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ABSTRACT

Numerous studies find a positive relationship between cognitive ability, IQ as measured in childhood or youth, and subsequent survival. Explanations range from the idea that low ability is an indicator of adverse systemic events in early life to the idea that high cognitive functioning is required continuously to maintain health and reduce threats to survival. The Wisconsin Longitudinal Study (WLS) has followed a cohort of 10,317 Wisconsin high school seniors from 1957 onward. As expected, in the WLS adolescent cognitive ability (IQ) is positively correlated with survival from ages 18 to 69. However, rank in high school class accounts completely for the relationship between IQ and survival, and it has a much larger effect on survival. This finding could be interpreted as suggesting that cognitive functioning improves survival by promoting behaviors that boost health status, minimize exposure to known risks and, more generally, optimize returns to health producing inputs, and that such behaviors are firmly in place by late adolescence. Future research should identify those behaviors, their antecedents, and their consequences.

In a large American sample of high school graduates the association between adolescent IQ and survival from ages 18 to 69 is entirely explained by a measure of academic performance (rank in high school class) that is only moderately associated ($r = 0.6$) with IQ. Moreover, the effect of rank in high school class is about three times larger than that of IQ. This finding suggests that higher cognitive functioning improves the chances of survival because it leads to behaviors that are responsible, well organized, timely, and appropriate to the situation, and that such patterns of behavior are well established by late adolescence.

Deary's (2008) essay in *Nature* noted that an association between "early life intelligence and mortality" has been established "across different populations, in different countries, and in different epochs." He offered four potential explanations of this ubiquitous finding: higher education, healthy behaviors, early insults to the brain, and system integrity: "First, … intelligence is associated with more education, and thereafter with more professional occupations that might place the person in healthier environments. …. Second, people with higher intelligence might engage in more healthy behaviours. … Third, mental test scores from early life might act as a record of insults to the brain that have occurred before that date. … Fourth, mental test scores obtained in youth might be an indicator of a well-put-together system. It is hypothesized that a well-wired body is more able to respond effectively to environmental insults" (p. 176). The essay referred only in passing to a finding that "being more dependable or conscientious in childhood is also significantly protective to health" (Schwartz, *et al.*, 1995; Deary, *et al.*, 2008), yet this may be the key to explaining the association between IQ and survival.

Research on the association between early IQ and survival has led to the development of a nascent subdiscipline, cognitive epidemiology (Deary & Batty, 2006, 2007; Deary, 2009b, 2009a; Deary, *et al.*, 2009; Lubinski, 2009). Much of this research has been integrated in a comprehensive account of follow-ups to the Scottish Mental Surveys (Deary, *et al.*, 2009). In addition to overall mortality (Whalley & Deary, 2001; Hart, *et al.*, 2003a; Hart, *et al.*, 2003b; Osler, *et al.*, 2003; Hart, *et al.*, 2005; Batty, *et al.*, 2009c; Leon, *et al.*, 2009), IQ has been associated with accidental deaths (O'Toole, 1990; O'Toole & Stankov, 1992; Batty, *et al.*, 2007a; Young, 2008; Batty, *et al.*, 2009b), with homicide (Batty, *et al.*, 2008), with hypertension, stroke, and cardiovascular disease (Lindgarde, *et al.*, 1987; Hart, *et al.*, 2003b; Starr, *et al.*, 2004; Batty, *et al.*, 2005; Batty, *et al.*, 2007b), with quitting smoking (Taylor, *et al.*, 2003), and with time to menopause (Shinberg, 1998; Richards, *et al.*, 1999; Whalley, *et al.*, 2004; Kuh, *et al.*, 2005). These studies provide little evidence that differential survival by IQ is explained by the correlation of IQ with social and economic origins. There is mixed evidence that the effects of IQ on mortality are mediated by education and socioeconomic success (Link & Phelan, 2005; Link, *et al.*, 2008; Batty, *et al.*, 2009a).

Some of the risk factors that account for health differentials, e.g., smoking, drinking, over-eating, and lack of exercise, are known by almost all adults. The important question is not whether these risks are known and understood, but why people continue to ignore them. Yet interpretations of correlations between IQ and morbidity or mortality have sometimes been speculative and exaggerated. One researcher has suggested that IQ is “the epidemiologists’ elusive fundamental cause of social class differences in health” (Gottfredson, 2004), thus implying that it may account for the influence of socioeconomic standing on survival. Deary has written “Whether you live to collect your old-age pension depends in part on your IQ at age 11. You just can’t keep a good predictor down” (Deary, 2005). Batty and Deary interpret the IQ differential as attributable to excessive cognitive demands in healthcare settings (Batty & Deary, 2004): “Given their inherently complex and sometimes conflicting nature, healthcare messages, treatment regimens, and preventative strategies perhaps surpass the cognitive abilities of some people. If this is the case—and bearing in mind that oversimplification of advice might reduce effectiveness substantially— proactive involvement of healthcare providers is warranted to reduce health inequalities attributable to differences in cognitive ability.” While cognitive limits may well affect understanding and compliance in healthcare settings, there is not a shred of evidence that this accounts for the life-long association between IQ and survival.

Moreover, the recent literature on IQ and survival, along with much other epidemiological and demographic literature, ignores the implications of findings that identify variables(s) as statistically significant predictor(s) of an outcome. Halting the analysis at the point where estimates of relative hazard or odds ratios and their standard errors are obtained ignores the possibility that their ultimate implications for outcomes with policy significance can be and sometimes are utterly trivial, despite their statistical reliability.

For example, consider the recent paper in which Batty et al. (2009c) estimated the relationship between IQ (military induction test) and mortality among 1 million Swedish men for approximately 20 years (from roughly age 18 to age 38). Their main finding is a highly significant hazard ratio of 1.32 for the association between a one standard deviation difference in IQ and the likelihood of death. While this effect appears to be large, it has almost no impact on expected years of life within the age span covered by the survey (roughly 20 years). Of the 968,846 men in the Swedish cohort, just 14,498 men died. At the ages in question, the overall hazard is small and virtually constant, so it is fair to approximate the hazard as 14,498/(20 * 968,846) = .0007482. This implies about19.85 years of expected life, that is, just 0.15 years below the maximum of 20. If average IQ in the cohort were a full standard deviation higher – a most unlikely event – the hazard would fall to .0005668, and the expected number of years of life would rise to 19.89 years, just 0.04 years higher than before. To be sure, under this assumption, the number of deaths would fall by 24 percent, but that merely underscores the extremity of assuming a one standard deviation rise in average IQ.

Is the association between IQ and survival a consequence of purely cognitive processes? Or are there other intervening mechanisms? If IQ were immutable, which is increasingly doubtful (Nisbett, 2009), what avenues of intervention are available? What good would it do to intervene in the medical care setting if the influence of cognition is pervasive in people's lives? Is cognition about health issues and medical procedures the real issue? And of what importance is the effect of IQ on survival, relative to other known correlates?

Data

The Wisconsin Longitudinal Study (WLS) has followed the lives of 10,317 Wisconsin high school graduates of 1957, a simple random sample of one third of their graduating class (Sewell, *et al.*, 2004). The Wisconsin sample covered 70 to 75% of appropriately aged youth in Wisconsin (Sewell & Hauser, 1975). However, participants are all high school graduates and almost all non-Hispanic whites, rather like 2/3 of Americans of their birth cohorts.

