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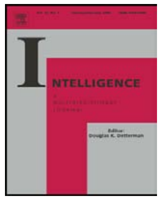

Fluid intelligence is independently associated with all-cause mortality over 17 years in an elderly community sample: An investigation of potential mechanisms

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ABSTRACT

The long-term relationship between lower intelligence and mortality risk in later life is well established, even when controlling for a range of health and sociodemographic measures. However, there is some evidence for differential effects in various domains of cognitive performance. Specifically, tests of fluid intelligence may have a stronger association with mortality than do tests of crystallized intelligence. The present study examines the relationship between intelligence and mortality in a sample of 896 Australian community-dwelling males and females, aged 70–97 at recruitment and followed for up to 17 years. There were 687 deaths during the follow-up period. Cox proportional hazard regression models examined whether the relationship between intelligence and mortality might be mediated by socioeconomic status, by health behaviors, by health status, or a combination of these. Higher fluid intelligence — as measured by the Symbol–Letter Modalities Test — was strongly associated with lower mortality rates (Hazard ratio = 0.80; 95% confidence interval = 0.72–0.88), even after accounting for any combination of potential mediators and confounders. A significant association between crystallized intelligence, as measured by the National Adult Reading Test, and mortality (HR = 0.89; 95% CI = 0.80–0.99) was attenuated by the inclusion of socioeconomic, health status measures, and health behavior measures and when deaths from the first four years of the study were excluded. The findings show little support for the hypothesized mechanisms of the intelligence–mortality relationship.

Long-term studies of intelligence and mortality demonstrate that higher intelligence is associated with lower all-cause mortality. A recent review (Batty, Deary, & Gottfredson, 2007) examined nine studies investigating the relationship between early-life intelligence and later mortality risk. The studies followed cohorts for between 17 and 69 years. All found that higher IQ was associated with lower mortality. For example, one of the reviewed studies retrospectively traced the vital status of 2230 participants in the 1932 Scottish Mental Survey after 65 years (Whalley & Deary, 2001). The hazard of mortality over the 65 year follow-up period was decreased by 21% for each 15-point increase in intelligence as measured by the Moray House test. Studies reporting follow-up into old age have also reported consistent findings (Deeg, Hofman, & van Zonneveld, 1990; Rabbitt, Lunn, & Wong, 2006; Shipley, Der, Taylor, & Deary, 2006). However, the intelligence–mortality relationship may be dependent of the type of test administered, the age of the cohort and the length of the follow-up period.

Poor performance on *executive tests* such as the Mini-Mental State Exam (Bassuk, Wypij, & Berkman, 2000; Dartigues et al., 2007) or the Short Portable Mental Status Questionnaire (Blazer, Sachs-Ericsson, & Hybels, 2005; Liang, Bennett, Sugisawa, Kobayashi, & Fukaya, 2003) tends to be associated with higher

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mortality risk, however the relationship has not always been found to be significant (Ganguli, Dodge, & Mulsant, 2002; Ostbye et al., 2006) and may be dependent on the length of the follow-up period (Ganguli et al., 2002; van Gelder, Tijhuis, Kalmijn, Giampaoli, & Kromhout, 2007). Performance on tests of *crystallized intelligence*, such as the National Adult Reading Test (Abas, Hotopf, & Prince, 2002; Anstey, Luszcz, Giles, & Andrews, 2001) or Raven's Mill Hill Vocabulary Scale (Rabbitt et al., 2002) tends to be robust to the effects of aging and is less likely to exhibit an association with mortality after health and social status are taken into account.

Tests of *fluid intelligence*, such as Digit–Symbol Substitution (Anstey et al., 2001; Ghisletta, McArdle, & Lindenberger, 2006; Pavlik et al., 2003; Portin et al., 2001) or various learning tasks (Abas et al., 2002; Ghisletta et al., 2006; Rabbitt et al., 2002; Royall, Chiodo, Mouton, & Polk, 2007) tend to decline more with age and are more strongly associated with mortality than performance on tests of general intelligence or tests of executive functioning. However, the effect size may be greater for long-term (e.g., Ghisletta et al., 2006) rather than short-term (e.g., Bosworth, Schaie, & Willis, 1999) studies and for older rather than younger cohorts (Lyyra, Heikkinen, Lyyra, & Jylha, 2006; Shipley et al., 2006). The association between *short-term memory performance* and mortality among non-demented adults is also well documented (Ghisletta et al., 2006; Portin et al., 2001; Shipley et al., 2006). In addition, two reviews have reported an association between dementia or mild cognitive disorders and mortality (Dewey & Saz, 2001; Guehne et al., 2006; Guehne, Riedel-Heller, & Angermeyer, 2005). Indeed, it has been contended that the relationship between intelligence and mortality is largely mediated by dementia (Backman & MacDonald, 2006).

