. W. (1982). Aging and cognitive changes. In B. B. Wolman (Ed.), *Handbook of developmental psychology* (pp. 807–827). Englewood Cliffs, NJ: Prentice-Hall.

Diamond, A. M., Jr. (1980). Age and the acceptance of cliometrics. *Journal of Economic History, 40,* 838–841.

Diamond, A. M., Jr. (1984). An economic model of the life-cycle research productivity of scientists. *Scientometrics, 6,* 189–196.

Diamond, A. M., Jr. (1986). The life-cycle research productivity of mathematicians and scientists. *Journal of Gerontology, 41,* 520–525.

Diemer, G. (1974). Creativity versus age. *Physics Today, 27,* 9.

Eagly, R. V. (1974). Contemporary profile of conventional economists. *History of Political Economy, 6,* 76–91.

Eisenman, R. (1970). Creativity change in student nurses: A cross-sectional and longitudinal study. *Developmental Psychology, 3,* 320–325.

Fulton, O., & Trow, M. (1974). Research activity in American higher education. *Sociology of Education, 47,* 29–73.

Galton, F. (1869). *Hereditary genius: An inquiry into its causes and consequences.* London: Macmillan.
Galton, F. (1883). *Inquiries into human faculty and its development.* London: Macmillan.
Garvey, W. D., & Tomita, K. (1972). Continuity of productivity by scientists in the years 1968–1971. *Science Studies, 2,* 379–383.
Green, S., Rich, T., & Nesman, E. (1985). A cross-cultural look at the relationship between age and innovative behavior. *International Journal of Aging and Human Development, 21,* 255–266.
Guilford, J. P. (1967). *The nature of human intelligence.* New York: McGraw-Hill.
Haefele, J. W. (1962). *Creativity and innovation.* New York: Reinhold.
Hall, G. S. (1922). *Senescence: The last half of life.* New York: Appleton.
Hargens, L. L., McCann, J. C., & Reskin, B. F. (1978). Productivity and reproductivity: Fertility and professional achievement among research scientists. *Social Forces, 57,* 154–163.
Helson, R., & Crutchfield, R. S. (1970). Mathematicians: The creative researcher and the average PhD. *Journal of Consulting and Clinical Psychology, 34,* 250–257.
Hermann, D. B. (1988). How old were the authors of significant research in twentieth century astronomy at the time of their greatest contribution? *Scientometrics, 13,* 135–138.
Hocevar, D. (1981). Measurement of creativity: Review and critique. *Journal of Personality Assessment, 45,* 450–464.
Horn, J. L. (1982). The aging of human abilities. In B. B. Wolman (Ed.), *Handbook of developmental psychology* (pp. 847–870). Englewood Cliffs, NJ: Prentice-Hall.
Horner, K. L., Rushton, J. P., & Vernon, P. A. (1986). Relation between aging and research productivity. *Psychology and Aging, 1,* 319–324.
Hudson, L. (1966). *Contrary imaginations.* Baltimore, MD: Penguin Books.
Hull, D. L., Tessner, P. D., & Diamond, A. M. (1978). Planck's principle: Do younger scientists accept new scientific ideas with greater alacrity than older scientists? *Science, 202,* 717–723.
Jaquish, G. A., & Ripple, R. E. (1981). Cognitive creative abilities and self-esteem across the adult life-span. *Human Development, 24,* 110–119.
Jernegan, H. W. (1927). Productivity of doctors of philosophy in history. *American Historical Review, 33,* 1–22.
Kogan, N. (1973). Creativity and cognitive style: A life-span perspective. In P. B. Baltes & K. W. Schaie (Eds.), *Life-span developmental psychology: Personality and socialization* (pp. 145–178). New York: Academic Press.
Kogan, N., & Pankove, E. (1974). Long-term predictive validity of divergent-thinking tests: Some negative evidence. *Journal of Educational Psychology, 66,* 802–810.
Lehman, H. C. (1953a). *Age and achievement.* Princeton, NJ: Princeton University Press.
Lehman, H. C. (1953b). The ages of scheduled participants at the 1948 APA annual meeting. *American Psychologist, 8,* 125–126.
Lehman, H. C. (1956). Reply to Dennis' critique of *Age and Achievement. Journal of Gerontology, 11,* 333–337.
Lehman, H. C. (1958). The chemist's most creative years. *Science, 127,* 1213–1222.
Lehman, H. C. (1960). The age decrement in outstanding scientific creativity. *American Psychologist, 15,* 128–134.