Gender was ascertained in a spring 1957 survey of the graduates. Cognitive ability (IQ) was measured in the junior year of high school (1956) using the Henmon-Nelson Test of Mental Ability (Henmon & Holt, 1931; Henmon & Nelson, 1946, 1954), and rank in high school class was ascertained directly from high school records. In U.S. high schools, rank in class is based on the mean grade assigned in courses taken throughout the high school career. Parents' incomes were obtained from federal income tax forms filed with the State of Wisconsin and averaged over the years 1957 to 1960, while parents' occupations were ascertained from the tax forms or from surveys conducted in 1957 and 1975. In this analysis, IQ, high school rank, and parents' income were each categorized in fifths of their distribution, and family head's occupation was classified as either farm or non-farm. Other social background variables were measured, but were not associated with survival. Years of death from 1957 through 2008 were obtained from the Social Security Death Index, from vital records of the State of Wisconsin, or from survivors of the decedent. Of the 10,317 members of the sample, 1603 had died by the end of 2008, and 8701 were known to have survived. Mortality status was unknown in 13 cases.

In fewer than 7 percent of cases, data on high school rank, parents' incomes, or parents' occupations were multiply imputed following the procedure suggested by Van Buuren et al. (1999) and implemented by Royston (2004, 2005, 2007) in the ICE routine in Stata 10. Conditional on each of five such imputations, missing years of death between 1957 and 1975 were multiply imputed for 50 cases assuming a Weibull distribution. Of these, 20 died before 1964, 22 between 1964 and 1975, and 8 between 1957 and 1975. Analyses of survival were estimated in Stata 10 assuming a Weibull distribution for each of the 25 fully imputed sets of data. In this large sample, adjustment of standard errors for the effect of imputation would be negligible. Imputations and estimates were also carried out assuming a Gompertz distribution, confirming the findings reported here.

Methods

The workhorse of our analyses is a parametric survival model defined on the age interval (18,68). Individuals whose survival was not ascertained (N = 13) or who survived to 2009 (N = 8701) were censored. The model is as follows:

$$\mu(x) = \mu(x) = \mu_o \exp(\beta\mathbf{X})\exp(\beta\mathbf{X}) \qquad (1)$$

where $\mu(x)$ is the force of mortality evaluated at x, μ_o is a baseline force of mortality evaluated at age x, β is a vector of parameters and **X** is a vector of covariates. For pragmatic reasons we choose a Weibull hazard to represent the baseline $\mu_o(x)$ thus imposing the following parametric form:

$$\mu_o(x) = \gamma\rho x^{(\rho-1)} \qquad (2)$$

where γ is a level parameter and ρ is the shape parameter. It is well-known that a Weibull hazard can be parameterized as a Gompertz hazard defined on the log of duration (rather than on duration). Both functions capture the pattern of mortality well from adolescence to late adulthood though the Weibull function rises too slowly at ages above 75 to represent mortality well above those ages. However, since the Gompertz and Weibull perform equally well below ages 75, and since a Weibull parametric hazard is also an accelerated failure time model (and hence more robust to some violations of the proportionality assumption), we chose to present results using the Weibull parameterization.

In addition to estimating the vector of parameters, β, along with ρ and γ, we calculated the predicted integrated hazard, $I(y; \beta, \rho, \gamma)$, for selected subgroups (setting all the variables not defining the subgroups to their sample mean) and the probabilities of surviving $S(x; \beta, \rho, \gamma) = \exp(-I(y; \beta, \rho, \gamma)$, and finally, the expected duration in the intervals (x, 68) for all x between 18 and 67. The latter quantities are much better measures of the ultimate effects of selected covariates than the vector, β, or the relative hazards, $\exp(\beta)$.

Our estimation strategy consisted of building successively more complicated models while paying close attention to the role of common causes and mediating mechanisms. The model of relations we have in mind is shown in Figure 1. Our main conjecture is that the effects of IQ are mediated by variables that could be correlated with it but that also represent traits quite different from intellectual skills and are more suitably thought of as indicators of character and personality as well as by behaviors during adulthood (Deary, *et al.*, 2008). The model in Figure 1 includes constructs whose indicators are not included in our analysis. Among these are variables representing early childhood environments and events that may have shaped or constrained IQ. Thus, the estimated effect of IQ overstates its true effects if early childhood conditions have independent effects on IQ and on mortality (Barker, 2001; Palloni, 2006; Nisbett, 2009).

Findings

Figures 2 and 3 describe observed mortality differentials by IQ and high school rank. Figure 2 shows Nelson-Aalen cumulative hazard estimates of mortality among the top and bottom fifths of Wisconsin graduates in IQ. The two groups have very similar cumulative mortality through the first 20 years after graduation, but life chances diverge modestly thereafter. On the same scale, Figure 3 shows corresponding estimates of the cumulative hazard of mortality for the top and bottom fifths in high school rank. Here, the mortality experience of the two groups diverges within 10 years of graduation, and by 2008, the cumulative risk of death is nearly twice as large among the lowest as among the highest ranking students. Plainly, while there is differential mortality by IQ in the Wisconsin cohort, the differential by high school rank is far larger.

Table 1 shows estimated parameters of Weibull models of survival in the Wisconsin cohort. Model 1 includes only a dummy variable for gender and dummy variables for fifths of the IQ distribution. As one should expect, men experience much higher mortality than women, while mortality decreases as IQ increases. The odds of mortality are almost 20 percent lower in the top fifth of IQ than in the bottom fifth. Model 2 adds social background variables to the model. Graduates with farm background have a mortality advantage that is roughly as large as that of the top fifth in IQ relative to the bottom fifth, while the differential in mortality by parents' income is substantially larger than that by IQ. The odds of mortality among the top fifth of graduates in parents' income are more than 25 percent less than among the bottom fifth. However, the effect of IQ barely changes when the social background variables are added to the model.

In model 3, high school rank is added; its effects are large and statistically reliable. The odds of mortality are more than 40 percent lower in the top fifth of the class than in the bottom fifth; the obverse is that the odds of mortality are 2/3 greater in the bottom than in the top fifth. The inclusion of high school rank in model 3 scarcely alters the effects of the social background variables, but it has marked effects on the estimated coefficients of gender and of IQ. In model 2, the odds of mortality among men are 62 percent greater than among women, but in model 3, the gender differential is reduced to 51 percent. The reason is that high school girls earn higher grades than high school boys of equal IQ – by nearly half a standard deviation – and that accounts in part for the gender differential in mortality.

More important, once high school rank enters the model, there are no longer any statistically significant differentials in mortality by IQ. That is, the association between IQ and mortality is entirely explained by its correlation – presumably a causal relationship – with high school rank. However, that correlation is far from perfect. Among the Wisconsin graduates, the correlation is $r = 0.6$, which is to say that nearly two thirds of the variance in high school rank is independent of IQ. Figure 4 displays a scatter-plot of the relationship between Henmon-Nelson IQ and class rank. Plainly, there is a great deal of variability in class rank among individuals with the same IQ. To be sure, this is due in part to the fact that average IQ varies among high schools, while the distribution of class rank is necessarily the same in each school. However, less than 13 percent of the variance in IQ lies between schools, and the within-school regression of rank on IQ – even after social background variables have been controlled – is virtually the same as the correlation reported here (Hauser*, et al.*, 1976: 323-24). While the independent features of high school rank may be partly cognitive, they must also include aspects of character, habit, and personality. Personal characteristics that lead students to do the right thing in the right way at the right time and place when they are in secondary school evidently persist in ways that lead to greater longevity.

