Research Article

Reaction Time Explains IQ’s Association With Death

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ABSTRACT—Lower IQ is associated with earlier death, but the cause of the relationship is unknown. In the present study, psychometric intelligence and reaction times were both significantly related to all-cause mortality in a representative sample of 898 people aged 56 years who were followed up with respect to survival until age 70. The association between IQ and mortality remained significant after adjusting for education, occupational social class, and smoking, all of which have been hypothesized as confounding variables. The effect of IQ on mortality was not significant after adjusting for reaction time, suggesting that reduced efficiency of information processing might link lower mental ability and earlier death. This new field of cognitive epidemiology provides arguably the strongest evidence for the importance of psychological factors in physical health and human survival. Finding the mechanisms that relate psychometric intelligence to mortality might help in formulating effective interventions to reduce inequalities in health.

There are few tasks so important for psychologists as discovering and understanding the psychological factors that influence how long and how healthily people live. New among these factors is psychometric intelligence as measured using IQ-type tests. In the past several years, there were calls in the psychological literature to correct the neglect of psychometric intelligence within epidemiology (Bouchard & Loehlin, 2001; Lubinski & Humphreys, 1997). Krueger, Caspi, and Moffitt (2000) urged that such individual differences, if applied to population-based sampling frames, could be especially informative concerning the role of psychological traits in important social and health outcomes. The response has produced the novel field of cognitive epidemiology.

It has recently been discovered that people with lower IQs tend to die younger than people with higher IQs. This association is found whether psychometric intelligence is measured in childhood (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Osler et al., 2003; Whalley & Deary, 2001), early adulthood (O’Toole, 1990; O’Toole & Stankov, 1992), middle age (Pavlik et al., 2003), or old age (Korten et al., 1999). For example, Whalley and Deary (2001) traced 80% of people born in 1921 who took part in the Scottish Mental Survey of 1932 in Aberdeen city (n = 2,230 from 2,792). They used medical and public databases to find whether people were still alive at age 76 in 1997, 65 years after the IQ test. People with a standard-deviation (15-point) disadvantage in IQ score relative to others at age 11 were only 79% as likely to live to age 76. Further linkage studies of the Scottish Mental Survey 1932 found that lower childhood IQ is associated with earlier death from a variety of diseases, including cardiovascular disease (Hart, Taylor et al., 2003) and stomach and lung cancers (Deary, Whalley, & Starr, 2003).

Why is there a significant association between lower psychometric intelligence and earlier death? Whalley and Deary (2001) suggested four reasons, none of which is exclusive of the others. For example, IQ might be an archaeological record of brain and bodily insults up to the age at which it is measured. Thus, IQ tests might capture a signal of suboptimal brain development that is correlated with later illness. This possibility is supported by the fact that lower birth weight is associated with lower childhood IQ and also higher risk of cardiovascular disease and diabetes in later life (Barker, 2002; Shenkin et al., 2001).

In the present study, we tested the three further hypotheses. First, higher IQ might be associated with more optimal health behaviors, such as not smoking. For example, a follow-up study of the Scottish Mental Survey 1932 found that although people with higher IQs were just as likely as people with lower IQs to begin smoking in the 1930s and 1940s, when the dangers were not known, they were more likely to stop smoking as health risks were discovered (Taylor et al., 2003). Evidence from more
recently born cohorts is needed to determine whether smoking behavior accounts for some of the association between psychometric intelligence and mortality.

Second, higher IQ might be associated with better health because it is predictive of states, such as educational qualifications and belonging to more professional occupational social classes, that confer entry to safer environments. In addition, more education might be associated with more optimal health behaviors. It is known that people who have less education and belong to manual occupations die younger than others (Davey Smith et al., 1998), and IQ is significantly correlated with education and occupational status (Hart, Deary, et al., 2003; Neisser et al., 1996). Hart, Taylor et al. (2003) found that adjusting for adult occupation-rated social class only minimally attenuated the association between IQ and mortality. However, the possibility that this relationship is mediated via education and social class has not been adequately examined.

The third possibility we examined is that IQ might be related to mortality because mental ability tests assess some aspects of bodily integrity (Whalley & Deary, 2001). We construed this concept as efficiency of information processing. Therefore, we examined this hypothesis by using the fact that IQ is moderately correlated with reaction times, which we postulate as simpler measures of the brain’s information processing efficiency (Deary, 2000, chap. 6). Unlike psychometric intelligence tests, reaction time assessments are almost knowledge free, and they are less likely to reflect an individual’s educational and social background. In the large, representative cohort we examined, a previous study found that simple and four-choice reaction time indices were significantly related to psychometric intelligence (Deary, Der, & Ford, 2001). No study to date has examined whether psychological measures as fundamental as reaction times are predictive of mortality, or whether they can account for the IQ-death association.

