Psychology and Aging
2012, Vol. 27, No. 3, 761–767

© 2011 American Psychological Association
0882-7974/11/$12.00 DOI: 10.1037/a0026527

BRIEF REPORT

Typical Intellectual Engagement and Cognition in the Ninth Decade of Life: The Lothian Birth Cohort 1921

Sophie von Stumm and Ian J. Deary
University of Edinburgh

Investment traits—the tendency to seek out and engage in cognitive activity—might affect intellectual growth across the life span, specifically the development from fluid to crystallized intelligence. Here we explore how childhood IQ at age 11 years, IQ at age 79, and the investment trait Typical Intellectual Engagement (TIE) at age 81 affect the mean level and change in verbal fluency scores, used as an indicator of crystallized intelligence, across the ages 79, 83, and 87 in the Lothian Birth Cohort 1921 (maximum $N = 569$; Deary, Whiteman, Starr, Whalley, & Fox, 2004). A first latent growth model showed significant variance in the mean level of verbal fluency and significant decline in verbal fluency from age 79 to age 87. The rate of change was invariant across study participants in the Lothian Birth Cohort 1921. A second model found that IQ at age 11 significantly predicted IQ at age 79 ($\beta = .66$; $p <$ .001), which in turn predicted verbal fluency and TIE in the ninth decade of life with standardized path parameters of .46 and .15 ($p < .001$), respectively. TIE had a significant association with verbal fluency ($\beta = .14$, $p = .002$); together, IQ at age 11 and 79 and TIE accounted for 25.5% of the variance in verbal fluency. A final model identified the TIE subfactor of intellectual curiosity as a significant mediator of the effect of IQ on verbal fluency; the TIE subfactors abstract thinking, reading, and problem solving showed no significant associations. In summary, TIE—in particular, intellectual curiosity—significantly mediated the effects of IQ on crystallized intelligence in old age. Because there was no significant between-subjects variance in verbal fluency trajectories in the current study, neither TIE nor IQ were associated with individual differences in cognitive decline.

Keywords: intelligence, investment, typical intellectual engagement, cognitive aging, latent growth curve model

Even though intelligence and personality are traditionally treated as separate entities, life span intellectual development is likely to be affected by both intelligence and personality traits (e.g., Cattell, 1943; Ackerman, 1996; Chamorro-Premuzic & Furnham, 2006). Crystallized ability (i.e., learned knowledge and experience) has been hypothesized to develop through the application of fluid intelligence (i.e., innate processing capacity) over time (cf. Horn & Cattell, 1982). So-called investment traits that originate from the realm of personality are thought to determine where, when and how individuals apply and invest their fluid ability. That is, individual differences in crystallized intelligence are hypothesized to be accounted for by people's differences in fluid intelligence and their differences in typical investment in intellectual development. Accordingly, investment traits refer to the pursuit of and engagement with learning opportunities, such as visiting museums and galleries; solving riddles and puzzles; and reading newspapers (Ackerman, 1996). Following a situation rather than a trait approach, Schooler (1987) hypothesized that individuals living in complex environments, such as stimuli-rich, possibly contradictory settings that demand multiple difficult decisions, will show greater maintenance and improvement of their abilities than individuals in simple environments with lower cognitive demands. Indeed, several studies have shown that engagement in intellectually engaging activities serves to buffer against cognitive decline (e.g., Bielak, Anstey, Christensen, & Windsor, 2011; Hultsch, Hertzog, Small, & Dixon, 1999; Schooler, 1987); however, to date only one longitudinal study focused on the role of investment traits rather than of investment-demanding environments for life span cognitive development (Gow, Whiteman, Pattie, & Deary, 2005; see below).

Although an abundance of so-called investment trait scales exists (von Stumm, 2010), most research has focused on Typical Intellectual Engagement (TIE), "a dispositional construct that [. . .] is associated with intelligence as typical performance" (Goff & Ackerman, 1992, p. 539). TIE captures people's typical expressions of engaging with and understanding their environments, and their desire to solve and be absorbed by complex intellectual problems (Goff & Ackerman, 1992). For example, the TIE scale assesses how much pleasure individuals derive from contemplat-

This article was published Online First December 19, 2011.

Sophie von Stumm and Ian J. Deary, Department of Psychology, Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, Scotland, United Kingdom.

Correspondence concerning this article should be addressed to Sophie von Stumm, Department of Psychology, University of Edinburgh, 7 George Square, EH8 9JZ Edinburgh, Midlothian, Scotland, United Kingdom. E-mail: svonstum@staffmail.ed.ac.uk

ing abstract ideas or how much time and effort they invest in exploring an unfamiliar topic.