Table 2 shows selected estimates of expected years of life, based on the Weibull models, during the 52 year period of observation. In models 1 and 2, women outlive men by 1.3 years, but in model 3 women's advantage is reduced to 1 year. In models 1 and 2, the highest fifth in IQ outlive the lowest fifth by about half a year, but that differential is actually reversed in model 3. Both in model 2 and in model 3, farm youth outlive nonfarm youth by about half a year, while high income youth outlive low income youth by almost a year. However, the largest differential in expected years of life is 1.4 years, between youth in the top and bottom fifths of their high school classes.

To investigate the possibility that the effect of IQ varies across levels of high school rank, we estimated the Weibull model separately in the top, middle, and bottom thirds of the distribution of high school rank. These findings are summarized in Figure 5, which shows the effect of IQ on the ratio of expected years of life to the maximum possible years of life by years since 1957 in each third of the distribution of high school rank. For clarity, each panel of the figure shows only the ratios for the top and bottom fifths of the IQ distribution. If higher IQ had a salutary effect on survival, the curves for the top fifth in IQ would always be higher than the curves for the bottom fifth in IQ. However, the opposite holds throughout the distribution of high school rank: Those with a very high IQ are less likely to survive than those with a very low IQ. Moreover, since each panel of Figure 5 is on the same vertical scale, a comparison among the panels clearly shows the positive effect of high school rank on survival.

The WLS data do not permit a thorough analysis of the health-related behavioral consequences of IQ and high school rank. However, smoking behavior and binge drinking provide striking examples that may help to explain the relationship of IQ with mortality. In 1993, 54 percent of the Wisconsin graduates reported that they had smoked cigarettes at some time in their life. Among those who ever smoked, 67 percent reported that they had stopped, and they also reported the number of years that they had smoked. Almost 95 percent of the graduates reported that they had alcoholic beverages at some time in their life, but just 59 percent had any alcoholic beverages in the month preceding the interview. Those participants were asked the number of occasions on which they had consumed more than four alcoholic drinks in that month.

Table 3 reports regression analyses of smoking, quitting smoking, and binge drinking as reported in 1993. For convenience in interpretation, both Henmon-Nelson IQ and high school rank have been expressed in standard form, that is, with a mean of 0 and a standard deviation of 1.0. In model 1, which includes only gender and IQ, the odds that a man ever smoked were 1.7 times as large as those of a woman, while IQ had no effect. Model 2 adds high school rank to the model. Here, the effect of IQ is statistically significant and positive, while increases in high school rank diminish the odds of smoking. That is, when high school rank is controlled, those with higher IQs were significantly more likely to smoke than those with lower IQs. The addition of high school rank to the model also explains about half the gender effect because men obtained lower grades in high school than women.

Models 3 and 4 pertain to the number of years of regular smoking among those who had ever smoked. In model 3, which includes only gender and IQ, men smoked for about a year longer than women, while a one standard deviation increase in IQ reduced the time to quitting by almost a year. However, the addition of high school rank in model 4 reduced the gender effect to non-significance, reversed the IQ effect, and yielded the estimate that a one standard deviation increase in IQ reduced the time to quitting by almost two years.

Analyses of binge drinking – the number of times per month that an individual had more than four drinks on the same occasion – yield estimates that parallel those of smoking behavior. In model 5, which includes only gender and IQ, the estimates suggest that men experience almost one more binge-drinking episode per month than women, while a one standard deviation shift in IQ reduces binge-drinking by about one eighth of an episode per month. Again, the introduction of high school rank in model 6 reduces the IQ effect to statistical insignificance and partly explains the gender difference. In that model, a one standard deviation increase in high school rank decreases binge-drinking by one fifth of an episode per month.

Both in analyses of smoking behavior and of binge-drinking, with just one exception, similar findings are obtained when the data for women and men are analyzed separately. In the case of women's binge-drinking, IQ and high school rank have small and virtually equal negative effects. Also, there are other cases where effects on health outcomes or behaviors do not follow the same pattern as survival, smoking, and binge-drinking. In the case of self-rated general health in 1993 (excellent or good vs. fair, poor, or very poor), both IQ and high school rank have small, significant positive effects. The same holds in the case of participation in light exercise and participation in vigorous exercise. On the other hand, neither IQ nor high school rank affects the likelihood that a participant had a complete physical examination within the past year. Because the reports of health and health behaviors were first obtained when participants were 53 to 54 years old, we have not tried to investigate the degree to which any health-related behaviors mediate the influence of IQ and high school rank on mortality. Thus, much remains to be done before their effects on mortality will be fully understood.

Discussion

Taken at face value, these findings suggest substantial modification in the previously offered explanations for the association between IQ and survival. There is no need to invoke "early insults to the brain" or "system integrity" to explain the association, nor is it necessarily mediated by post-secondary schooling – though some studies have found that the IQ-survival relationship is partly mediated by educational attainment (Link & Phelan, 2005; Link, *et al.*, 2008). The latter finding may be attributable to the fact that high school grades, more than test scores, account for the completion of college (Bowen, *et al.*, 2009). Neither is it necessary to invoke health literacy, except to the extent that it may reflect highly motivated or compliant behavior. The leading candidate to explain the IQ-survival relationship would appear to be lifelong attitudinal and behavioral patterns that contribute both to academic success in secondary school and to systematic accumulation of health benefits.

The present analysis cannot claim to parse the content of high school rank in terms of personality or motivation. That should be a goal of future research. What does seem clear is that high school rank is a cumulative indicator of responsible, compliant behavior, of consistently doing the right thing in the right way at the right time and place. That possibility has been noted by Deary (2008): "For example, it seems that, independently of any association with intelligence, being more dependable or conscientious in childhood is also significantly protective to health." Class rank in itself probably has little or no causal importance, and, to be sure, not everyone can be at the head of the class. The important things more likely are the personal characteristics, the habits and tendencies that lead to academic success.

Where educational attainment or other economic characteristics have been shown to mediate the association between IQ and survival, cognitive epidemiologists have sometimes attempted to diminish such findings with the claim that the mediating variables are merely proxies or surrogates for IQ. For example, Gottfredson (2004:175) writes,

> "[S]uccessively better surrogates for g—income, occupation, education, health literacy—are successively stronger correlates of health outcomes. Analyses of the "job" of being a patient show that it requires the same cognitive skills that g represents and that most jobs require for good performance: efficient learning, reasoning, and problem solving. Both chronic diseases and accidents incubate, erupt, and do damage largely because of cognitive error, because both require many efforts to prevent what does not yet exist (disease or injury) and to limit damage not yet incurred (disability and death) if one is already ill or injured."

According to Gottfredson and Deary (2004: 2),

> "The socioeconomic measures that best predict health inequality also correlate most with intelligence (education best, then occupation, then income). This means that instead of IQ being a proxy for SES in health matters, SES measures might be operating primarily as rough proxies for social-class differences in mental rather than material resources."

Finally, Deary (2008: 176) writes,

> "It may be that a person with more and better education achieves a higher IQ score; but a child with a high IQ score is more likely to undergo more years of

> education, attain higher qualifications and go on to a better job. Thus, adjusting for education and social class in the intelligence– mortality association could be an over-adjustment — it might weed out some of the very influence of intelligence that we are trying to detect."

