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BRIEF REPORT

Intellect and Cognitive Performance in the Lothian Birth Cohort 1936

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Investment personality traits are thought to positively affect cognitive performance in old age, even after controlling for prior cognitive ability. In the Lothian Birth Cohort 1936 ($N = 1{,}091$), a cross-lagged model tested for reciprocal effects of the investment trait Intellect on verbal fluency, an indicator of crystallized intelligence, at age 70 and 73 years, while adjusting for general IQ at age 11 and 70 years. Intellect at age 70 was weakly associated with contemporaneous verbal fluency but had no significant effects on fluency at age 73. Conversely, verbal fluency at age 70 was significantly, positively related to Intellect at age 73. The results suggest that better verbal fluency precedes intellectual investment in old age rather than the other way around.

Keywords: investment, cognitive aging, intelligence, personality, childhood IQ

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The investment theory of cognitive development proposes that personality traits determine when, where, and how people invest their cognitive ability, thereby affecting life span cognitive development (Ackerman, 1996; Cattell, 1943). Thus, individual differences in knowledge or crystallized ability are thought to be accounted for by differences in general mental ability and by differences in typical levels of investment (cf. Ackerman, 1996; Horn & Cattell, 1982). Accordingly, investment traits refer to the tendency to seek out, engage in, enjoy, and continuously pursue opportunities for effortful cognitive activity (von Stumm, Chamorro-Premuzic, & Ackerman, 2011). Investment traits may enhance cognitive performance through two pathways: First, investment traits encourage cognitive activity engagement, which in turn "exercises" the brain (Bielak, 2010; Sharp, Reynolds, Pedersen, & Gatz, 2010; von Stumm, 2012). Second, investment traits may help in constructing even mundane everyday experiences (e.g., shopping or laundry) in a cognitively stimulating manner that contributes to mental flexibility (Stine-Morrow, 2007).

To date, it remains unclear whether positive effects of investment traits on cognitive change (i.e., differential preservation) are explained by alternative factors, in particular by prior cognitive ability (i.e., preserved differentiation; Salthouse, 2006). In other words, the association of investment traits with cognitive performance may be a spurious one that is entirely due to more intelligent people applying their intelligence more often rather than becoming smarter because of investing their intelligence. Three previous longitudinal studies on this issue, all of which reported data from participants of the Scottish Mental Surveys who were tested on IQ at the age of 11 in the first half of the 20th century (Deary, Whalley, & Starr, 2009), found inconsistent results. In the Lothian Birth Cohort 1921, Gow, Whiteman, Pattie, and Deary (2005) found that IQ at age 11 significantly predicted Intellect at age 81 as well as IQ at age 79. Intellect is an investment trait from the five-factor model of personality that refers to intellectual curiosity, including a preference for abstract thinking, ideas, and imagination (Goldberg, 1992). Gow et al. reported that IQ at age 79 and Intellect at age 81 were no longer associated after adjusting for childhood IQ. They concluded that the association between old age cognition and investment traits was entirely caused by the confounding variable of childhood IQ. Analyzing different data from the same cohort, von Stumm and Deary (2012) found that higher Typical Intellectual Engagement at age 81 significantly contributed to better verbal fluency from age 79 to age 87, even after adjusting for childhood and late adulthood IQ. Typical Intellectual Engagement is an investment trait that captures people's desire to solve and be absorbed by intellectual problems (Goff & Ackerman, 1992). Although it resembles intellect, Typical Intellectual Engagement emphasizes intellectual pursuits, such as reading books or watching educational TV, to a greater extent. In a third study, Hogan, Staff, Bunting, Deary, and Whalley (in press) reported on data from the Aberdeen Birth Cohort 1936, showing that Openness to experience was related to better cognitive performance from age 64 to age 68 after adjusting for childhood IQ. The study also included a short measure of Typical Intellectual Engagement, which had no consistent effect on cognition. Openness to experience is an alternative to Intellect as the fifth personality dimension from the five-factor model and spans six trait aspects, for example, intellectual curiosity, imagination, and aesthetic awareness (Costa & McCrae, 1992).

The discrepancies of previous findings may, on the one hand, result from using different investment trait scales. That said, In-

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tellect, Openness to experience, and Typical Intellectual Engagement assess an overlapping construct space, partially comprising identical items, and are positively intercorrelated (Ferguson, 1999; Gow et al., 2005; Mussel, 2010; see also von Stumm & Ackerman, 2013). Another explanation for the inconsistency of earlier results may lie with the type of cognitive performance measure that the studies included. Investment traits were originally hypothesized to specifically augment crystallized ability but not general mental capacity (Ackerman, 1996). Thus, the long-term positive effects of investment on cognition may not detectable when using omnibus IQ tests or measures that are more representative of fluid than crystallized intelligence (Ackerman, 1996; Cattell, 1943). Gow et al. (2005) reported on an omnibus IQ measure; Hogan et al. (in press) used reading ability, inductive reasoning, memory, and speed of processing; and von Stumm and Deary (2012) included a verbal fluency measure. Of those measures, reading ability (i.e., word recognition and correct pronunciation) and verbal fluency (i.e., ability to retrieve vocabulary through associations) are the most likely to assess crystallized intelligence (e.g., Johnson & Bouchard, 2005; McGrew, 2009).