A recent meta-analysis reported that TIE correlated .39 and .38 with crystallized intelligence and general knowledge, respectively (von Stumm, 2010). Several cross-sectional studies found significant associations of TIE with crystallized intelligence and related outcomes after controlling for fluid or general intelligence (e.g., Chamorro-Premuzic, Furnham, & Ackerman, 2006a, 2006b; Dellenbach & Zimprich, 2008). In the only longitudinal study on TIE and cognition, Gow et al. (2005) investigated associations of childhood and late adulthood IQs (measured by the Moray House Test No. 12, which has a preponderance of verbal reasoning questions) with TIE in the Lothian Birth Cohort 1921 (LBC1921). Age 11 IQ predicted TIE at age 81 as well as IQ at age 79. However, TIE was no longer significantly associated with old age IQ after adjustment for IQ at age 11 (Gow et al., 2005). These findings appeared to refute investment theories as accurate models of intellectual development in old age. The authors concluded that the association of old-age cognition and TIE was entirely caused by the confounding variable of childhood IQ, which accounted for variance in both old-age IQ and TIE. This conclusion might have been premature for two reasons. First, the LBC1921 study in 2005 did not allow for evaluating the prospective effects of TIE on intellectual development within old age. TIE had been assessed after IQ had been measured (both in childhood and in late adulthood). Second, the Moray House Test score is not an ideal proxy for crystallized ability, but it is more representative of general or even fluid intelligence (Deary, Whalley, Lemmon, Crawford, & Starr, 2000; Deary et al., 2004; cf. Ackerman, 1996). Therefore, long-term positive effects of TIE on intellectual development may not be detectable when using more fluid-type IQ test scores as a criterion variable or when TIE has been measured after the cognitive ability "outcome" variable.

With new data from the LBC1921 sample, the present study overcomes some limitations of Gow et al.'s (2005) study. The LBC1921 cohort members have been followed up twice—at mean ages of 83 and 87—since their initial recruitment at mean age 79, and they have completed a series of cognitive ability tests, including measures of verbal fluency. Verbal ability tests are commonly understood to comprise a good indicator of crystallized intelligence (Carroll, 1993; Ekstrom, French, Harman, & Derman, 1976); therefore, verbal fluency measures, which require the recall of learned words usually beginning with the same letter or prefix, are likely to be more representative of crystallized ability than an omnibus IQ measure. Here, we fit latent growth curve models to test the effect of TIE on the level (intercept) of verbal fluency and change (slope) in verbal fluency from age 79 to age 87, after adjusting for childhood IQ at age 11 and for IQ at age 79. These adjustments allow us to make conclusions about the effect of TIE on crystallized intelligence in old age without the confounding of early life individual differences in ability. We control for the possibility that changes in TIE and verbal fluency might be driven by the same cause, for example a decline in general cognitive ability, by including IQ at age 79 in our analyses. Moreover, we investigate the effects of the total TIE score, as well as those of its subfacets, on the level and change in verbal fluency. Rather than relying on previously suggested TIE subcomponents that were based on samples of American college students (cf. Ackerman & Goff, 1994; Goff & Ackerman, 1992), we explore the scale anew in the current sample to acknowledge the cohort's uniqueness.

In summary, the present study examines first the level and change in verbal fluency from age 79 to age 87. It tests the effect of TIE at age 81 as a potential mediating variable between IQ at age 79, which is predicted by childhood IQ at age 11, and the mean level of verbal fluency—as a marker of crystallized intelligence—in the ninth decade of life. The study also tests if IQ at age 79 and TIE at age 81 are determinants of individual differences in changes of verbal fluency in the ninth decade of life.