Such arguments are fallacious. Figure 6 shows a causal model in which high school rank is only a proxy measure of IQ. In this scheme, high school rank is affected by social background, IQ, and gender, and by other, non-intellective causes that are uncorrelated with its observed causes. Mortality also depends on social background, IQ, gender and other variables that are unrelated to its observable causes. To the extent that high school rank is affected by IQ, one can properly call it a proxy or surrogate for IQ. However, high school rank itself has no influence on mortality. The correlation of high school rank with mortality is entirely explained by their common dependence on social background, IQ, and gender.

Figure 7 revises the model of Figure 6 to represent the findings of the present analysis. There are two major changes in the scheme. First, IQ no longer has any direct effect on mortality, and, second, high school rank has a direct effect on mortality. That is, the effect of IQ on mortality is entirely mediated by high school rank. This can only occur because there are additional, non-intellective causes of high school rank that are not correlated with IQ. To be sure, to the extent that IQ is associated with survival, independent of social background and other prior events and circumstances, its effects are real, and they are not at all diminished by the introduction of mediating variables. Figure 7 does not say that IQ has no effect on mortality, but only that the effect is mediated by high school rank. However, a mediating variable must have sources of variability other than IQ and whose effects thus are necessarily distinct from those of IQ. In the present analysis, for example, the correlation between IQ and high school rank is just

0.60, so 64 percent ($100 \times (1 - 0.6^2)$) of the variance in rank is independent of IQ and cannot properly be labeled a proxy effect.

The present analysis locates the explanation of the IQ-survival association firmly in personal characteristics, attitudes, and behaviors that are well established by late adolescence. However, it also raises many more questions than it answers. Are the present findings peculiar to the social circumstances of those who grew up in mid-20th century America? Among the many studies establishing the correlation between IQ and survival, are there others in which these findings can be tested? What are the specific, behaviorally relevant characteristics of individuals that are reflected both in high school rank and in later survival? Throughout life, what salutary behaviors are affected by them? And perhaps most important, how can those behaviors be altered, even in the absence of responsible habits in adolescence?

References

Barker, D. J. P. (2001). *Fetal origins of cardiovascular and lung disease*. New York: M. Dekker.

Batty, G., Wennerstad, K., Smith, G., Gunnell, D., Deary, I., Tynelius, P., et al. (2009a). IQ in Early Adulthood and Mortality By Middle Age: Cohort Study of 1 Million Swedish Men. *Epidemiology, 20*(1), 100.

Batty, G. D., & Deary, I. J. (2004). Early life intelligence and adult health. *BMJ, 329*(7466), 585-586.

Batty, G. D., Deary, I. J., Schoon, I., & Gale, C. (2007a). Childhood mental ability in relation to cause-specific accidents in adulthood: the 1970 British Cohort Study. *QJM*.

Batty, G. D., Deary, I. J., Tengstrom, A., & Rasmussen, F. (2008). IQ in early adulthood and later risk of death by homicide: cohort study of 1 million men. *The British Journal of Psychiatry, 193*(6), 461.

Batty, G. D., Gale, C., Tynelius, P., Deary, I. J., & Rasmussen, F. (2009b). IQ in Early Adulthood, Socioeconomic Position, and Unintentional Injury Mortality by Middle Age: A Cohort Study of More Than 1 Million Swedish Men. *American Journal of Epidemiology, 169*(5), 606.

Batty, G. D., Modig Wennerstad, K., Davey Smith, G., Gunnell, D., Deary, I. J., Tynelius, P., et al. (2007b). IQ in early adulthood and later cancer risk: cohort study of one million Swedish men. *Annals of Oncology, 18*(1), 21.

Batty, G. D., Mortensen, E., Andersen, A., & Osler, M. (2005). Childhood intelligence in relation to adult coronary heart disease and stroke risk: evidence from a Danish birth cohort study. *Paediatric and Perinatal Epidemiology, 19*(6), 452.

Batty, G. D., Wennerstad, K., Smith, G., Gunnell, D., Deary, I. J., Tynelius, P., et al. (2009c). IQ in Early Adulthood and Mortality By Middle Age: Cohort Study of 1 Million Swedish Men. *Epidemiology, 20*(1), 100.

Bowen, W. G., Chingos, M. M., & McPherson, M. S. (2009). *Crossing the finish line: Completing college at America's public universities*. Princeton, N.J.: Princeton University Press.

Deary, I. J. (2005). Intelligence, health and death. *The Psychologist, 18*(10), 610-613.

Deary, I. J. (2008). Why do intelligent people live longer? *Nature, 456*(7219), 175-176.

Deary, I. J. (2009a). Cognitive epidemiology: Its rise, its current issues, and its challenges. *Personality and individual differences*.

Deary, I. J. (2009b). Introduction to the special issue on cognitive epidemiology. *Intelligence*.

Deary, I. J., & Batty, G. D. (2006). Commentary: Pre-morbid IQ and later health--the rapidly evolving field of cognitive epidemiology. *International Journal of Epidemiology, 35*(3), 670.

Deary, I. J., & Batty, G. D. (2007). Cognitive epidemiology. *Journal of Epidemiology & Community Health, 61*(5), 378-384.

Deary, I. J., Batty, G. D., Pattie, A., & Gale, C. (2008). More Intelligent, More Dependable Children Live Longer: A 55-Year Longitudinal Study of a Representative Sample of the Scottish Nation. *Psychological Science, 19*(9), 874-880.

Deary, I. J., Whalley, L. J., & Starr, J. M. (2009). *A lifetime of intelligence: Follow-up studies of the Scottish mental surveys of 1932 and 1947*. Washington, DC: American Psychological Association.

Gottfredson, L. S. (2004). Intelligence: is it the epidemiologists' elusive "fundamental cause" of social class inequalities in health? *J Pers Soc Psychol, 86*(1), 174-199.

Gottfredson, L. S., & Deary, I. J. (2004). Intelligence Predicts Health and Longevity, but Why? *Current Directions in Psychological Science, 13*(1), 1-4.

Hart, C., Deary, I. J., Taylor, M., MacKinnon, P., Davey Smith, G., Whalley, L., et al. (2003a). The Scottish Mental Survey 1932 linked to the Midspan studies: a prospective investigation of childhood intelligence and future health. *Public Health, 117*(3), 187-195.

Hart, C., Taylor, M., Davey Smith, G., Whalley, L., Starr, J., Hole, D., et al. (2003b). Childhood IQ, social class, deprivation, and their relationships with mortality and morbidity risk in later life: prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies (Vol. 65, pp. 877-883): Am Psychosomatic Soc.

Hart, C., Taylor, M., Smith, D., Whalley, L., Starr, J., Hole, D., et al. (2005). Childhood IQ and all-cause mortality before and after age 65: Prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies. *British journal of health psychology, 10*(2), 153-165.

Hauser, R. M., Sewell, W. H., & Alwin, D. F. (1976). High School Effects on Achievement. In W. H. Sewell, R. M. Hauser & D. L. Featherman (Eds.), *Schooling and Achievement in American Society* (pp. 309-341). New York: Academic Press.

Henmon, V. A. C., & Holt, F. O. (1931). *A report on the administration of scholastic aptitude tests to 34,000 high school seniors in Wisconsin in 1929 and 1930 prepared for the committee on cooperation, Wisconsin secondary schools and colleges*. Madison: Bureau of Guidance and Records of the University of Wisconsin.

