Sudden Declines in Intelligence in Old Age Predict Death and Dropout From Longitudinal Studies

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It is well known that approaching death accelerates cognitive decline. The converse issue, that is, the question of whether rapid declines in mental ability are risk factors for imminent death, has not been investigated. Every 4 years between 1983 and 2003, we gave 1,414 healthy community residents who were aged between 49 and 93 years the Heim AH4-1 test of fluid intelligence. A modified Andersen–Gill model evaluated AH4-1 scores at entry to the study and changes in scores between successive quadrennial test sessions as risk factors for death and dropout. Deaths, dropouts, age, gender, occupational categories, and recruitment cohorts were also taken into account. Participants with lower AH4-1 scores on entry were significantly more likely to die or to drop out. At all ages and levels of baseline intelligence, the risks of deaths and dropouts further increased if test scores fell by 10%, and again increased if they fell by 20% during 4-year intervals between successive assessments.

Key Words: Cognitive decline—Death—Dropout.

CONVINCING evidence that mental abilities decline as death approaches has been derived mainly from cross-sectional studies in which participants are given cognitive tests on a single occasion and the scores of those who do and do not survive are retrospectively compared at a single subsequent census date. Studies using this paradigm find that individuals who are destined to die within 1 to 8 years of assessment score lower on tests of fluid intelligence, memory, and vocabulary than those who live longer (e.g., Berg, 1987; Johannsen & Berg, 1989; Lieberman, 1965; Palmore & Cleveland, 1976; Rabbitt et al., 2002; Reimanis & Green, 1971; Riegel & Riegel, 1972; Siegler, McCarty, & Logue, 1982). The onset and progress of pathologies, which also entail increased risks of death, are also main reasons for withdrawal (dropout) from longitudinal studies of changes in cognitive function in old age (e.g., Rabbitt, Watson, Donlan, Bent, & Mclnnes, 1994).

Many pathologies bring about declines in cognitive performance, so it is unsurprising that declining health associated with impending death or dropout should be associated with cognitive decline. It may seem self-evident that abrupt declines in cognitive performance should predict impending death but, in fact, tests of this hypothesis require quite different experimental designs and analytic models. Because they have not yet been made, we do not have unambiguous evidence for this.

There is some evidence that higher intelligence test scores assessed on a single occasion are associated with better subsequent health and greater longevity (Anstey, Luszcz, Giles, & Andrews, 2001). However, as Sliwinski and colleagues (2006) point out, conclusions based on the logging of deaths after a single cognitive assessment are questionable because individuals’ levels of cognitive performance on initial assessment necessarily reflect marked differences in their abilities throughout their lifetimes as well as possible additional differences associated with recent changes in general health status or the progress of terminal pathologies. Indeed, there is evidence that lifetime ability also predicts mortality independently of terminal declines. For example, in the Scottish National Sample Study, participants who had higher intelligence test scores at age 11 were found to experience better health and reduced risk of death in old age (Hart et al., 2005; Whalley & Deary, 2001).

For all these reasons, studies in which single cognitive assessments are followed by census of times of death do not adequately test the hypothesis that sudden cognitive declines predict impending mortality and dropout. A more appropriate methodology is to repeatedly assess cognitive function at regular intervals until death occurs. In this way, irrespective of differences in participants’ cognitive status on entry to a longitudinal study and, it follows, probably also throughout their lifetimes, sudden declines in their performance between successive evaluations can be evaluated as risk factors.

Studies of associations between intelligence and mortality must also take into account demographic factors that affect both. For example, socioeconomic advantage is associated with higher scores on intelligence tests and also with a reduced risk of mortality (Nagi & Stockwell, 1973); men score higher than women on some intelligence tests but also die younger (Rabbitt, Lunn, & Wong, 2005) and decline more rapidly (Rabbitt, Lunn, & Wong, in press 2008); and greater age increases the risk of death and reduces intelligence test scores. Analyses of relationships between cognitive performance and risk of death should include at least these three factors.