Given the evidence for the relationship between intelligence and mortality, potential mechanisms driving this association warrant further examination. In early research on the relationship between cognitive decline and mortality, Riegel and Riegel (1972) described the effect in terms of "terminal drop". While the relationship between childhood intelligence and mortality cannot be explained by terminal decline alone, two theories posited by Riegel and Riegel (1972) form the basis of contemporary understanding of the intelligence–mortality relationship. Firstly, a biological theory suggested that physiological mechanisms related to cell aging were responsible for the decline and also for death. Secondly, a sociological theory suggested that performance and chance of survival drops earlier in life for those who cope less well with their environment due to disadvantages in, for example, education, income, nutrition and medical assistance.

More recently, three potential mechanisms for the relationship have been detailed by Whalley and Deary (2001) and Deary (2005) and tested by Kuh, Richards, Hardy, Butterworth, and Wadsworth (2004) and Shipley et al. (2006). First, socio-economic status (SES) may mediate the relationship between intelligence and mortality. This theory, advocated by Siegrist and Marmot (2004), is similar to the sociological theory of Riegel and Riegel (1972), suggesting that disadvantages in intelligence lead to burdens in occupation, which are linked to poorer health outcomes. Siegrist and Marmot (2004) elaborate on the relationship by taking into account the mediating effect of control on health outcomes. The demand–control model (Karasek, 1979) proposes that high work demands interact with low levels of perceived control to cause such outcomes as depression and exhaustion, which adversely effect health outcomes and consequent mortality. A second explanation is that the relationship between intelligence and mortality is mediated by health behaviors and knowledge, which include substance use, diet, physical activity, healthcare utilization, and accident and illness prevention (Deary, 2005). Gottfredson and Deary (2004) argued that a high level of cognitive resources is required to prevent disease and to ameliorate illness through behaviors such as health monitoring, screening, medication adherence, understanding health information and becoming health literate. Failure to adequately undertake these health behaviors can lead to illness or more severe illness, resulting in hospitalization and health costs, and consequently, greater risk of mortality (Gottfredson & Deary, 2004).

A third explanation is that the relationship between intelligence and mortality may be due to a common association with health status. There are two possible explanations for an association between intelligence and health (Deary, 2005): (i) intelligence may be viewed as a marker of biological "fitness" or of system integrity, or (ii) intelligence may be an indicator of developmental problems that impact on later health. The former explanation aligns with the biological theory proposed by Riegel and Riegel (1972), with evidence from studies of the common cause hypothesis linking sensory function, lung function, grip strength and other biological markers with performance on cognitive tests (Christensen et al., 2000; Christensen, Mackinnon, Korten, & Jorm, 2001; Salthouse, Hancock, Meinz, & Hambrick, 1996). The latter explanation suggests that development in early life, such as fetal events, birth weight and early nutrition, shape future patterns of health and disease, which confound the relationship between intelligence and mortality (Deary, 2005). A refinement of (i) is that intelligence is associated with mortality because it reflects basic or core information processing mechanisms reflected in measures such as RT and grip strength (Deary & Der, 2005; Shipley et al., 2006). These two studies demonstrated that SES and health factors affect the relationship but that core processes such as reaction time are critical in predicting mortality.

The three proposed explanations of the link between mortality and intelligence are testable. The first predicts that education, employment history and other measures of lifetime opportunity will be associated with both intelligence and mortality and will consequently reduce the effect of intelligence on mortality. The second predicts that health behaviors, such as substance use history and healthcare utilization measured both currently and retrospectively over the lifespan, will likewise mediate the association between intelligence and mortality. The third set of explanations is more complex but suggests that disease status and a range of health or biological markers may account for a large proportion of the variance in the relationship between intelligence and mortality. The refinement of the explanation proposed by Deary and Der (2005) is that after accounting for core biological processes (reflected in biological measures such as grip strength, sensory processing and reaction time), the relationship between intelligence and mortality should be reduced or eliminated.

Two tests that capture the construct of intelligence are used in the present study. The Symbol–Letter Modalities Test (SLMT), a task similar to Smith's (1973) Symbol–Digit