Lehman, H. C. (1962). More about age and achievement. *Gerontologist, 2,* 141–148.
Lehman, H. C. (1963). Chronological age versus present-day contributions to medical progress. *Gerontologist, 3,* 71–75.
Lehman, H. C. (1966a). The most creative years of engineers and other technologists. *Journal of Genetic Psychology, 108,* 263–270.
Lehman, H. C. (1966b). The psychologist's most creative years. *American Psychologist, 21,* 363–369.
Lotka, A. J. (1926). The frequency distribution of scientific productivity. *Journal of the Washington Academy of Sciences, 16,* 317–323.
Lyons, J. (1968). Chronological age, professional age, and eminence in psychology. *American Psychologist, 23,* 371–374.
Maslow, A. (1962). *Toward a psychology of being.* Princeton, NJ: Van Nostrand.
McClelland, D. C. (1973). Testing for competence rather than for "intelligence." *American Psychologist, 8,* 1–14.
McCrae, R. R., Arenberg, D., & Costa, P. T., Jr. (1987). Declines in divergent thinking with age: Cross-sectional, longitudinal, and cross-sequential analyses. *Psychology and Aging, 2,* 130–137.
McDowell, J. M. (1982). Obsolescence of knowledge and career publication profiles: Some evidence of differences among fields in costs of interrupted careers. *American Economic Review, 72,* 752–768.
Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69,* 220–232.
Moulin, L. (1955). The Nobel prizes for the sciences from 1901–1950: An essay in sociological analysis. *British Journal of Sociology, 6,* 246–263.
Mumford, M. D. (1984). Age and outstanding occupational achievement: Lehman revisited. *Journal of Vocational Behavior, 25,* 225–244.
Murphy, A. B. (1984). Evaluating the presidents of the United States. *Presidential Studies Quarterly, 14,* 117–126.
Myers, C. R. (1970). Journal citations and scientific eminence in contemporary psychology. *American Psychologist, 25,* 1041–1048.
Oleszek, W. (1969). Age and political careers. *Public Opinion Quarterly, 33,* 100–103.
Oromaner, M. (1977). Professional age and the reception of sociological publications: A test of the Zuckerman-Merton hypothesis. *Social Studies of Science, 7,* 381–388.
Oromaner, M. (1981). The quality of scientific scholarship and the "graying" of the academic profession: A skeptical view. *Research in Higher Education, 15,* 231–239.
Over, R. (1982a). Does research productivity decline with age? *Higher Education, 11,* 511–520.
Over, R. (1982b). Is age a good predictor of research productivity? *Australian Psychologist, 17,* 129–139.
Pelz, D. C., & Andrews, F. M. (1976). *Scientists in organizations.* New York: Wiley.
Planck, M. (1949). *Scientific autobiography and other papers* (F. Gaynor, Trans.). New York: Philosophical Library.
Poincaré, H. (1921). *The foundations of science.* New York: Science Press.
Price, D. (1963). *Little science, big science.* New York: Columbia University Press.
Raskin, E. A. (1936). Comparison of scientific and literary ability: A biographical study of eminent scientists and men of letters of the nineteenth century. *Journal of Abnormal and Social Psychology, 31,* 20–35.
Rejai, M., & Phillips, K. (1979). *Leaders of revolution.* Beverly Hills, CA: Sage.
Riley, M., Johnson, M., & Foner, A. (Eds.) (1972). *Aging and society: Vol. 3. A sociology of age stratification.* New York: Russell Sage Foundation.
Robinson, W. S. (1950). Ecological correlations and the behavior of individuals. *American Sociological Review, 15,* 351–357.
Roe, A. (1952). *The making of a scientist.* New York: Dodd Mead.
Roe, A. (1965). Changes in scientific activities with age. *Science, 150,* 313–318.
Roe, A. (1972a). Maintenance of creative output through the years. In C. W. Taylor (Ed.), *Climate for creativity* (pp. 167–191). New York: Pergamon.
Roe, A. (1972b). Patterns of productivity of scientists. *Science, 176,* 940–941.
Rogers, C. R. (1954). Toward a theory of creativity. *ETC: A Review of General Semantics, 11,* 249–260.
Romanuik, J. G., & Romanuik, M. (1981). Creativity across the life