Another methodological issue is the effect of self-selective recruitment cohort effects and of selective attrition. Analyses of data from the University of Manchester Longitudinal Study found that both average performance on intelligence tests and mortality varied significantly between successive waves of volunteers recruited as the study continued, between 1986 and 1993 (Rabbitt et al., 2008a in press). Therefore, we found it necessary to take these variations in cohort self-selection into consideration. Further, as any prolonged study continues, older and less healthy individuals become more likely to withdraw; in this way, survivors become an increasingly elite and
unrepresentative subset (e.g., Lachman, Lachman, & Taylor, 1982; Rabbitt et al., 1994; Schaie, Labouvie, & Barrett, 1973). Recent analyses show that if dropout is neglected, then relationships between mortality and cognitive change are severely miscalculated (Rabbitt et al., 2005). Thus, studies of relationships between cognitive status and risk of death must also take separate account both of dropouts followed by survival and of dropouts followed by death.

Yet another methodological issue is that participants in longitudinal studies who are repeatedly given the same or very similar tests then experience gains in scores. These are the result of practice, and they can mask possible cognitive declines (Beglinger, 2005; Dikmen, Heaton, Grant, & Temkin, 1999; Falleti, 2006; Ferrer, Salthouse, McArdle, Stewart, & Schwartz, 2005; Ferrer, Salthouse, Stewart, & Schwartz, 2004; Hultsch, Hertzog, Dixon, & Small, 1988; Kulik, Chen-Lin, Kulik, & Bangert, 1984; Mitrushima & Satz, 1991; Rabbitt, Diggle, Holland, & McInnes, 2004; Rabbitt, Diggle, Smith, Holland, & McInnes, 2001). Therefore, practice gains can mask cognitive declines associated with approaching mortality. Further, because younger and more able participants show greater practice gains between successive cognitive assessments than do older and less able participants, the true extent of their declines in intelligence between assessments may be selectively masked (Rabbitt, Diggle, Holland, & McInnes, 2004; Rabbitt et al., 2008b in press).

Data from the University of Manchester Longitudinal Study of cognitive changes in normal healthy old age (Rabbitt, Diggle, Holland, McInnes, Bent, et al., 2004) enabled us to conduct analyses assessing decline in cognitive performance between successive testing occasions as a risk factor for mortality, after we had taken into consideration the effects of baseline level of ability, sample selection (entry cohort differences), selective sample attrition by death and dropout, practice effects, and differences in gender and socioeconomic advantage. The specific questions that we asked were whether participants' intelligence test scores on entry to the study affect their risks of death and of dropout during the next 20 years and whether abrupt declines in intelligence test scores between successive quadrennial assessments affect risks of death, of dropout followed by survival, and of dropout followed by death.

METHODS

Participants and Procedure

We recruited 833 men aged from 49 to 93 years and 1,787 women aged from 50 to 90 years, all residents of Greater Manchester, United Kingdom, by appeals on local media. Details of waves of recruitment, occupational categories, schedules of testing, all measures used, and conduct of the entire study are given by Rabbitt, Diggle, Holland, McInnes, Bent, et al. (2004). All volunteers were healthy and sufficiently motivated to make their own way to the Department of Psychology at the University of Manchester, where, in groups of 5 to 20, they were given batteries of cognitive tests in quiet rooms supervised by two experienced testers.

Exploratory analyses had found that, in the battery used, the test score that was most sensitive both to age-related cognitive decline and impending dropout and death was the Heim (1970) AH4-1 group intelligence test, and that this test also robustly predicts scores on all other measures administered (Rabbitt & Anderson, 2006). Accordingly, we chose the AH4-1 as the most appropriate measure of cognitive status on entry to the study and of the extent of cognitive changes thereafter. A search by the Office of the Registrar General, Stockport, United Kingdom, identified all 955 deaths between the start of the study in 1983 to 1984 and its end in 2004. Exact dates and proximate causes of all these deaths were also recorded. Five individuals whose death certificates cited dementias are excluded from the analysis. Since the end of the study in 2004, all survivors have been screened, every 6 months, for risk of dementia on the Mini-Mental State Examination. Four cases were found and these are also excluded.

During the study, there were 1,712 participants who dropped out. Of these, 524 died before a complete census of deaths in July 2004 and 1,188 survived beyond this date. Because many withdrawals only became apparent when individuals did not respond to invitations for further testing, we dated all dropouts at the last of the four possible testing sessions attended. Many dropouts did not respond to letters asking reasons for withdrawal, so it was not possible for us to differentiate between individuals who dropped out for “positive” reasons, such as reengagement in employment or involvement in new interests and who were therefore presumably healthy and able, and others who dropped out because of worsening health. Therefore, the mean AH4-1 scores for this combined sample of “positive” and “negative” dropouts certainly underestimate the extent of decline experienced by those who withdrew because of worsening health and increased frailty.