Methods

Participants

The Lothian Birth Cohort 1921 (LBC1921) study is a follow-up of participants of the Scottish Mental Survey of 1932, in which almost all children aged between 10.5 and 11.5 years took the Moray House Test (MHT) of general intelligence (N = 87,498; Scottish Council for Research in Education, 1933). The recruitment and testing of the LBC1921 have been described in detail elsewhere (Deary et al., 2004; Deary, Whalley, & Starr, 2009; Gow et al., 2008; Gow et al., 2011). In summary, the LBC1921 were relatively healthy residents in Edinburgh and the surrounding areas when they were recruited between 1999 and 2001. They retook the MHT, which they had completed at age 11, and completed a series of cognitive and physical assessments. In this first wave of follow-up, 550 (316 women) cohort members completed a series of cognitive and medical measures around the age of 79. At the ages 80 to 81 (henceforth referred to as 81), a mail-in questionnaire package was sent to 569 individuals from the LBC1921 (including a small number who had not participated in the previous assessment wave at age 79). The package included personality questionnaires (e.g., TIE), and was completed by 450 individuals (263 women; Gow et al., 2005). The cohort members were further followed up with in-person clinic visits at ages 82 to 83 (henceforth referred to as 83) with N = 321 (176 women), and at ages 86 to 87 (henceforth referred to as 87) with N = 207 (128 women; Gow et al., 2008; Gow et al., 2011). From the first follow-up assessment wave in 1999 to the third follow-up assessment wave in 2008, the study lost a total of 343 participants who were deceased, had withdrawn, or were unable to take part in the study or who were no longer contactable. In total, data points for 569 individuals were available for this study.

Measures

Moray House Test (MHT). The MHT consists of 71 items with a maximum score of 76. The test includes a variety of types of items: following directions (14 items), same–opposites (11), word classification (10), analogies (8), practical items (6), reasoning (5), proverbs (4), arithmetic (4), spatial items (4), mixed sentences (3), cypher decoding (2), and other items (4). It was validated in 1932 in 1,000 children against the Stanford Revision of the Binet Scale with $r \sim .80$ (Scottish Council for Research in Education, 1933).

Verbal fluency (Lezak, Howieson, & Loring, 2004). This task is commonly used to assess executive function. The participant is asked to name as many words as possible beginning with the letters *C*, *F*, and *L*, and is given one minute for each letter. Proper names are not allowed and repeated words are scored only once.

Typical Intellectual Engagement (TIE; Goff & Ackerman, 1992). TIE is a 59-item self-report inventory that requires participants to respond on a six-point Likert-type scale to a variety of items assessing the extent to which they seek, engage in, and enjoy intellectual activities. For the purpose of this study, the wording of certain questions was altered (with permission from the authors); for example, "The notion of thinking abstractly is not appealing to me" was replaced with "Thinking about theories or abstract ideas is not appealing to me." Internal consistencies around .85 are commonly reported for factors of the TIE (e.g., Goff & Ackerman, 1992).

Statistical Analysis

The TIE scale was explored in the LBC1921 using principal factor analysis. Items with initial communalities below .30 were excluded (cf. Kline, 1994). The remaining 31 items were best represented by four obliquely rotated factors, which accounted for 42.2% of the total variance. The factors were identified as Abstract Thinking (e.g., "I deeply think about things"), Intellectual Curiosity (e.g., "I have no great desire to learn new things," reversed), Reading (e.g., "I read a great deal"), and Problem Solving (e.g., "I prefer my life to be filled with puzzles")[1]. This factor solution matches closely with a previous, more theoretically driven analysis of TIE in an older population (Dellenbach & Zimprich, 2008). Unit-weighted composite scores, adjusted for the number of items, were computed for each factor (see Table 1 for further details and coefficient alpha values). The first unrotated principal component extracted from all TIE 59 items was retained as a general TIE measure.

For verbal fluency at ages 79, 83, and 87, the number of words named per letter (*F*, *L*, and *C*) was added to form unit-weighted composite scores for each assessment age, respectively. To adjust for age in days at the time of testing, the raw verbal fluency score (age 79, 83, and 87), as well as the MHT scores (age 11 and 79) was entered as the dependent variable in a linear regression while age in days was the independent variable; standardized residuals were saved. Mean and variances in verbal fluency were not found to be affected by sex; therefore, data from men and women were analyzed together.

Three separate latent growth models were tested. A first baseline model estimated intercept (mean level) and slope (rate of change) in verbal fluency across age. In line with latent growth modeling conventions (Byrne, 2010), two latent traits—intercept and slope—were extracted from three observed verbal fluency variables at ages 79, 83, and 87. Path parameters of the intercept were restricted to 1; path parameters of the slope were defined as 0, 4, and 8 to represent time intervals of 4 years each between assessment points (cf. Byrne, 2010). With that, the intercept was defined where the slope had a zero loading, that is, at age 79 years. To test if there was an association between the level of verbal fluency and the rate of change, intercept and slope were allowed to covary.