In the present study, we tested the hypothesis that the relationship between IQ and mortality holds for people whose cognitive ability was measured in middle age, an age that has attracted little attention in this field. We investigated whether any significant IQ-mortality association is accounted for by smoking, education, or occupational status. We also compared the predictive power of reaction time and psychometric intelligence with respect to death, and we investigated whether information processing efficiency accounts for the IQ-death association.

PARTICIPANTS

Subjects were participants in the Twenty-07 study conducted in the west of Scotland. This is a population-based cohort study of social determinants of health inequalities. Details of the design and sampling are described elsewhere (Ford, Ecob, Hunt, Macintyre, & West, 1994). One cohort in the Twenty-07 study comprised 1,042 people who first provided data in 1983, when they were around 56 years old. Full data were available for 898 subjects in this cohort (412 men, 486 women). Their ages were as follows: 54 (n = 1), 55 (n = 164), 56 (n = 550), 57 (n = 173), and 58 (n = 10). This working sample did not differ from a comparable sample of the relevant local population drawn from the United Kingdom’s 1991 Census Samples of Anonymised Records (Deary et al., 2001). These records contain individual and household data on local areas in the United Kingdom and thus enabled us to compare the sample tested here with the population from which they were drawn.

MEASURES

Alice Heim 4 Test of General Intelligence (AH4)
Participants took Part I of the AH4, which measures verbal and numeric cognitive abilities (Heim, 1970). It was administered according to instructions in the test manual.

Reaction Time
Participants were assessed on simple and four-choice reaction time tasks. The device and procedure are described in detail and illustrated elsewhere (Deary et al., 2001). There was a variable delay—1 s to 3 s—between a subject’s response and the display of the next trial. Eight practice trials were presented before the simple and the choice reaction time tasks. There were 20 trials for simple reaction time and 40 for choice reaction time. Means and standard deviations (intra-individual variabilities) were obtained for simple and four-choice reaction times. Choice reaction time means and standard deviations are based on correct responses only.

Demographic and Lifestyle Factors
Other measures were recorded at interview. Education was recorded as years of full-time education. Occupational social class was assessed using head of the household’s social class as indexed in the United Kingdom Registrar General’s Classification of Occupations (Office of Population Censuses and Surveys, 1980). This classification allocates occupations into six ordered categories: professional, managerial and technical, skilled nonmanual, skilled manual, semiskilled manual, and unskilled. Smoking status was recorded as whether the subject was currently a smoker or not.

Assessment of Survival
The study participants were flagged at the United Kingdom’s National Health Service central registry, which records all births, marriages, and deaths. Whenever a study participant dies, the registry sends a copy of the death certificate to the study office. The analysis we report here included all deaths for which notification was received at the study office by the end of 2002.
STATISTICAL ANALYSES

Cox proportional hazards regression, as implemented in the SAS/STAT® Phreg procedure (SAS Institute, 1999), was used for all analyses. The hazard in this case is mortality risk at a given age. Cox regression models the log of the hazard as an additive function of age and the predictor variables. When antilogged, the resulting regression parameters yield hazard ratios, sometimes referred to as incidence-rate ratios. These are estimates of the proportionate change in the mortality risk for a unit change in the predictor. Alternatively, calculating \[100 \times \text{hazard ratio} \times (\text{hazard ratio} - 1)] gives the percentage change in the mortality risk per unit change in the predictor. To facilitate comparison, we standardized the AH4 scores and reaction time variables to zero mean and unit variance, and reversed the sign of AH4. So, for example, a hazard ratio of 1.5 for one of these variables would mean that a standard-deviation increase in that variable is associated with a 50% increase in mortality risk. In addition to the hazard ratios, we present the 95% confidence intervals (CIs) and \(p\) values.

Examining change in the ratios after adjustment for putative mediating or confounding variables allowed us to test hypotheses about which variables might explain the association between IQ and mortality.

RESULTS

By the end of 2002, 185 of the 898 subjects had died (99 men, 86 women). Table 1 gives three sets of results: first, the unadjusted hazard ratios for all variables; next, the effects of the cognitive variables individually adjusted for the socio-demographic control variables (sex, smoking, education, and social class); and, finally, the effects in the fully adjusted model, in which each predictor variable was adjusted for the effects of all the others.

