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"Trajectories of Morbidity, Disability, and Mortality among the U.S. Elderly Population: Evidence from the 1984–1999 NLTCS," Eric Stallard, July 2007

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In the movie *About Schmidt,* the protagonist is an insurance company actuary deftly played by Jack Nicholson. Bemoaning his retirement, Schmidt returns one last time to finish clearing out his office, only to discover the culmination of his life's work, mortality tables recorded on reams of paper, already trashed by a much younger successor who has all the actuarial data he needs stored on so many gigabytes of computer memory.

Those of us who spent entire actuarial careers pricing contingencies of life, health, and disability by analyzing mortality and morbidity tables may lament the revelation that our methodologies have gone by the board. Professor Stallard's observation that "Full realization of the analytic potential" of data collected on longitudinally followed populations "will require new models and methods" lets us down somewhat more politely than Schmidt's treatment by his upstart replacement, but the implication is clear. Our attempts to coax predictors of longevity and wellness from family histories and lifestyle behaviors were rooted in methodologies and models dating to the first part of the nineteenth century, if not earlier. These ancient efforts seem destined to become supplanted by a prototype that from an analysis of 95 discretely quantifiable characteristics constructs separate life and health trajectories for each individual studied.

All this said, Professor Stallard is to be congratulated for this novel contribution to the literature, tantalizingly spurring the imagination of old-timers as to what we might have done with more powerful computing capacity. Not that many of us don't now realize, in retrospect, that we were creating crude precursors to "Grades of Membership" (GoMs) when subdividing insured populations, first by sex, then into "standard," "substandard," and "select" groupings on the basis of far fewer than 95 variables. Nor that we didn't appreciate the importance of heterogeneity, which the author emphasized in earlier work with Manton and Vaupel (1986). Quite to the contrary, some of us still bear battle scars from having defended the right to segment our data by sex at a time when political correctness run amok was insisting on "unisex" tables. Even a few actuarial colleagues, who should have known better than to temporarily abandon their science, were chiding us for appealing to biological rationale to explain the reasons that women outlive men. As mathematicians, we recognize the power of the law of large numbers. But, provided we have statistically credible samples, we also understand, if only intuitively, that the "purer," or more homogeneous, each of our subgroupings is with respect to the a priori risk of mortality or morbidity, the more tightly the actual numbers of deaths, illnesses, or disabilities will cluster around the mean values of our estimates. And the smaller the variance relative to the mean, the lower the risk premium, and the more efficient the pricing of insurance products, with benefits to the consumer and the market in general.

Professor Stallard refreshingly reinforces the importance of not only heterogeneity but also biology, confirming with references to other research that about half the variability in individual vitality—ability to resist the forces of aging—is genetically based. It is also instructive to explore the extent to which the remaining nongenetic half can be managed, but, except for the concluding comments, a more complete examination is beyond the scope of this discussion. Other claimants for the importance of biology to longevity have cited studies showing that those who live to advanced ages tend to cluster in families, and that children of centenarians are less susceptible in their own old age to such ailments as diabetes and heart disease than are their counterparts whose parents were not long-lived (Browner et al. 2004). This validation of the importance given in life and health insurance underwriting to family history is additionally helpful in the quest that Tenenbein and Vanderhoof, in their paper "New Mathematical Laws of Mortality," pursued to "reground actuarial science in the substructure of biology and gerontology" (1980, p. x).

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In that seminal work the authors depended heavily on the law expounded in 1825 by Gompertz, namely, that the force of mortality $\mu_x = Bc^x$. This discussant has suggested elsewhere the mnemonic he finds useful: that the constant, B, captures part of the behavioral, that is, the nongenetic risk of mortality, while c largely transmits to this mathematical form the genetic information encoded in the human cell (Cowell 2008). Professor Stallard's principal criticism of Gompertz is that at advanced ages—he suggests a threshold of 80–90 years—increases in actual mortality are less than those predicted, though he also cites studies showing the opposite result. This leads to his question as to whether the delamination of actual mortality at advanced ages from that predicted by a Gompertz-type fit of rates from constants based on mortality at younger ages is an artifact of differential mortality selection, or evidence that Gompertz's formula should be considered a useful approximation rather than an immutable law of mortality. This discussant leans more to the former explanation.