The second latent growth curve model tested first the effects of IQ at age 11 on IQ at age 79, and second if IQ at age 79, mediated by TIE at age 81, accounted for individual differences in mean level and rate of change in verbal fluency across ages 79, 83, and 87. To this end, intercept and slope were specified to have correlated disturbance terms, while IQ at age 79 and TIE had direct effects on the intercept and slope factors (Byrne, 2010). IQ at age 11 affected intercept and slope indirectly through its association with IQ at age 79.

The third and final model examined if the four subfactors of TIE mediated the effects of IQ at age 79 on verbal fluency level and slope. TIE subfactors were modeled in the same fashion as the general TIE component in the previous model; the error terms of TIE subfactors were allowed to covary freely. To test for mediation, we followed Baron and Kenny's (1986) classical approach, testing (1) if IQ at age 79 was associated with TIE, (2) if IQ at age 79 was associated with verbal fluency in old age, and (3) if TIE was associated with verbal fluency in old age after controlling for IQ at age 79. The significance of the indirect effect was evaluated using Sobel's test. To ensure the accuracy of the results, all latent growth curve models were tested in (a) the full sample; (b) a subsample of the LBC1921 excluding cases with a score of 23 and below on the Mini-Mental State Examination, which indicates cognitive impairment (cf. Mungas, 1991), at the first follow-up wave; and (c) a subsample of the LBC1921 excluding cases with a score of 23 and below on the Mini-Mental State Examination at each assessment wave.

Full information maximum likelihood estimation was employed to avoid omission of cases with missing data points, whereby data were understood to be missing at random (Arbuckle, 1996). Model fit was assessed with the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Root-mean-square error of approximation (RMSEA). CFI and TLI indicate an adequate model fit at values of .90 and .95 or above (Hu & Bentler, 1999). RMSEA values of .08 and below are considered acceptable (Browne & Cudeck, 1993).

Results

Table 1 shows descriptives of measures employed in the current study, as well as their correlations. IQ at age 11 and IQ at age 79 were associated with verbal fluency at ages 79, 83, and 87, with coefficients ranging between .31 and .66. Childhood and age 79 IQ correlated with TIE at age 81 at .21 and .13, respectively. Verbal fluency scores were highly intercorrelated across ages, with coefficients ranging from .72 to .81. Conversely, TIE subfactors were not substantially related to one another, with the exception of Problem Solving and Abstract Thinking ($r = .51$). Finally, verbal fluency at ages 79, 83, and 87 correlated modestly with TIE and its subfactors with coefficients ranging from −.01 to .20 (see Table 1).

The first latent growth model fitted the data well, $\chi^2(1) = .001$, $p > .05$; CFI = 1.000; TLI = 1.012; RMSEA = .000 with a Confidence Interval of 90% (CI) from .000 to .000. The intercept's variance was significant with a value of .77 ($p < .001$), reflecting interindividual differences in the mean level of verbal fluency in old age. The slope's mean was significant ($p < .005$) with a value of −.07 per year. With reference to the typical IQ distribution ($M = 100$; $SD = 15$), it implies a decline in verbal fluency by 1.05

[1] Details on the retained TIE factors are available from Sophie von Stumm upon request.

Table 1
Descriptives of and Correlations Between Study Measures

Measure	*N*	*M*	*SD*	Min	Max	*n*	α	1	2	3	4	5	6	7	8	9
1. IQ at 11[a]	493	100	14.98	44.05	130.73	71	NA	—								
2. IQ at 79[a]	540	100	14.99	35.55	123.94	71	NA	.66								
3. VF 79[a]	544	0	1	−2.78	3.02	3	.88	.34	.41							
4. VF 83[a]	320	0	1	−2.36	2.92	3	.89	.34	.39	.76						
5. VF 87[a]	207	0	1	−2.23	2.93	3	.88	.31	.38	.72	.81					
6. TIE	456	0	1	−2.96	2.87	59	.82	.21	.13	.17	.17	.18				
7. Abstract Thinking	476	3.46	0.75	0.82	5.00	11	.81	−.08	−.12	.05	.04	−.01	.78			
8. Intellectual Curiosity	480	2.47	0.91	0.44	4.78	9	.75	.25	.22	.18	.20	.20	.47	.11		
9. Reading	479	2.92	1.24	0.00	5.00	6	.81	.25	.21	.12	.14	.17	.62	.25	.20	
10. Problem Solving	479	2.81	1.00	0.00	5.00	5	.72	.11	.08	.09	.07	.09	.69	.51	.17	.32

Note. VF = verbal fluency; TIE = first unrotated component of Typical Intellectual Engagement; Min = minimum score; Max = maximum score; *n* = Number of items; α = Cronbach's coefficient alpha.
[a] Corrected for age in days. Sample sizes for correlations vary between $N = 183$ and $N = 536$, after pairwise omission.