Henmon, V. A. C., & Nelson, M. J. (1946). *Henmon-Nelson Tests of Mental Ability, High School Examination - Grades 7 to 12 - Forms A, B, and C. Teacher's Manual*. Boston: Houghton-Mifflin Company.

Henmon, V. A. C., & Nelson, M. J. (1954). *The Henmon-Nelson Tests of Mental Ability. Manual for Administration*. Boston: Houghton-Mifflin Company.

Kuh, D., Butterworth, S., Kok, H., Richards, M., Hardy, R., Wadsworth, M., et al. (2005). Childhood cognitive ability and age at menopause: evidence from two cohort studies. *Menopause, 12*(4), 475.

Leon, D., Lawlor, D., Clark, H., Batty, G. D., & Macintyre, S. (2009). The association of childhood intelligence with mortality risk from adolescence to middle age: Findings from the Aberdeen Children of the 1950s cohort study. *Intelligence*.

Lindgarde, F., Furu, M., & Ljung, B. (1987). A longitudinal study on the significance of environmental and individual factors associated with the development of essential hypertension. *British Medical Journal, 41*(3), 220-226.

Link, B., & Phelan, J. (2005). Fundamental sources of health inequalities. In D. Mechanic, L. B. Rogut, D. C. Colby & J. R. Knickman (Eds.), *Policy Challenges in Modern Health Care* (pp. 71–84). Piscataway, New Jersey: Rutgers University Press.

Link, B., Phelan, J., Miech, R., & Westin, E. (2008). The Resources That Matter: Fundamental Social Causes of Health Disparities and the Challenge of Intelligence. *Journal of Health and Social Behavior, 49*(1), 72-91.

Lubinski, D. (2009). Cognitive epidemiology: With emphasis on untangling cognitive ability and socioeconomic status. [doi: DOI: 10.1016/j.intell.2009.09.001]. *Intelligence, In Press, Corrected Proof*.

Nisbett, R. E. (2009). *Intelligence and how to get it: Why schools and cultures count* (1st ed.). New York: W. W. Norton & Co.

O'Toole, B. (1990). Intelligence and behaviour and motor vehicle accident mortality. *Accident Analysis & Prevention, 22*(3), 211-221.

O'Toole, B., & Stankov, L. (1992). Ultimate validity of psychological tests. *Personality and individual differences, 13*(6), 699-716.

Osler, M., Andersen, A., Due, P., Lund, R., Damsgaard, M., & Holstein, B. (2003). Socioeconomic position in early life, birth weight, childhood cognitive function, and adult mortality. A longitudinal study of Danish men born in 1953 (Vol. 57, pp. 681-686): Journal of Epidemiology and Community Health.

Palloni, A. (2006). Reproducing Inequalities: Luck, Wallets, and the Enduring Effects of Childhood Health. *Demography, 43*, 587-615.

Richards, M., Kuh, D., Hardy, R., & Wadsworth, M. (1999). Lifetime cognitive function and timing of the natural menopause. *Neurology, 53*(2), 308-314.

Royston, P. (2004). Multiple imputation of missing values. *Stata Journal, 4*, 227-241.

Royston, P. (2005). Multiple imputation of missing values: Update of ice. *Stata Journal, 5*, 527–536.

Royston, P. (2007). Multiple imputation of missing values: further update of ice, with an emphasis on interval censoring. *Stata Journal, 7*(4), 445-464.

Schwartz, J., Friedman, H., Tucker, J., Tomlinson-Keasey, C., Wingard, D., & Criqui, M. (1995). Sociodemographic and psychosocial factors in childhood as predictors of adult mortality (Vol. 85, pp. 1237-1245): Am Public Health Assoc.

Sewell, W. H., & Hauser, R. M. (1975). *Education, Occupation, and Earnings: Achievement in the Early Career*. New York: Academic Press.

Sewell, W. H., Hauser, R. M., Springer, K. W., & Hauser, T. S. (2004). As We Age: The Wisconsin Longitudinal Study, 1957-2001. In K. Leicht (Ed.), *Research in Social Stratification and Mobility* (Vol. 20, pp. 3-111). London: Elsevier.

Shinberg, D. S. (1998). An event history analysis of age at last menstrual period: correlates of natural and surgical menopause among midlife Wisconsin women. *Social Science and Medicine, 46*(10), 1381-1396.

Starr, J., Taylor, M., Hart, C., Davey Smith, G., Whalley, L., Hole, D., et al. (2004). Childhood mental ability and blood pressure at midlife: linking the Scottish Mental Survey 1932 and the Midspan studies. *Journal of Hypertension, 22*(5), 893.

Taylor, M., Hart, C., Davey Smith, G., Starr, J., Hole, D., Whalley, L., et al. (2003). Childhood mental ability and smoking cessation in adulthood: prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies (Vol. 57, pp. 464-465): Journal of Epidemiology and Community Health.

Van Buuren, S., Boshuizen, H., & Knook, D. (1999). Multiple imputation of missing blood pressure covariates in survival analysis. *STATISTICS IN MEDICINE, 18*(6), 681-694.

Whalley, L., & Deary, I. J. (2001). Longitudinal cohort study of childhood IQ and survival up to age 76. *British Medical Journal, 322*(7290), 819.

Whalley, L., Fox, H., Starr, J., & Deary, I. J. (2004). Age at natural menopause and cognition. *Maturitas, 49*(2), 148-156.

Young, J. (2008). *Individual differences as predictors of accidents in early adulthood.* Unpublished Doctoral, Baylor University, Waco Texas.

Table 1. Estimated Parameters of Weibull Models: Survival of Wisconsin High School Graduates from 1957 to 2008

Variable	Model 1	Model 2	Model3
Constant	-11.437	-11.244	-11.105
	(0.240)	(0.245)	(0.247)
Shape	0.879	0.879	0.880
	(0.025)	(0.025)	(0.025)
Male	0.479	0.482	0.410
	(0.051)	(0.051)	(0.053)
Medium Low IQ	-0.141	-0.136	-0.058
	(0.075)	(0.075)	(0.077)
Medium IQ	-0.061	-0.049	0.070
	(0.074)	(0.074)	(0.079)
Medium High IQ	-0.213	-0.195	-0.026
	(0.079)	(0.079)	(0.087)
High IQ	-0.216	-0.188	0.069
	(0.080)	(0.081)	(0.097)
Farm background		-0.204	-0.183
		(0.070)	(0.071)
Medium Low Parents' Income		-0.211	-0.205
		(0.078)	(0.078)
Medium Parents' Income		-0.140	-0.133
		(0.079)	(0.079)
Medium High Parents' Income		-0.220	-0.221
		(0.081)	(0.081)
High Parents' Income		-0.319	-0.312
		(0.084)	(0.084)
Medium Low Rank in High School Class			-0.201
			(0.075)
Medium Rank in High School Class			-0.301
			(0.079)
Medium High Rank in High School Class			-0.249
			(0.084)
High Rank in High School Class			-0.513
			(0.100)

Note: Parenthetic entries are approximate standard errors.