Baseline characteristics that were significantly related to death between 1988 and 2002 were male gender \((p = .016)\), current smoking \((p < .0001)\), lower social class \((p = .027)\), lower AH4 score \((p < .0001)\), longer \((p < .0001)\) and more variable \((p < .0001)\) simple reaction times, and longer \((p < .0001)\) and more variable \((p = .023)\) choice reaction times (Table 1). Only education was not significantly associated with subsequent mortality. The size of the effects can be appreciated by considering that two standard deviations of disadvantage in either IQ or choice reaction time mean would imply an approximate doubling of mortality risk, which is comparable with the effect of smoking.

After AH4 scores and each of the reaction time measures were adjusted for sex, smoking status, social class, and years of education, all effects remained significant, and the hazard ratios were only slightly attenuated (Table 1). Thus, the relation between IQ and mortality in this sample was not substantially mediated by social class, education, or smoking. Nor was the relation between reaction times and mortality substantially mediated by these variables. Again, AH4 score and choice reaction time mean had very similar effect sizes, with AH4 having a slightly wider CI. Simple reaction time mean and standard deviation had similar effect sizes, and choice reaction time standard deviation had a weaker effect.

In the fully adjusted model, all effects were considerably attenuated, as expected. Clearly, the individual reaction time variables were not all independent predictors of mortality, but neither was AH4 independent of reaction times. This attenuation was expected, given that the reaction time measures were moderately correlated with AH4 scores. The correlations were .49 and .31 with choice and simple reaction time means, respectively, and

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unadjusted effects</th>
<th>Effects adjusted for sex, smoking, social class, and years of education</th>
<th>Fully adjusted effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazard ratio</td>
<td>95% CI</td>
<td>(p)</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>1.428</td>
<td>1.070–1.907</td>
<td>.016</td>
</tr>
<tr>
<td>Smoking (yes)</td>
<td>2.212</td>
<td>1.647–2.976</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Social class (more manual)</td>
<td>1.128</td>
<td>1.014–1.255</td>
<td>.027</td>
</tr>
<tr>
<td>Years of education (fewer)</td>
<td>1.059</td>
<td>0.971–1.156</td>
<td>.20</td>
</tr>
<tr>
<td>Alice Heim 4 score (lower)</td>
<td>1.417</td>
<td>1.215–1.654</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Choice RT mean (slower)</td>
<td>1.411</td>
<td>1.249–1.595</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Simple RT mean (slower)</td>
<td>1.329</td>
<td>1.186–1.488</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Choice RT SD (more variable)</td>
<td>1.168</td>
<td>1.021–1.335</td>
<td>.023</td>
</tr>
<tr>
<td>Simple RT SD (more variable)</td>
<td>1.205</td>
<td>1.146–1.440</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Note. All variables were coded so that higher scores were associated with less favorable outcomes. The direction of each variable associated with higher mortality is shown in parentheses after the variable name. Sex was analyzed as male (1) versus female (0). Smoking was analyzed as nonsmoker (0) versus current smoker (1). Social class was analyzed per class, with six classes included; higher numbers represent more manual occupations. Education was analyzed per year of education; the sign was reversed. Alice Heim 4 and reaction time (RT) measures were analyzed per standard deviation unit, with the sign reversed for Alice Heim 4. CI = confidence interval.
.26 with both choice and simple reaction time standard deviations (all at \( p < .0001 \); reported in Deary et al., 2001).

To determine the best independent predictors of mortality, we used backwards elimination from the fully adjusted model, while retaining adjustment for the socio-demographic controls. The model selected included choice reaction time mean (hazard ratio = 1.281, 95% CI = 1.102–1.488, \( p < .001 \)) and simple reaction time standard deviation (hazard ratio = 1.175, 95% CI = 1.026–1.345, \( p < .020 \)). The results were checked by using three methods of variable selection (backwards elimination, forward stepwise, and all possible subsets) both with all socio-demographic controls included and with only the significant controls included. In all cases, the same two reaction time variables were selected.

**DISCUSSION**

Psychometric intelligence tested at age 56 was significantly related to being alive or dead 14 years later. This association was only slightly attenuated after adjusting for putative mediators of the effect: smoking, education, and social class. A novel finding is that simple and choice reaction time variables measured at age 56 were also significantly associated with mortality in the following 14 years. Again, these effects were not much attenuated after adjusting for smoking, education, and social class. The reaction time variables were stronger predictors of death than was psychometric intelligence. Crucially, after adjustment for reaction time indices, the influence of AH4 score on mortality was no longer significant. Taken together, the lack of attenuation of the mental ability-mortality association when social and demographic factors were controlled and the strong attenuation when reaction time measures were controlled suggest that part of the association is related to the organism’s efficiency of processing information.