IQ points per year. However, the variance of the slope was nonsignificant with a value .002 ($p > .05$). That is, there were no significant individual differences in the rate of verbal fluency decline; rather change trajectories were homogenous in the LBC1921 (cf. Gow et al., 2008; Gow et al., 2011). In line with this finding, the verbal fluency intercept and slope did not significantly covary ($r = .03$; $p > .05$).

The second model tested the effect of life span IQ (age 11 and 79) on the intercept, mediated by TIE at age 81, to account for some of variance in verbal fluency (the slope had no meaningful variances to account for). IQ at age 11 was therefore modeled as a predictor of IQ at age 79, which in turn was modeled to have a direct effect on the intercept and also an indirect one via TIE, which operated as a mediating variable between IQ at age 79 and verbal fluency. The model fit was good, $\chi^2(9) = 13.32$, ($p = .149$); CFI = .995; TLI = .989; RMSEA = .029; CI from .000 to .060. IQ at age 11 significantly predicted IQ at age 79 with a standardized path weight of .66 ($p < .001$), which was significantly associated with verbal fluency across the ninth decade of life with path weight of .46 ($p < .001$), and on TIE at age 81 with a parameter of .15 ($p < .001$). TIE also had a significant effect on the verbal fluency intercept with a path parameter of .15 ($p = .002$). To be sure that the effect of TIE on verbal fluency was not due to residual variance, we also tested a model including direct path from childhood IQ at age 11 to TIE at age 81, whereby childhood IQ at age 11 affected both IQ at age 79 and TIE at age 81. However, the association of TIE with verbal fluency was not affected in this model. Together, TIE and IQ at age 11 and age 79 accounted for 25.5% of the variance in the intercept.

The final model was an extension of the previous model in that it included the four subfactors of TIE. The model fitted well, $\chi^2(18) = 22.76$; $p = .200$; CFI = .996; TLI = .990; RMSEA = .022; CI from .000 to .045. Again, IQ at age 11 had a significant effect on IQ at age 79, which in turn accounted for 22.1% of the variance in the verbal fluency intercept (see Figure 1). Furthermore, IQ at age 79 significantly predicted all TIE factors of intellectual curiosity, reading, abstract thinking, and problem solving, with standardized path parameters of .24 ($p < .001$), .24 ($p < .001$), −.13 ($p = .006$), and .09 ($p = .044$), respectively. From the TIE subfactors, only intellectual curiosity was significantly associated with the verbal fluency intercept, with a path parameter of .11 ($p = .021$). We tested an alternative model, allowing for direct effects of childhood IQ onto the TIE subfactors, which did not alter the association between intellectual curiosity and the verbal fluency intercept. A Sobel's test confirmed that intellectual curiosity significantly mediated the effects of childhood IQ ($z = 2.14$; $p = .016$). Taken together, childhood IQ, IQ at age 79, and the TIE subfactors accounted for 25.8% of the variance in the intercept. The current results did not significantly differ across LBC1921 subsamples that excluded individuals who were likely to suffer from cognitive impairment ($N = 31$).

In summary, the latent growth models showed that (a) the sample was heterogeneous in the level of verbal fluency; (b) there was a modest but significant mean level of decline in verbal fluency from age 79 to age 87 of about 1.05 IQ points per year; (c) the rate of decline was invariant across study participants; and (d) variances in verbal fluency means were partially accounted for by life span IQ and to a lesser extent by the mediating variable TIE.

Discussion

The current study examined the effects of life span IQ on an investment trait (Typical Intellectual Engagement; TIE) and on the mean level (intercept) and change (slope) of crystallized intelligence, measured by verbal fluency, in old age. A latent growth model found a significant rate of decline in verbal fluency from age 79 to age 87. With reference to a typical IQ distribution curve with a mean of 100 and a standard deviation of 15, the rate of decline translates into 1.05 IQ points per year, or a total of 8.4 IQ points across the given study period of 8 years. However, the rate of decline was invariant; that is, study members did not significantly differ in their level of decline in crystallized intelligence. These results are in line with previous reports of cognitive development and decline in the LBC1921 (Gow et al., 2008; Gow et al., 2011), although studies of other samples found evidence for individual differences in the rate of cognitive decline (e.g., Finkel, Reynolds, McArdle, Gatz, & Pedersen, 2003). Furthermore, the LBC1921 has limited power to detect differences in change trajectories (cf. Hertzog, Lindenberger, Ghisletta, & Oertzen, 2006), which may have led to Type II errors in the current analyses.