In earlier research, some of us (Rabbitt, Diggle, Holland, & McInnes, 2004) had found that, in this sample of individuals, the scores on all cognitive tests, especially intelligence tests, varied significantly with levels of socioeconomic advantage (SEA) as categorized by reference to the UK Office of Population Census and Surveys Classification of Occupational Categories (1980). Categories are SEA C1, made up of professionals such as senior managers, lawyers, doctors, and academics; SEA C2, made up of other professionals such as junior managers, schoolteachers, and pharmacists; SEA C3N, made up of skilled nonmanual workers such as secretaries; SEA C3M, made up of skilled manual workers such as joiners, craftsmen, fitters, and machinists; SEA C4, made up of nonskilled nonmanual workers such as storekeepers and clerical assistants; and SEA C5, made up of nonskilled manual workers such as janitors, cleaners, and laborers. Data were not provided by 201 participants (labeled NR). Because SEA is associated with both longevity and lifetime level of intelligence, we entered these SEA data in the analysis. Age markedly affects both mortality and intelligence test scores, and so we entered it as well. We entered gender because our earlier analyses had also found that women live longer and decline less rapidly than men do, but they have lower average AH4-1 scores. Because our earlier analyses had also found significant differences in intelligence test scores, SEA, and health between waves of volunteers recruited between 1986 and 1991, we also entered recruitment cohorts.

In our earlier analyses we found that rates of changes in cognitive performance during this study substantially differed between individuals who survived the entire study and those
who experienced three other kinds of career within it: death before census in July 2004; dropout before June 2003 followed by survival beyond July 2004; and dropout before June 2003 followed by death before July 2004 (Rabbitt et al., 2005). Accordingly, the analyses compared subsets of the 1,188 participants who survived and completed the study, the 431 who died without first dropping out, the 524 who first dropped out and then died before the end of the study, the 1,188 who dropped out but did not die before 2004, and the 278 who both completed the study and survived beyond 2004. We also considered the overall effects of age-related cognitive changes by comparing scores on successive sessions (dates of testing) irrespective of later death or dropout.

**Statistical Model**

We analyzed the data by using a modified Andersen–Gill model with the subjects’ improvements from the previous test entered as a covariate (Andersen & Gill, 1982). This model uses proportional hazard assumptions as in survival analysis, with an extension that allows for multiple events of differing types. Each subject has several rows in the prepared data set, one for each type of event with a start–stop interval during which the subject is at risk for that particular event. The method also allows time-dependent covariates, such as the indicator of most recent session number, which necessarily changes when a further AH4-1 test is administered. After a pilot analysis in which improvement was used as a continuous covariate, it was shown that the model fit was improved, and we obtained a clearer picture as to how amount of improvement from the previous test influences risk of death and dropout if, at the second, third, and fourth testing sessions, amounts of improvement with respect to AH4-1 scores on the immediately previous assessments were coded into categories of –20% or less, –20% to –10%, –10% to 0%, 0% to +10%, and +10% or more (negative values indicating declines).

We are aware of the potential problems in subdividing the sample into groups with respect to the continuous variable AH4-1, but, as in the present case, treatment of a factor as a continuous variable sometimes loses the substantive research question asked and misses the special problems that are frequently posed by particular data sets. For this analysis, the main issues were whether there is an overall effect of lifetime intelligence test score on risk of death and whether a sudden decline in intelligence test score during the interval between successive AH4-1 assessments is a risk factor for imminent death. In other words, the question is whether or not there is a variable risk of mortality associated with changes in AH4-1 scores over 4-year periods. The use of AH4-1 scores as a continuous measure would still give mean estimates of effects for participants with different levels of test scores; therefore (and especially when, as in this case, the main interest is in interactions between test score and risk), these interactions would reflect differences between small numbers of cases.