Table 2. Expected Years of Life from 1957 to 2008 by Gender, IQ, Farm Origin, Parents' Income, and Rank in High School Class: Wisconsin Longitudinal Study

Variables in Weibull Model	Men	Women	Low IQ	High IQ	Farm	Nonfarm	Low income	High Income	Low rank	High rank
Model 1: Gender and IQ	50.5	51.8	50.9	51.5						
Model 2: Gender, IQ, Farm Origin, Parents' Income	50.5	51.8	50.9	51.4	51.6	51.1	50.7	51.6		
Model 3: Gender, IQ, Farm Origin, Parents' Income, Rank in High School Class	50.7	51.7	51.3	51.1	51.6	51.2	50.8	51.6	50.5	51.9

Table 3. Regression Analyses of Health-Related Behaviors in 1993 by IQ, High School Rank, and Gender: Wisconsin Longitudinal Study

Outcome variable	Male	Henmon-Nelson IQ	High School Rank
Model 1. Ever smoked (odds-ratio)	1.695	0.993	--
	(0.084)	(0.025)	
Model 2. Ever smoked (odds-ratio)	1.313	1.363	0.585
	(0.071)	(0.046)	(0.021)
Model 3. Years smoked among quitters	0.946	-0.827	--
	(0.397)	(0.202)	
Model 4. Years smoked among quitters	0.164	0.298	-1.967
	(0.428)	(0.260)	(0.277)
Model 5. Binge-drinking occasions	0.822	-0.125	--
	(0.064)	(0.033)	
Model 6. Binge-drinking occasions	0.713	-0.024	-0.194
	(0.070)	(0.043)	(0.044)

Note: Henmon-Nelson IQ and High School Rank are standardized with a mean of 0 and a standard deviation of 1.