The effect of AH4 score on mortality in this sample was similar in size to the effect of IQ at age 11 on mortality to age 76 in another Scottish area (Whalley & Deary, 2001). However, in the latter study, it was not possible to control for potential confounders such as education, social class, smoking, or reaction time. Despite the lack of attenuation when socio-demographic factors were controlled in the present study, it should not be concluded that the IQ-mortality association is wholly based on physiological integrity. The association might in part be related to cognitive-level factors. Maintaining health, protecting oneself against chronic disease and accidents, and adhering to treatment regimens can be construed as one of life’s jobs, and success in this job might be associated with cognitive competence as measured by psychometric intelligence tests (see Gottfredson & Deary, 2004). The strong association between cognitive ability and health knowledge supports this suggestion (Beier & Ackerman, 2003).

Reaction time variables are used to study the basis of mental ability differences in terms of the efficiency of simple information processing (Deary, 2000, chap. 6; Deary et al., 2001). These variables are considered more tractable than the complex and more culturally specific behaviors involved in responses to IQ-type items. In the present study, reaction times proved slightly better predictors of mortality than IQ, and controlling for reaction time variables reduced the IQ-mortality association to a nonsignificant level. These variables might, therefore, constitute a simple, relatively sensitive indicator of the organism’s integrity, and of clinical and subclinical pathology, which could provide a route to discovering the as-yet-unknown mechanism of this intriguing relationship between IQ and longevity.

This important area of research requires an open mind regarding potential explanatory variables, mechanisms, and direction of causation. It is tempting to posit that cognitive ability in old age relates prospectively to mortality because the brain sensitively reflects deteriorations in the state of the body. In this common-cause hypothesis, the association is more correlation than causation: A deteriorating brain is a part of a body that is deteriorating generally (Christensen, Mackinnon, Korten, & Jorm, 2001). This hypothesis implies that reaction time might be able to pick up bodily deterioration earlier than the terminal decline found in psychometric tests of cognition preceding death (Wilson, Beckett, Bienias, Evans, & Bennett, 2003). However, this is not the whole story, because IQ of healthy 11-year-olds predicts survival almost 70 years later just as well as IQ of 56-year-olds predicted survival in this 14-year prospective study. Thus, there is something traitlike as well as possibly state-like about cognitive ability that offers a clue to longevity.

Middle-aged subjects provide an interesting case. Here, we found that psychometric intelligence and reaction times were significantly related to survival over the next 14 years, with an effect size comparable to that of smoking status. But what is the direction of explanation? Social class, education, and smoking did not explain the association, so perhaps the present results replicate the 11-year-old effect, reflecting traitlike aspects of even healthy brains that correlate with survival. Or did the IQ test and reaction time indices sensitively pick up preclinical decline in physiological mechanisms that subserve good health and survival? Findings in children support the first explanation, and findings in older people support the second. But perhaps such a trait-state dichotomy is false. It might be the case that, even in children, lower IQ relates to earlier death partly because it is a reflection of a body with suboptimal physiological integrity. This possibility is consistent with the finding that the association between lower IQ and earlier death is especially strong in the lowest quartile of IQ scores (Deary et al., 2003; Hart, Taylor, et al., 2003).

Two lines of further research would be useful in clarifying some of the issues we have just raised. First, it will be informative to discover whether reaction time indices are related to mortality and account for any IQ-mortality association in younger samples. If so, reaction time is probably not acting as
an indicator of subtle, age-related physiological deteriorations. Second, a twin study of cognitive ability, reaction time, and mortality would provide evidence about the environmental and genetic contributions to the covariance among these variables.

The emergence of cognitive epidemiology has provided strong, replicated associations between a psychological trait and human survival. The effects of, say, hostility and other psychosocial factors on coronary heart disease are less strong and more equivocal than the effects of psychometric intelligence on health, despite a far greater research history and effort (Smith & Ruiz, 2002). The growing evidence that lower psychometric intelligence and now slower and more variable reaction times are strong risk factors for mortality—regardless of the age at which intelligence is measured and the period between IQ measurement and follow-up—requires explaining. Epidemiological studies should be followed by studies that can elucidate mechanisms, which might lead to interventions that attenuate these health inequalities.

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