Childhood IQ at age 11 accounted for 43.6% of the variance in IQ at age 79, and together both general ability variables explained

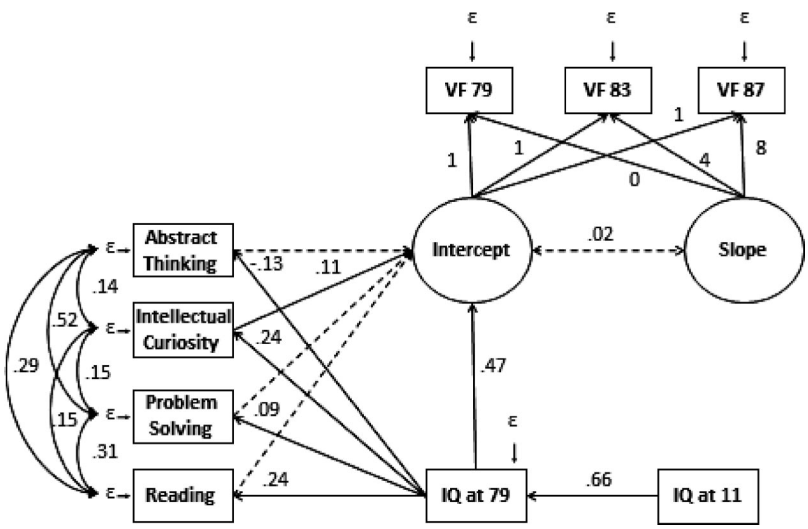

Figure 1. Latent growth curve model of verbal fluency with IQ at age 11 and TIE subfactors as time-invariant predictors of change. Dashed lines show nonsignificant paths ($p > .05$). ε denotes error terms of observed variables. Both intercept and slope had disturbance terms, which were omitted to sustain graphical clarity. VF = verbal fluency.

2.3% of the variance in TIE. IQ at age 79 was also a significant predictor of TIE's four subfacets, including positive associations with intellectual curiosity, problem solving, and reading, and a negative link with abstract thinking. TIE and most importantly, its subfactor of intellectual curiosity, were found to partially mediate the effects of childhood IQ on verbal fluency in old age. Overall, these results afford three conclusions.

First, TIE mediated the effects of IQ at age 79, which was predicted by childhood IQ at age 11, on crystallized intelligence, offering support for investment theories as a model of cognitive development (e.g., Ackerman, 1996; Horn & Cattell, 1982; Gow et al., 2005). One the one hand, individual differences in childhood and old age IQ had a direct effect on differences in crystallized intelligence. On the other hand, individual differences in intellectual investment, that is, where, when and how people apply their reasoning abilities, accounted for some additional variance in old age crystallized intelligence.

Second, our findings suggest that it is intellectual curiosity rather than other aspects of TIE that drives individual differences in crystallized intelligence, at least with regard to verbal fluency. Intellectual curiosity has been defined as the tendency to seek out, engage in, enjoy, and continuously pursue opportunities for effortful cognitive activity (von Stumm, 2010). In line with previous findings (von Stumm, Chamorro-Premuzic, & Ackerman, 2011), intellectual curiosity appears to comprise the core of so-called investment traits in the current study because of its association with the mean levels of verbal fluency in old age. That said, the observed effect size for this link was comparatively modest and should be replicated to test its robustness.

Finally, even though cognitive ability, in this case verbal fluency, declines in old age, the rate of decline is homogenous, at least in the current sample (cf. Gow et al., 2008; Gow et al., 2011; see also Finkel et al., 2003). One might conclude that individual differences in childhood intelligence or in intellectual investment, or in both, did not cause significant differences in growth (or maybe better, decline) trajectories in verbal fluency from age 79 to 87. In support of this notion, a recent study examined whether Openness to Experience, a personality trait from the Five Factor Model that is considered to resemble investment trait constructs (Goff & Ackerman, 1992), affected cognitive development across a time span of 15 years in 857 older adults (Sharp, Reynolds, Pedersen, & Gatz, 2010). Individual differences in Openness accounted for a significant amount of variance in the mean level of cognitive ability, but they were not associated with differences in the trajectories of cognitive performance across age (Sharp et al., 2010).