Figures

Figure 1. Relations between factors producing mortality risks at adult ages

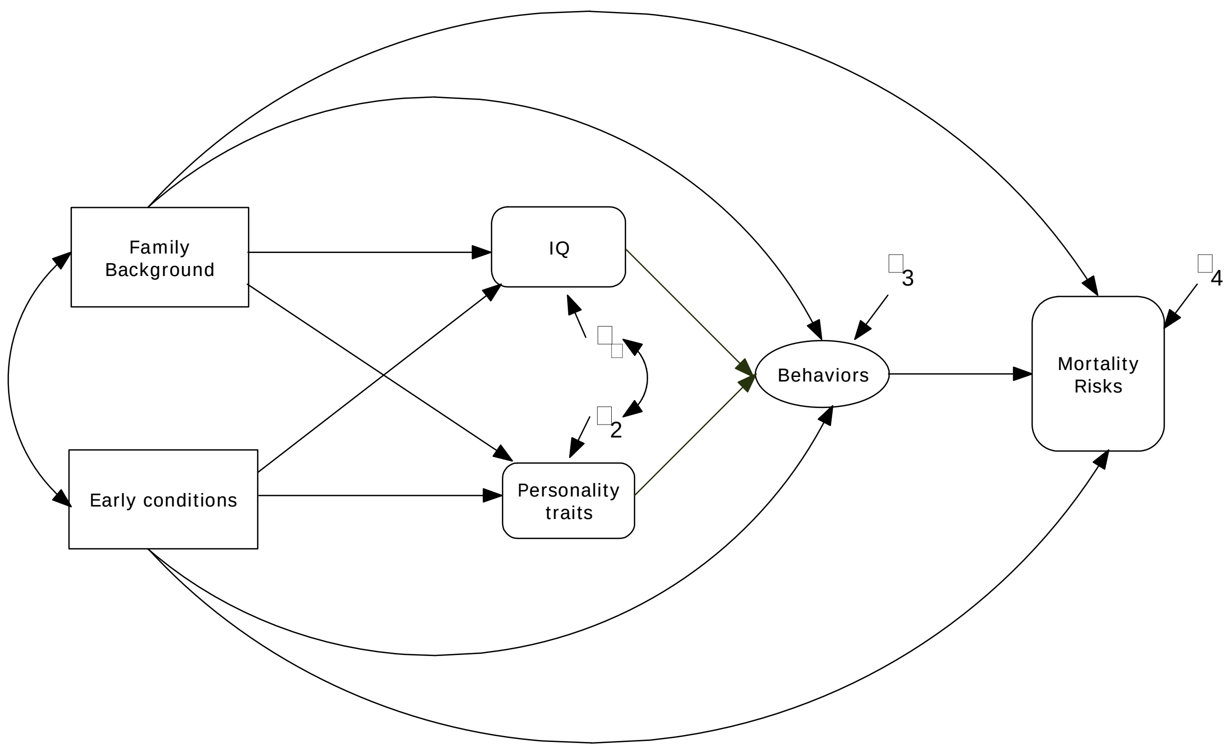


Figure 2. Nelson-Aalen Cumulative Hazard Estimates by IQ

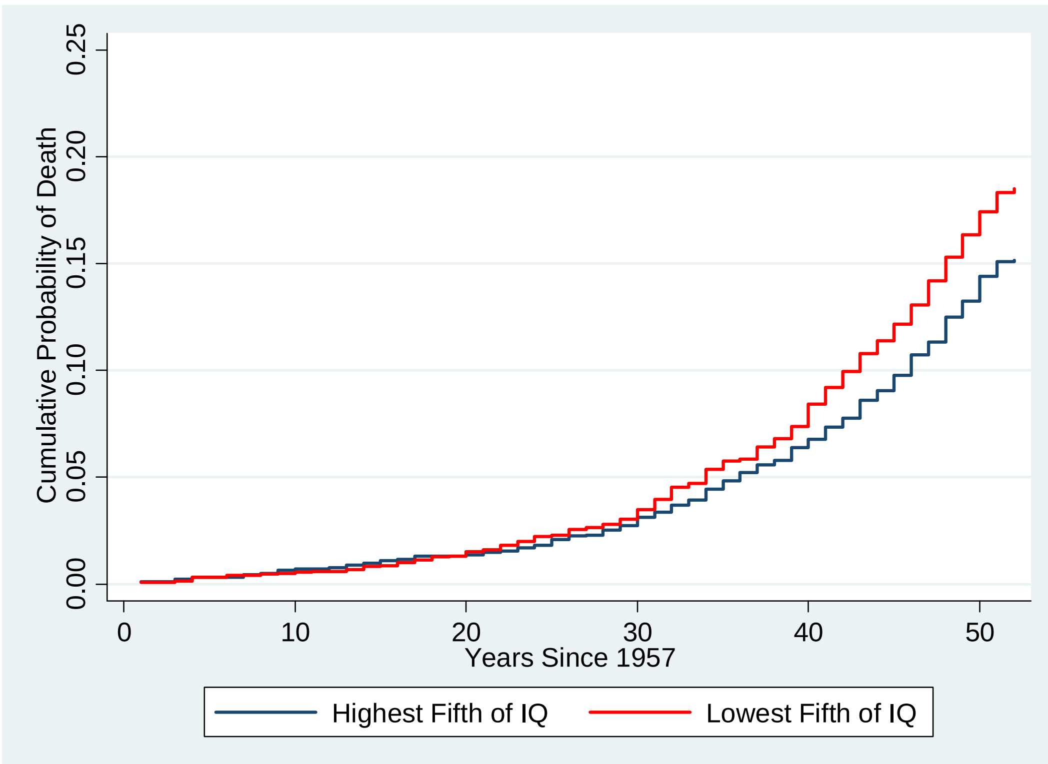


Figure 3. Nelson-Aalen Cumulative Hazard Estimates by Class Rank

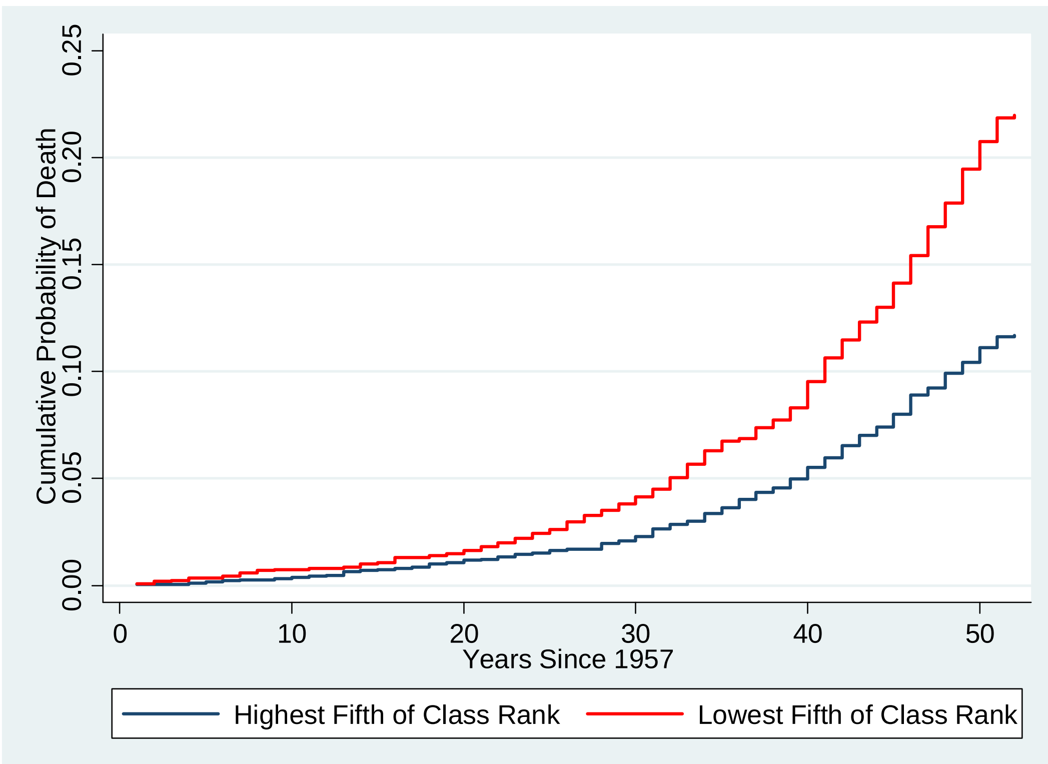


Figure 4. Scatter-Plot of Rank in High School Class by Henmon-Nelson IQ

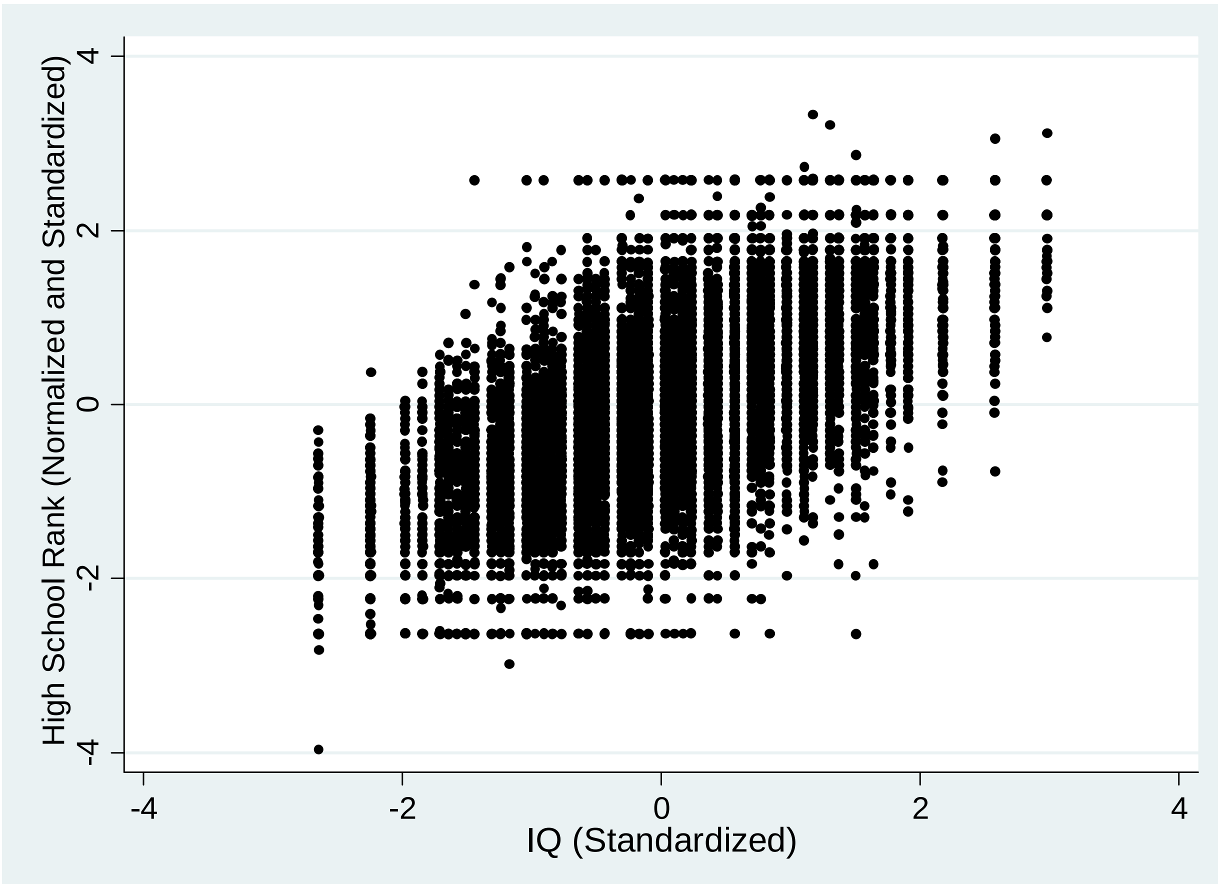


Figure 5. Ratio of Years Lived to the Maximum Possible by High School Rank among the Extreme Fifths in IQ: Weibull Model with Gender, IQ, Family Background, and High School Rank