span: A measurement perspective. *Human Development, 24,* 366–381.

Rushton, J. P. (1984). Evaluating research eminence in psychology: The construct validity of citation counts. *Bulletin of the British Psychological Society, 37,* 33–36.

Ruth, J.-E., & Birren, J. E. (1985). Creativity in adulthood and old age: Relations to intelligence, sex and mode of testing. *International Journal of Behavioral Development, 8,* 99–109.

Schaie, K. W., & Strother, C. R. (1968). A cross-sequential study of age changes in cognitive behavior. *Psychological Bulletin, 70,* 671–680.

Segal, S. M., Busse, T. V., & Mansfield, R. S. (1980). The relationship of scientific creativity in the biological sciences to predoctoral accomplishments and experiences. *American Educational Research Journal, 17,* 491–502.

Shockley, W. (1957). On the statistics of individual variations of productivity in research laboratories. *Proceedings of the Institute of Radio Engineers, 45,* 279–290.

Simon, H. A. (1954). Productivity among American psychologists: An explanation. *American Psychologist, 9,* 804–805.

Simon, H. A. (1955). On a class of skew distribution functions. *Biometrika, 42,* 425–440.

Simon, R. J. (1974). The work habits of eminent scientists. *Sociology of Work and Occupations, 1,* 327–335.

Simonton, D. K. (1975a). Age and literary creativity: A cross-cultural and transhistorical survey. *Journal of Cross-Cultural Psychology, 6,* 259–277.

Simonton, D. K. (1975b). Sociocultural context of individual creativity: A transhistorical time-series analysis. *Journal of Personality and Social Psychology, 32,* 1119–1133.

Simonton, D. K. (1976a). Biographical determinants of achieved eminence: A multivariate approach to the Cox data. *Journal of Personality and Social Psychology, 33,* 218–226.

Simonton, D. K. (1976b). Philosophical eminence, beliefs, and zeitgeist: An individual-generational analysis. *Journal of Personality and Social Psychology, 34,* 630–640.

Simonton, D. K. (1977a). Creative productivity, age, and stress: A biographical time-series analysis of 10 classical composers. *Journal of Personality and Social Psychology, 35,* 791–804.

Simonton, D. K. (1977b). Cross-sectional time-series experiments: Some suggested statistical analyses. *Psychological Bulletin, 84,* 489–502.

Simonton, D. K. (1977c). Eminence, creativity, and geographic marginality: A recursive structural equation model. *Journal of Personality and Social Psychology, 35,* 805–816.

Simonton, D. K. (1978). Independent discovery in science and technology: A closer look at the Poisson distribution. *Social Studies of Science, 8,* 521–532.

Simonton, D. K. (1979a). Multiple discovery and invention: Zeitgeist, genius, or chance? *Journal of Personality and Social Psychology, 37,* 1603–1616.

Simonton, D. K. (1979b). Was Napoleon a military genius? Score: Carlyle 1, Tolstoy 1. *Psychological Reports, 44,* 21–22.

Simonton, D. K. (1980a). Land battles, generals, and armies: Individual and situational determinants of victory and casualties. *Journal of Personality and Social Psychology, 38,* 110–119.