However, it would premature to conclude that intellectual investment was not a meaningful factor in cognitive development (cf. Bielak et al., 2011; Hultsch et al., 1999; Schaie, 1984). The present study tested the level and change in cognition over a relatively short time period of eight years at the end of the normal human life span. The short assessment period and the sample's specific time of life might have militated against finding significant between-subjects variation in verbal fluency slopes. Moreover, the intercepts derived from ages 79, 83, and 87 comprise variation in two things: people's prior levels of verbal fluency (i.e., early childhood individual differences in cognition) and any change that took place through life up to age 87. While the present study provides valuable information about level and slope—and their determinants—of cognitive ability in the ninth decade of life, it also mandates similar studies during other periods of life so that a more complete picture can be assembled.

This study has some notable strengths, including its large cohort sample that was assessed in childhood and also repeatedly in late adulthood. Here, the homogeneity of age largely eliminated the confounding effect of chronological age. Also, the ninth decade of life is rarely studied. However, this study is also not without limitations. For one, verbal fluency may be an adequate but not ideal marker of crystallized intelligence, which is thought to span the entirety of an individual's knowledge, experience, and skills

(Ackerman, 1996; Cattell, 1943). Also, the age of the members of the LBC1921 and the comparatively late assessment of TIE (i.e., at age 81) are likely to mask the effects of investment traits on life span intellectual development (cf. Gow et al., 2005). Finally, the sample suffered from considerable attrition since its first follow-up wave in 1999 and its latest assessment in 2008 (60.3%), which is largely owed to the high age of the LBC1921. As only a small fraction of the initial study population from 1921 was followed up (cf. Scottish Council for Research in Education, 1933), the generalizability of the current findings may be questioned.

Despite its limitations, the current study lends support to the investment theory as an adequate model for intellectual development from childhood to late adulthood, highlighting intellectual curiosity as core factor in investment. The results also suggest that decline in verbal fluency in old age does not differ across relatively healthy individuals in the ninth decade. It may be, however, that investment traits affect growth trajectories of cognitive performance earlier in development.

References

Ackerman, P. L., & Goff, M. (1994). Typical intellectual engagement and personality: Reply to Rocklin (1994). *Journal of Educational Psychology, 86,* 150–153. doi:10.1037/0022-0663.86.1.150

Ackerman, P. L. (1996). A theory of adult intellectual development: Process, personality, interests, and knowledge. *Intelligence, 22,* 227–257. doi:10.1016/S0160-2896(96)90016-1

Arbuckle, J. L. (1996). Full information estimation in the presence of incomplete data. In G. A. Marcoulides & R. E. Schumacker (Eds.), *Advanced structural equation modeling: Issues and techniques.* Hillsdale, NJ: Erlbaum, 243–277.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173–1182. doi:10.1037/0022-3514.51.6.1173

Bielak, A. A. M., Anstey, K. J., Christensen, H., & Windsor, T. D. (2011). Activity engagement is related to level, but not change in cognitive ability across adulthood. *Psychology and Aging.* Advance online publication. doi:10.1037/a0024667

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming.* New York, NY: Taylor and Francis Group LLC.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytical studies.* New York, NY: Cambridge University Press. doi:10.1017/CBO9780511571312

Cattell, R. B. (1943). The measurement of adult intelligence. *Psychological Bulletin, 40,* 153–193. doi:10.1037/h0059973

Chamorro-Premuzic, T., & Furnham, A. (2006). Intellectual Competence and the intelligent personality: A third way in differential psychology. *Review of General Psychology, 10,* 251–267. doi:10.1037/1089-2680.10.3.251

Chamorro-Premuzic, T., Furnham, A., & Ackerman, P. (2006a). Ability and non-ability correlates of general knowledge. *Personality and Individual Differences, 41,* 419–429. doi:10.1016/j.paid.2005.11.036

Chamorro-Premuzic, T., Furnham, A., & Ackerman, P. (2006b). Incremental validity of typical intellectual engagement as predictor of different academic performance measures. *Journal of Personality Assessment, 87,* 261–268. doi:10.1207/s15327752jpa8703_07

Deary, I. J., Whalley, L. J., Lemmon, H., Crawford, J. R., & Starr, J. M. (2000). The stability of individual differences in mental ability from childhood to old age: Follow-up of the 1932 Scottish Mental Survey. *Intelligence, 28,* 49–55. doi:10.1016/S0160-2896(99)00031-8

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.