We considered fitting a linear term in AH4-1 with interaction, but this was inappropriate because changes in risk appeared only when declines between successive testing sessions were marked. In other words, the relationship between gains and losses between sessions and risks of death and dropout are best represented by an inverted L-shaped function, and this is best revealed by subdivision into five groups. We also considered a linear + quadratic term in AH4-2. Again the fit to the data was not acceptable. At this stage it became apparent (a) that the data set was complicated, and (b) that it was the precise form of the relationship between changes in scores and risk of death that was of interest. What was of particular interest was whether risks were reduced in those individuals who experienced substantial improvements in scores between successive sessions relative to those whose scores remained unchanged or reduced between sessions. Exploratory analyses suggested that the form of the interaction reveals that risk of death and dropout does not vary until a critical threshold of decline in scores between sessions is exceeded. The model used here gave a good fit to the data and gave an answer to the theoretically and practically important question as to what may be the threshold amount of decline for increasing risk.

**RESULTS**

Because our topic of interest was change between successive testing sessions, our analyses could be based only on the 1,414 out of the 2,620 original volunteers who had two or more AH4-1 measurements. To test whether level of AH4-1 test scores on entry affected risks of subsequent death or dropout these were also included. There are three hazards in the model: hazard of death, \( h_D \), hazard of withdrawal, \( h_W \), and hazard of death consequent upon prior withdrawal \( h_{D|W} \). Table 1 shows results of the analysis of hazard of death, Table 2 gives results of the analysis of hazard of withdrawal, and Table 3 gives results of the analysis of the hazard of death following prior withdrawal. In this particular sample, occupational category did

<table>
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*Note: AH4-1 = Heim AH4-1 group intelligence test. The estimated parameters use a proportional hazard. Note that, as indicated in the first row of this table, this analysis has been centered on the age of 70.*
Effects of Age and Demographics on Overall Risk of Death

As we expected, risk of death significantly increases with age and is greater for men than for women. Table 1 shows that, when the other covariates are held constant, an additional year of age (which is centered at 70 years) increases the hazard of dying by a factor of 1.086, that is, by 8.6%. Risk of death also varies between recruitment cohorts, being significantly greater for the 1986, 1987, and 1988 entries than for the 1985 entries. This finding emphasizes that analyses of data from longitudinal studies with more than one wave of recruitment must allow for the possibility of significant differences in self-selection effects between them.

Effects of Age and Demographics on Overall Risk of Dropout

A new finding is that, after age and other demographic factors have been taken into consideration, the longer that participants continue in the study without dropping out, the lower their risk of death becomes. Table 1 illustrates that at the third test session the risk is 0.163 of that at the second test session, and at the fourth and final test session it is 0.055 of that at the second test session. A significant interaction with age shows that this reduced risk of death with longer continuance in the study is greater for older than for younger participants, but this age difference is only apparent at the final test session. This confirms, in a new way, that dropout selectively removes the least healthy and able participants so that the survivors become a progressively more elite and healthy subset, with proportionately longer life expectancy, and so also become progressively less representative of the initial sample recruited (see discussions by Rabbitt, 2002; Richards, Hardy, Kuh, & Wadsworth, 1971; Schaie et al., 1973; Shenkin et al., 2000). The interactions found in the present analysis make an additional methodological point that the effects of this progressive selection by attrition are most marked in the oldest age groups.

Table 2 shows that, for every additional year of age, the risk of dropout increases by 3% as compared with 8.6% for death. Although men have an overall higher risk of mortality than women do, (Table 1) gender does not affect the risk of dropout (see Table 2). For those who have dropped out before the end of the study, there is an expected increase in risk of death with increasing age and a reduced risk for women compared with men. Members of the more able entry cohorts are less likely to drop out and also subsequently to die before the July 2004 census date than are those in the less able entry cohorts.

Effects of Levels of Intelligence Test Scores on Entry to the Study, on Mortality, and on Dropout

Participants with higher AH4-1 scores on entry have significantly lower risks of death, of dropout, and of death following prior dropout throughout the study (see Tables 1–3). For every percentage increase in intelligence test score on entry to the study, the probability of death, of dropout followed by survival, and of dropout followed by death during the study all decrease by a factor of 0.98. When we compare the models for risk of dropout and for risk of death (Tables 1 and 2), it seems that volunteers with lower AH4-1 scores on entry (initial assessment) are equally likely to withdraw as to die during the study. This again emphasizes that to study the relationship between cognitive performance and other factors, such as intelligence, it is essential to take dropout into account. It also entails the further methodological point that, because members of the less able recruitment cohorts are more likely to drop out than are members of the more able recruitment cohorts, relationships between cognitive ability and survival are miscalculated if cohort effects are not also considered.
Effects of Changes in Intelligence Test Scores During the 4-Year Intervals Between Successive Testing Sessions

We analyzed the effects of changes in scores between successive testing sessions on risks of death, dropout, and dropout followed by death after we also took into consideration the variance associated with age, gender, SEA, recruitment cohort, and intelligence test scores on entry to the study.