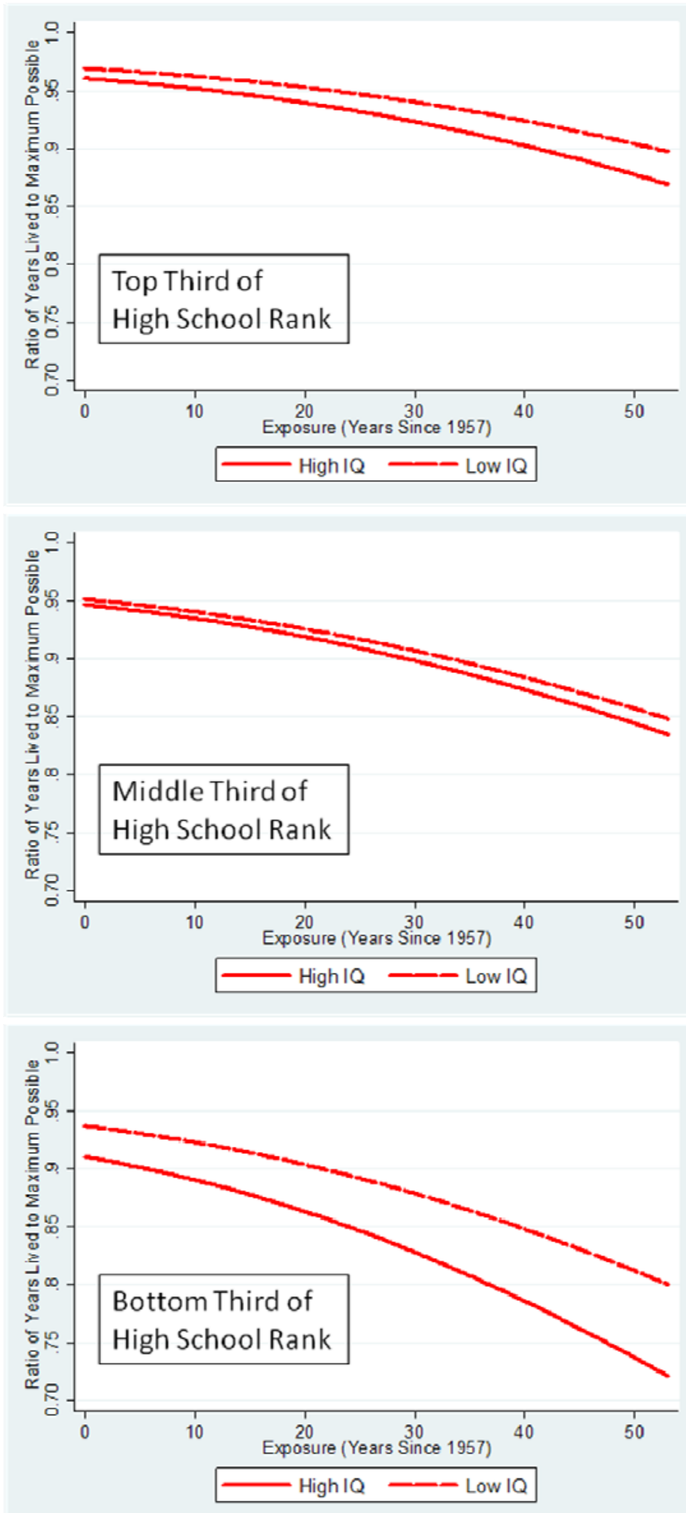


Figure 6. High School Rank as a Proxy or Surrogate Measure of IQ

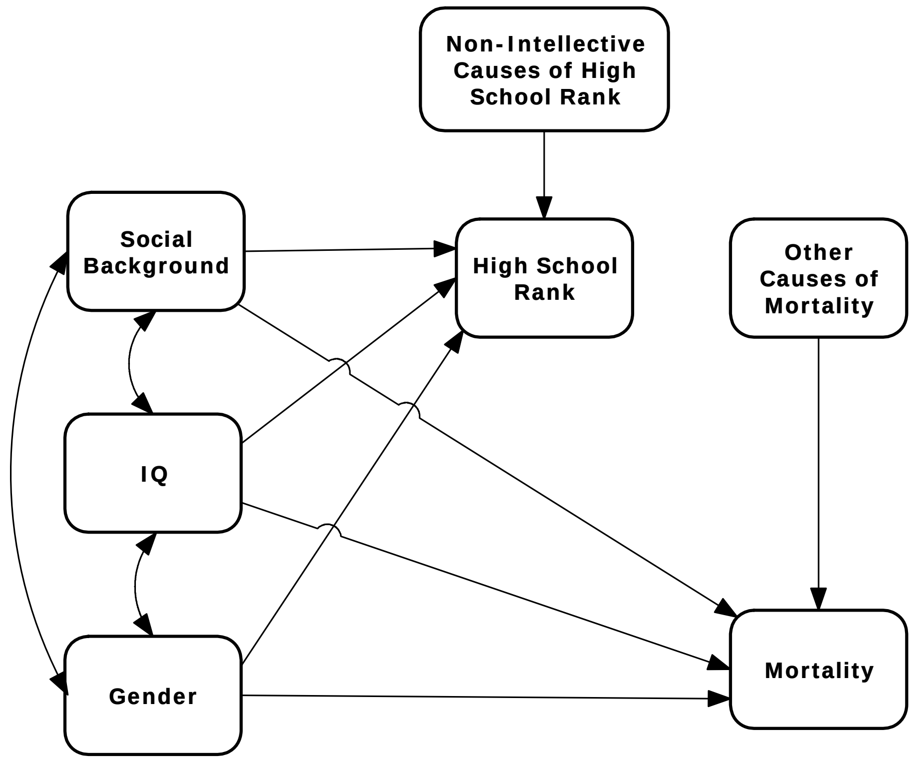
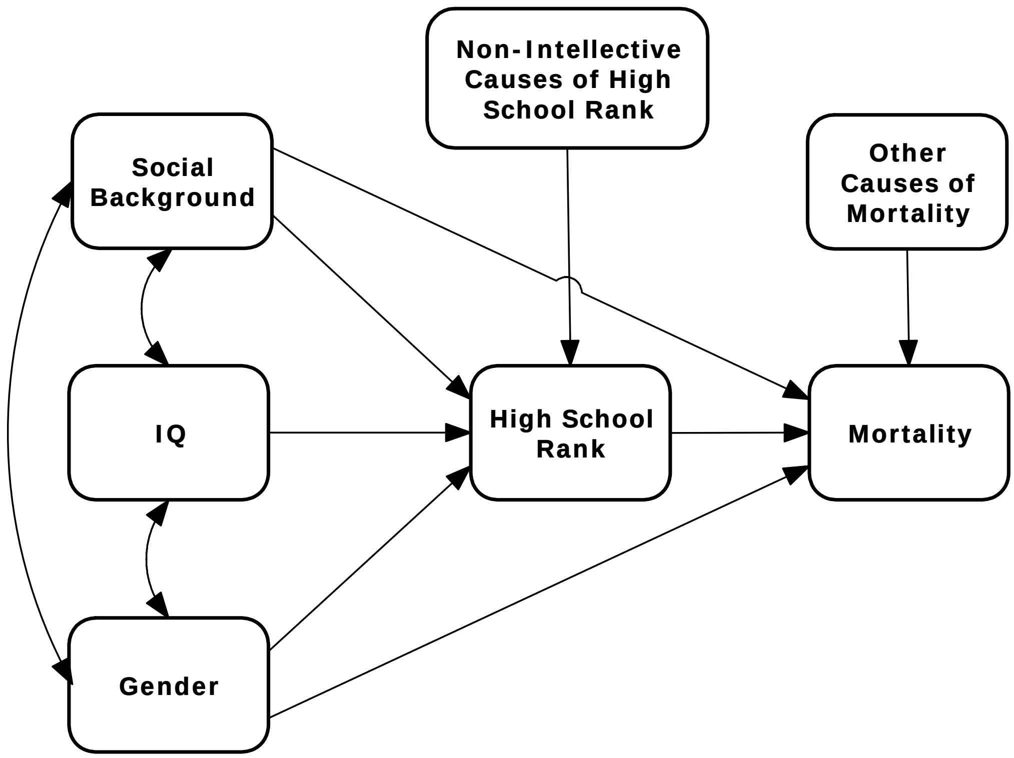


Figure 7. A Causal Model of Social Background, Gender, IQ, High School Rank, and Mortality



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