One mortality-differentiating behavior with which this discussant is familiar is smoking habits. Appendix 1 of the paper shows two distinct Gompertz-type fits of mortality, one based on aggregate data, the other with the population separated by smoking status. For the nonsmokers—a healthier and ‘‘purer'' type than the general population—prediction of mortality rates from ages 80 through 96 from a Gompertz-type fit of constants based on mortality from ages 35 through 64 is extremely good, in fact, a few percentage points lower than actual mortality from ages 80–91, almost exactly reproducing rates for ages 92–95, and once again lower at age 96. But the same methodology applied to an aggregate population in which smokers and nonsmokers are not segregated produces predicted rates that do, indeed, as Professor Stallard would expect, exceed actual mortality, and by a considerable enough margin that Gompertz might not be accepted, not even as a ‘‘useful approximation.'' As one discussion of the Tenenbein-Vanderhoof paper observed, ‘‘the survivors [of the more select group] are there not just because of the stochastic process, but because they have a greater resistance to death, thereby lightening the observed mortality'' (Cohen discussing Tenebein and Vanderhoof 1980). This is the ‘‘intuitive'' understanding of predicted mortality for the ‘‘purer,'' more homogeneous subgroupings referred to above.

In a separate exercise to validate the utility of Gompertz, I submit a comparison of a graduation of female central death rates from the NLTCS study shown in Professor Stallard's Table 8 to one based on mortality rates from ages 85–109 taken from Social Security records over the period 1990–1999 (Kestenbaum and Ferguson 2005, p. 7). These graduations are detailed in Stallard's Appendix 2 and summarized in Table 1.

Admittedly, Professor Stallard's Table 8—from National Long-Term Care Surveys of 1984, 1989, 1994, and 1999—and the Social Security Administration's study of Centenarians based on Medicare data from 1990–1999 were drawn from ostensibly different sources, age groups, and periods that, while overlapping, were not coterminous. Nevertheless, the nature of the two populations—elderly females covered under Medicare—suggests that significant numbers of individuals were probably included in both studies. The resulting graduations are remarkably close, the former based on central rates from the eight quinquennial age groupings 65–69 through 100–104, the latter on discrete ages 85 through 109. While in no way detracting from Professor Stallard's highly refined and individually oriented methodology, these two examples are presented to suggest that Gompertz's law, which has served us well for almost two centuries, deserves better press that a mere ‘‘useful approximation.'' It still provides closeness of fit that is more than adequate for many practical purposes, and, although

Table 1
Summary of Stallard Appendix 2

	NLTCS Study	Social Security 1990–1999
B	**0.0000233**	**0.0000231**
c	**1.10372**	**1.10362**
x	μ_x	μ_x
67	0.017	0.017
72	0.028	0.028
77	0.047	0.046
82	0.076	0.075
87	0.125	0.123
92	0.204	0.201
97	0.335	0.329
102	0.548	0.539

it may fall short of an ''immutable fact,'' it does, as Tenenbein and Vanderhoof set out to demonstrate, forge a plausible link between the mathematics of life contingencies and the underlying ''substructure of biology and gerontology.''

Going, in a sense, from the ridiculousness of Schmidt to the sublime, this reviewer suggests a parallel to the derogation of Newton after Einstein came along. Einstein didn't invalidate Newton's laws, though he critically described their limitations over sufficiently large distances. In much the same way, modern cosmologists are discovering anomalies in Einstein's General Theory at the outermost reaches of extragalactic space. Professor Stallard's geometric analogy for a four-pure-type GoM model to a regular tetrahedron with the healthiest of the pure types moving over time on a trajectory from the apex toward the base should provide imaginative actuarial students with ammunition to conceive four-dimensional models of nested tetrahedra, each successively smaller one at single-year intervals bounding the new temporal trajectories that its observed subjects can take as they age. In the most extreme case in recent memory, Jeanne Calment of Arles would have been the sole occupant, at the apex of the tiniest Matryoshka doll, innermost tetrahedron number 119, the believed upper age limit of mortality, but descending ever so slowly, taking another three-and-a-half years to reach its base (*New York Times* 1997).