Risk of Death

Table 1 shows that participants who show declines of 10% or more between successive testing sessions have almost twice the risk, and those with declines of 20% have more than 2.5 times the risk, of dying than all other volunteers. Risks for individuals whose AH4-1 test scores remain constant or improve between sessions are the same as those whose scores decline by 1% to 9%. In other words, there is no evidence that increases in AH4-1 scores over a 4-year period reduce the risk of subsequent mortality.

Risk of Dropout

Table 2 illustrates that declines of 10% in scores between successive testing sessions result in similar increases in risk of both dropout and death. However, volunteers whose scores fall by 20% or more between successive testing sessions are 1.8 times more likely to withdraw and 2.5 times more likely to die than are their coevals. There is no interaction between the effects on risks of death of intelligence test scores on entry and of amounts of declines in scores between successive test sessions. In other words, at all levels of scores on entry to the study, any given percentage change in scores between successive test sessions affects risk in the same way and by the same amount. The effects of amounts of changes in test scores remain the same, no matter how often participants have previously experienced the AH4-1 test and so at all levels of practice on this test (see Table 1). Thus, at all time points during the study, a drop in AH4-1 score of 10% or more during a period of 4 years is a significant marker for approach to death or for problems that lead to withdrawal. These effects are independent of age, of general level of intelligence, or amount of previous practice on the test, and, by the same token, of duration of previous service in a prolonged longitudinal study.

Risk of Death Following Prior Dropout

Table 3 shows that the risk of dying before 2004, following previous dropout, falls as entry score (also a reasonable proxy for lifetime intelligence test score) increases. The effects of level of intelligence on entry to the study do not interact with the effects of declines in scores between sessions. Individuals whose scores improve between successive testing sessions do not experience a reduced risk of death following dropout compared with those whose scores remain constant.

Discussion

Even after differences in ages and demographic risk factors for mortality have been taken into account, higher intelligence test scores on entry to the study significantly reduce risk of death, whether or not this has also been preceded by dropout. Those persons with higher intelligence scores also experience significantly less risk of dropout followed by survival beyond the census date. Because these individuals can reasonably be assumed to have enjoyed relatively higher levels of intelligence throughout their lifetimes, this provides further evidence that more intelligent individuals tend to live longer, even after differences in demographics have been taken into account.

These analyses replicate, on a different and a larger sample, and with a different and better standardized measure of intelligence, earlier findings that individuals with higher lifetime attainment on an intelligence test also tend to live longer (e.g., Hart et al., 2005; Shenkin et al., 2001; Whalley & Deary, 2001). Associations between lifetime levels of intellectual ability and survival are of obvious practical and sociopolitical interest, and they are also theoretically intriguing. Our current data do not allow us to completely explain these associations because they may be due to some, or all, of many nonexclusive factors that cannot be disentangled. For example, one plausible explanation is that higher intelligence is associated with more advantaged occupational category and so with SEAs that promote longevity. However, occupational category is an imperfect proxy measure for the multiple benefits of SEAs, some but not all of which are also associated with higher intelligence. Among these benefits are higher income, lower exposure to accident and toxicity, better diet and housing, and better access to medical care.

Nevertheless, independent of these advantages of affluence, higher intelligence may deliver additional benefits: more intelligent individuals tend to pay greater and more knowledgeable attention to healthy diet and lifestyles and to the need to seek timely medical advice and to punctiliously observe it when it is obtained (e.g., Nagi & Stockwell, 1973). Because descriptions such as occupational category or income level are necessarily proxies for a number of disparate factors, to enter them into statistical models such as those used here cannot guarantee that the “pure” residual effects of intelligence, independent of socioeconomic factors, have been identified.