Simonton, D. K. (1980b). Thematic fame and melodic originality: A multivariate computer-content analysis. *Journal of Personality, 48,* 206–219.

Simonton, D. K. (1980c). Thematic fame, melodic originality, and musical zeitgeist: A biographical and transhistorical content analysis. *Journal of Personality and Social Psychology, 39,* 972–983.

Simonton, D. K. (1981a). The library laboratory: Archival data in personality and social psychology. In L. Wheeler (Ed.), *Review of Personality and Social Psychology* (Vol. 2, pp. 217–243). Beverly Hills, CA: Sage.

Simonton, D. K. (1981b). Presidential greatness and performance: Can we predict leadership in the White House? *Journal of Personality, 49,* 306–323.

Simonton, D. K. (1983). Dramatic greatness and content: A quantitative study of 81 Athenian and Shakespearean plays. *Empirical Studies of the Arts, 1,* 109–123.

Simonton, D. K. (1984a). Creative productivity and age: A mathematical model based on a two-step cognitive process. *Developmental Review, 4,* 77–111.

Simonton, D. K. (1984b). *Genius, creativity, and leadership: Historiometric inquiries.* Cambridge, MA: Harvard University Press.

Simonton, D. K. (1984c). Leader age and national condition: A longitudinal analysis of 25 European monarchs. *Social Behavior and Personality, 12,* 111–114.

Simonton, D. K. (1984d). Leaders as eponyms: Individual and situational determinants of monarchal eminence. *Journal of Personality, 52,* 1–21.

Simonton, D. K. (1984e). Melodic structure and note transition probabilities: A content analysis of 15,618 classical themes. *Psychology of Music, 12,* 3–16.

Simonton, D. K. (1985a). Intelligence and personal influence in groups: Four nonlinear models. *Psychological Review, 92,* 532–547.

Simonton, D. K. (1985b). Quality, quantity, and age: The careers of 10 distinguished psychologists. *International Journal of Aging and Human Development, 21,* 241–254.

Simonton, D. K. (1985c). The vice-presidential succession effect: Individual or situational determinants? *Political Behavior, 7,* 79–99.

Simonton, D. K. (1986a). Aesthetic success in classical music: A computer analysis of 1935 compositions. *Empirical Studies of the Arts, 4,* 1–17.

Simonton, D. K. (1986b). Biographical typicality, eminence, and achievement style. *Journal of Creative Behavior, 20,* 14–22.

Simonton, D. K. (1986c). Dispositional attributions of (presidential) leadership: An experimental simulation of historiometric results. *Journal of Experimental Social Psychology, 22,* 389–418.

Simonton, D. K. (1986d). Popularity, content, and context in 37 Shakespeare plays. *Poetics, 15,* 493–510.

Simonton, D. K. (1986e). Presidential greatness: The historical consensus and its psychological significance. *Political Psychology, 7,* 259–283.

Simonton, D. K. (1986f). Presidential personality: Biographical use of the Gough Adjective Check List. *Journal of Personality and Social Psychology, 51,* 149–160.

Simonton, D. K. (1986g). Stochastic models of multiple discovery. *Czechoslovak Journal of Physics, B36,* 138–141.

Simonton, D. K. (1987a). Creativity, leadership, and chance. In R. J. Sternberg (Ed.), *The nature of creativity.* Cambridge, England: Cambridge University Press.

Simonton, D. K. (1987b). Developmental antecedents of achieved eminence. *Annals of Child Development, 5,* 131–169.

Simonton, D. K. (1987c). Musical aesthetics and creativity in Beethoven: A computer analysis of 105 compositions. *Empirical Studies of the Arts, 5,* 87–104.

Simonton, D. K. (1987d). *Why presidents succeed: A political psychology of leadership.* New Haven, CT: Yale University Press.

Simonton, D. K. (1988a). The chance-configuration theory of scientific creativity. In B. Gholson, A. C. Houts, R. A. Neimeyer, & W. R. Shadish (Eds.), *The psychology of science.* Cambridge, England: Cambridge University Press.