Deary, I. J., Whiteman, M. C., Starr, J. M. S., Whalley, L. J., & Fox, H. (2004). The impact of childhood intelligence on later life: Following up the Scottish Mental Surveys of 1932 and 1947. *Journal of Personality and Social Psychology, 86,* 130–147. doi:10.1037/0022-3514.86.1.130

Dellenbach, M., & Zimprich, D. (2008). Typical intellectual engagement and cognition in old age. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 15,* 208–231. doi:10.1080/13825580701338094

Ekstrom, R. B., French, J. W., Harman, H., & Derman, D. (1976). *Kit of factor referenced cognitive tests.* Princeton, NJ: Educational Testing Service.

Finkel, D., Reynolds, C. A., McArdle, J. J., Gatz, M., & Pedersen, N. L. (2003). Latent growth curve analyses of accelerating decline in cognitive abilities in late adulthood. *Developmental Psychology, 39,* 535–550. doi:10.1037/0012-1649.39.3.535

Goff, M., & Ackerman, P. L. (1992). Personality-intelligence relations: Assessment of typical intellectual engagement. *Journal of Educational Psychology, 84,* 537–552.

Gow, A. J., Johnson, W., Pattie, A., Brett, C. E., Roberts, B., Starr, J. M., & Deary, I. J. (2011). Stability and change in intelligence from age 11 to ages 70, 79 and 87: The Lothian Birth Cohorts of 1921 and 1936. *Psychology and Aging, 26,* 232–240. doi:10.1037/a0021072

Gow, A. J., Johnson, W., Pattie, A., Whiteman, M. C., Whalley, L., Starr, J., & Deary, I. J. (2008). Mental ability in childhood and cognitive aging. *Gerontology, 54,* 177–186. doi:10.1159/000118098

Gow, A. J., Whiteman, M. C., Pattie, A., & Deary, I. J. (2005). The personality-intelligence interface: Insights from an ageing cohort. *Personality and Individual Differences, 39,* 751–761. doi:10.1016/j.paid.2005.01.028

Hertzog, C., Lindenberger, U., Ghisletta, P., & Oertzen, T. (2006). On the power of multivariate latent growth curve models to detect correlated change. *Psychological Methods, 11,* 244–252. doi:10.1037/1082-989X.11.3.244

Horn, J. L., & Cattell, R. B. (1982). Whimsy and misunderstandings of Gf-Gc theory: A comment on Gilford. *Psychological Bulletin, 91,* 623–633. doi:10.1037/0033-2909.91.3.623

Hu, L., & Bentler, P. M. (1999). Cut-off criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1–55. doi:10.1080/10705519909540118

Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. (1999). Use it or lose it? Engaged life style as a buffer of cognitive decline in aging. *Psychology and Aging, 14,* 245–263. doi:10.1037/0882-7974.14.2.245

Kline, P. (1994). *An easy guide to factor analysis.* New York, NY: Routledge.

Lezak, M., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological testing.* Oxford, England: Oxford University Press.

Mungas, D. (1991). In-office mental status testing: A practical guide. *Geriatrics, 46,* 54–58.

Schaie, K. W. (1984). Midlife influences upon intellectual functioning in old age. *International Journal of Behavioral Development, 7,* 463–478.

Schooler, C. (1987). Psychological effects of complex environments during the life span: A review and theory. In C. Schooler & K. W. Schaie (Eds.), *Cognitive functioning and social structure over the life course* (pp. 24–49). Norwood, NJ: Ablex.

Scottish Council for Research in Education (1933). *The intelligence of Scottish children: A national survey of an age-group.* London, England: University of London Press, Ltd.

Sharp, E. S., Reynolds, C. A., Pedersen, N. L., Gatz, M. (2010). Personality and cognitive aging: Is openness protective? *Psychology and Aging, 25,* 60–73. doi:10.1037/a0018748

von Stumm, S. (2010). *Intelligence, investment and intellect: Re-examining intelligence-personality associations* (Doctoral thesis, Goldsmiths University of London, London, England). Available from the Senate House Library at the University of London.

von Stumm, S., Chamorro-Premuzic, T., & Ackerman, P. L. (2011). Re-visiting intelligence-personality associations: Vindicating intellectual investment. In T. Chamorro-Premuzic, S. von Stumm, & A. Furnham (Eds.), *Handbook of individual differences* (pp. 217–241). Chichester, England: Wiley-Blackwell.

Received June 6, 2011
Revision received September 14, 2011
Accepted October 17, 2011 ■