Findings that more intelligent people tend to live longer may also reflect some commonality of genetic determinants of intelligence and physiological robustness. For example, it is well established that the quality of the uterine environment affects both health and cognitive function throughout the subsequent life span. Heavier babies thrive in infancy, enjoy better lifetime health and reduced mortality, and tend to have higher intelligence test scores in childhood and maturity (e.g., Shenkin et al., 2001). However, the functional etiology of such associations is complex because individuals with relatively high birth weights tend to be born to more intelligent and socially advantaged parents and, in particular, to more intelligent mothers who have avoided alcohol and tobacco and have taken better care of their diet and health during pregnancy. Better maternal education leads to higher child intelligence and decreased risk of mortality, even after socioeconomic factors have been taken into consideration (e.g., Sandiford, Cassel, Sanchez, & Coldham, 1997). The survival benefits of higher intelligence evidently reflect a very broad range of disparate factors, including levels of maternal competence, relative SEA, enablement of better lifetime attention to health education, and, consequently, also better health habits and more prompt and explicit requests for and access to medical advice. This still leaves room for the speculation about the possible role of intelligence as a marker
for other, imperfectly understood, biological and possibly genetic factors that also reduce the risk of death.

Declines in test scores of less than 10% during the 4-year intervals between successive assessments do not significantly affect risk of death. Increases in test scores between successive sessions also do not reduce risks of death. However, declines of 10% or greater are associated with increased risk of death, of dropout, and of dropout followed by death. These risks again increase significantly as amounts of decline rise to 20% or more.

The main new finding from these analyses is that declines in intelligence test scores over periods of 4 years or less are sensitive indicators of approaching frailty and death. In this sample, only five cases of dementias were recorded before 2004, and further screens of survivors between 2004 and 2007 have identified four new cases. Although all these individuals have been excluded from our analyses, it remains possible that there were other undetected cases of progression into dementias, particularly within the samples of deaths and dropouts. Inclusion of these cases would obviously have contributed to the increase in risk of death after sudden cognitive decline. Nevertheless, the incidence of detected dementias is so low as to suggest that this could not, on its own, account for the markedly increased risk of death, dropout, and death following prior dropout caused by declines in intelligence test scores of up to 10% or more.

A striking feature of these increased risks from marked cognitive decline over a 4-year interval is that they remain the constant throughout the entire age range of 43 to 92 years examined in this sample, are independent of levels of intelligence test score on entry to the study, and so are also, presumably, independent of lifetime levels of intelligence. They are also independent of duration of service in the study and so of amount of practice on the particular task on which they were measured. Although baseline level of intelligence significantly affects risk of death, at all levels of intelligence, the changes in scores over 4 years affect the risk of death in the same ways and by the same amounts. This stability of effects of declines on a particular test, independent of age, ability, and practice, makes it more interesting as a possible clinical diagnostic index of impending, and perhaps avertable, burdens of pathologies and health problems that may lead to decline and death if left untreated.

Table 1 shows that participants who experience declines of 10% or more within the 4-year intervals between successive testing sessions have almost twice the risk, and those with declines of 20% have more than 2.5 times the risk, of dying as do all other volunteers whose scores remain constant or improve over the same time periods. Risks for individuals whose AH4-1 scores stay stable or improve are the same as those for individuals whose scores decline by up to 9%. Increases in scores between testing sessions are not associated with reduced risks, as we might expect them to be if they signaled improved health resulting in better cognitive performance. This does not, of course, mean that improvements in health status may not be reflected in improvements in cognitive performance, because, in this study, intervals between successive assessments were long, and the cognitive test used might not have been sufficiently sensitive to detect any such associations. The possibility that cognitive improvement may be a marker for improved health status and so longer life is a fruitful and atypically cheerful topic for further research in cognitive gerontology.

Declines in scores between successive testing sessions result in similar patterns of increases in risk of dropout, but this association seems slightly weaker than for risks of death. Volunteers with a 20% or greater decline between successive testing sessions are 1.8 times more likely to withdraw but are 2.5 times more likely to die than are their surviving coevals. In this and other ways these analyses cast some new light on the well-known methodological problems associated with sample selection and selective attrition. Successive waves of recruits were contacted in the same way through media advertisements but nevertheless differed significantly both in levels of cognitive performance and in risks of death and dropout. The effects of test sessions show that more intelligent individuals remain longer in the study and also that, independent of this relationship, the longer that participants serve in the study, the less likely they are to withdraw or die relative to their age peers. These findings directly show that, as a longitudinal study continues, selective attrition hones a sample down to an elite subgroup of individuals who are not only unusually highly motivated but also atypically healthy and able for their ages.

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