Professor Stallard's conclusions on the significance of the 95 variables in predicting declining frailty are as intriguing as his methodology and deserve the attention of actuaries pricing life and health contingencies at older ages. Again, those of us still rooted in the experience of the twentieth century will find it a challenge to abandon our notions of smoking and, more recently, obesity as among the nation's most serious health problems. More than 40 years of mortality experience on the former have confirmed the Surgeon General's position, demonstrating death rates for smokers two to three times those for nonsmokers, and consequent reductions in life expectancy for 35-year-old male smokers of perhaps as much as 13 years compared to their nonsmoking counterparts. In contrast, Professor Stallard shows cigarette usage in 91st position among the 95 variables in terms of its significance. Similarly, the average significance ranking of 60th for body mass index and obesity (mean of rankings of variables 6, 7, 8, and 27) tends to belie the seriousness attached by the Surgeon General to the health problems of excess weight. It would be interesting to examine how these rank orders might change if the population studied were much younger, age 35–64, say, where the differential mortality selection of these two risks is taking its major toll numerically. By age 65 the prevalence of smoking is below 10%, as against almost 30% for males and 25% for females from ages 18–64. Obesity is also less prevalent among the elderly, only 20% among males and 23% among females at ages 75 and higher, in contrast to rates well above 30% at younger ages. It should be obvious that these patterns are not the result of people suddenly quitting smoking or becoming lean as they cross the threshold to the ranks of the elderly; millions of smokers and unknown numbers of obese simply never get into the population studied by Professor Stallard. He starts out, so to speak, with much ''purer'' types at age 65 than had the population he studied been much younger.

It is clear from Professor Stallard's research that those studying the consequences of lifestyle behaviors on survival to advanced ages cannot rely solely on patterns that pertain principally to the lower end of the age spectrum. Even so, it comes as a revelation that the most significant predictors of declining vitality should be activities of daily living, both institutional (IADLs) and otherwise (ADLs). Further, given Professor Stallard's concurrence in findings that about half the variability in individual vitality is genetically based, it may seem surprising that family history is not accorded prominence as a potential variable. He points explicitly to five factors—education, income, occupation, marital status, and religion—excluded from his study ''because they did not directly measure health, disability, and health-related behaviors.'' Fortunately, though, he does suggest that, with the exception of occupation—which should be less significant above age 65—these could be included in further analysis.

Again, without regard to stratification by age, this discussant has shown a high correlation of longevity to education and income both across nations and by state within the United States (Cowell 2008, Charts 4a, 4b, 5). Another group of researchers has published evidence of significant differences in longevity—seven to eight years for females, nine to 10 for males—by county of residence, with the healthiest locations in Hawaii, the California coast, Pacific Northwest, northern Great Plains, and upper Midwest, and along the I-95 corridor from Boston to Washington. The unhealthiest counties cover a wide swath extending from Appalachia through the Southeast and along the Mississippi Valley. That study also points to life expectancies in the unhealthiest counties comparable to Mexico's or Panama's. This discussant observes that they may be even worse, more like those of Peru's or Algeria's, and that, unremarked by the study's director, longevity in the healthiest U.S. counties compares favorably to Norway's and Sweden's. The study does acknowledge, though, that it is not so much geography, rather social and cultural factors, that drive these differences (*Harvard Magazine* 2007).

As to marital status, it has been identified in at least one actuarial study as being a significant differentiator of mortality across a wide range of ages, especially for males (Trowbridge 1994). In editing the Society of Actuaries 2005 series of reports on the *Risks and Process of Retirement Survey,* I cited data from the U.S. Census and the Social Security Administration showing central death rates for divorced, widowed, separated, and never married men as much as three times those of their married counterparts (Wade 1984; *National Vital Statistics Report* 2004). These differences translate to a longevity advantage of more than four years for a 65-year-old man, and more than three for his spouse the same age. Professor Stallard is encouraged to consider including marital status as a variable in his follow-up study.

Last, occupation, which has traditionally been a significant factor in life and health insurance underwriting, is generally considered less important at the higher ages, where most people are no longer working. Several studies, however, have been made of the unusually favorable longevity of actuaries, most of which attribute the outcomes to the profession's taking the results of its own mortality analysis more seriously than might others (Larus 1938; Cook and Moorhead 1990). Most recently Philip Lehpamer (2007) has published findings that Fellows of the Society of Actuaries experience mortality rates about half those in the general population. So instead of bemoaning his retirement, Schmidt ought, perhaps, to have been celebrating the probability that it would be longer than many enjoy, and more likely healthier.

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