Simonton, D. K. (1988b). *Scientific genius: A psychology of science.* Cambridge, England: Cambridge University Press.

Simonton, D. K. (in press). The swan-song phenomenon: Last-works effects for 172 classical composers. *Psychology and Aging.*

Sorokin, P. A. (1925). Monarchs and rulers: A comparative statistical study: I. *Social Forces, 4,* 22–35.

Sorokin, P. A. (1926). Monarchs and rulers: A comparative statistical study: II. *Social Forces, 4,* 523–533.

Stern, N. (1978). Age and achievement in mathematics: A case-study in the sociology of science. *Social Studies of Science, 8,* 127–140.

Sternberg, R. J. (1985). Implicit theories of intelligence, creativity, and wisdom. *Journal of Personality and Social Psychology, 49,* 607–677.

Taagepera, R., & Colby, B. N. (1979). Growth of western civilization: Epicyclical or exponential? *American Anthropologist, 81,* 907–912.

Terman, L. M. (1925). *Mental and physical traits of a thousand gifted children.* Stanford, CA: Stanford University Press.

Van Heeringen, A., & Dijkwel, P. A. (1987). The relationships between age, mobility and scientific productivity: II. *Scientometrics, 11,* 281–293.

Vroom, V. H., & Pahl, B. (1971). Relationship between age and risk taking among managers. *Journal of Applied Psychology, 55,* 399–405.

Weisberg, R. W. (1986). *Creativity: Genius and other myths.* San Francisco: Freeman.

Yuasa, M. (1974). The shifting center of scientific activity in the West: From the 16th to the 20th century. In N. Shigeru, D. L. Swain, & Y. Eri (Eds.), *Science and society in modern Japan* (pp. 81–103). Tokyo: University of Tokyo Press.

Zhao, H., & Jiang, G. (1985). Shifting of world's scientific center and scientists' social ages. *Scientometrics, 8,* 59–80.

Zhao, H., & Jiang, G. (1986). Life-span and precocity of scientists. *Scientometrics, 9,* 27–36.

Zuckerman, H. (1977). *Scientific elite: Nobel laureates in the United States.* New York: Free Press.

Zuckerman, H., & Merton, R. K. (1972). Age, aging, and age structure in science. In M. W. Riley, M. Johnson, & A. Foner (Eds.), *Aging and society: Vol. 3. A sociology of age stratification* (pp. 292–356). New York: Russell Sage Foundation.

Zusne, L. (1976). Age and achievement in psychology: The harmonic mean as a model. *American Psychologist, 31,* 805–807.

Received September 24, 1987
Revision received January 4, 1988
Accepted January 15, 1988 ■

Calls for Nominations for *JCCP, Educational, JPSP: Attitudes,* and *JPSP: Interpersonal*

The Publications and Communications Board has opened nominations for the editorships of the *Journal of Consulting and Clinical Psychology,* the *Journal of Educational Psychology,* and the Attitudes and Social Cognition section and the Interpersonal Relations and Group Processes section of the *Journal of Personality and Social Psychology* for the years 1991–1996. Alan Kazdin, Robert Calfee, Steven Sherman, and Harry Reis, respectively, are the incumbent editors. Candidates must be members of APA and should be available to start receiving manuscripts in early 1990 to prepare for issues published in 1991. Please note that the P&C Board encourages more participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. To nominate candidates, prepare a statement of one page or less in support of each candidate.

- For *Consulting and Clinical,* submit nominations to Martha Storandt, Department of Psychology, Washington University, St. Louis, Missouri 63130.
- For *Educational,* submit nominations to Richard Mayer, Department of Psychology, University of California, Santa Barbara, California 93106.
- For *JPSP: Attitudes,* submit nominations to Don Foss, Department of Psychology, University of Texas, Austin, Texas 78712.
- For *JPSP: Interpersonal,* submit nominations to Frances Horowitz, Human Development, University of Kansas, 130 Haworth, Lawrence, Kansas 66045.

First review of nominations will begin February 15, 1989.