Beyond the inconsistencies in measures, the three previous studies also assessed investment only at one time. Therefore, they could not address whether investment and verbal fluency have reciprocal effects on one another over time, or whether they are largely independent entities. If the investment theory of differential preservation is accurate, then one would expect to find long-term and concurrent positive effects of investment on crystallized ability. We report here on members of the Lothian Birth Cohort 1936, who were tested on IQ test at the age of 11 and who were followed up twice at the ages of 70 and 73 years. At both occasions, they completed Goldberg's (1992) Intellect scale and measures of verbal fluency, which plausibly reflect positive effects of investment if such effects are meaningful after adjusting for childhood IQ. Path models tested associations between Intellect and verbal fluency at age 70 and 73 years, after controlling for differences in childhood and late adulthood IQ (i.e., ages 11 and 70) to rule out the possibility that changes in investment and verbal fluency are driven by the same cause (e.g., prior cognitive ability and general cognitive decline; von Stumm & Deary, 2012). It was predicted that (a) Intellect and verbal fluency would be highly stable from age 70 to age 73, (b) Intellect at age 70 significantly would predict verbal fluency at age 73, and (c) the associations between Intellect and verbal fluency would be robust after adjusting for IQ at ages 11 and 70. Thus, verbal fluency and Intellect were expected to have reciprocal effects on each other over time.

Method

Sample

The Lothian Birth Cohort 1936 included 1,091 relatively healthy participants (548 men and 543 women), most of whom completed the Moray House Test in 1947 during the Scottish Mental Survey at a mean age of 10.9 years ($SD = 0.3$). They were first followed up at a mean age of 69.5 years ($SD = 0.8$; herein age 70) and a second time at a mean age of 72.5 years ($SD = 0.7$; $n = 866$; herein age 73). The recruitment and testing of the sample have been described elsewhere (Deary, Gow, Pattie, & Starr, 2012; Deary et al., 2007). Only variables relevant to the current analysis are reported here in detail.

Measures

Moray House Test. The test consists of 71 items with a maximum score of 76. The test includes a variety of item types (e.g., following directions, word classifications, analogies, and reasoning) and was validated in 1932 in 1,000 children against the Stanford Revision of the Binet Scale with $r = .80$ (Scottish Council for Research in Education, 1933).

Verbal fluency (Lezak, Howieson, & Loring, 2004). The participant is asked to name as many words as possible beginning with the letters C, *F*, and *L*, and is given 1 min for each letter. Proper names are not allowed and repeated words are scored only once.

International Personality Item Pool (Goldberg, 1999). The International Personality Item Pool assesses intellect with 10 items on a 5-point scale ranging from *very inaccurate* to *very accurate*. Intellect refers to intellectual curiosity and quick thinking (Goldberg, 1999). The items were in sentence fragment form (e.g., "have a rich vocabulary") and so *I* was added to make them simpler to read.

Analysis

All measures were corrected for age in days at time of testing. The factorial invariance of verbal fluency and Intellect was tested over time by fitting increasingly restrictive equality constraints on the respective factor model parameters. Verbal fluency was specified by three observed indicator variables and Intellect by 10 at ages 70 and 73, respectively. A first model established restricted the factor loadings to be equal at both times; a second model constrained the residual variances of the observed indicator variables to also be equal over time; and in a third model, equality constraints were added to the intercepts associated with age 70 and age 73 (Horn & McArdle, 1992). The constrained models were compared to unconstrained factor models of verbal fluency and Intellect respectively, suggesting that the factors were invariant over time (p values for $\chi^2_{\text{difference}} > .001$).[1] Subsequently, the observed indicators of verbal fluency and Intellect were added to form unit-weighted composite scores at age 70 and age 73, respectively. After calculating the study variables' correlations, we fitted path models (see Figure 1). First, stability coefficients of intellect and verbal fluency at ages 70 and 73 were tested, as well as their cross-lagged association. Verbal fluency and intellect had free contemporaneous intercorrelations at age 70 and age 73, respectively. Second, IQ at age 11 was modeled to predict IQ at age 70, which in turn had direct effects on intellect and verbal fluency at age 70, to test whether changes in intellect and verbal fluency are driven by the same cause. Expanding the second model, IQ at age 11 was specified to have direct effects on intellect and verbal fluency at ages 70 and 73. In a fourth and final model, IQ at age 70 also had direct paths on verbal fluency and intellect at age 73 to test whether their respective associations childhood IQ were unchanged after adjusting for IQ at age 70. Models were fitted

[1] Details on χ^2 values are available from the first author on request.

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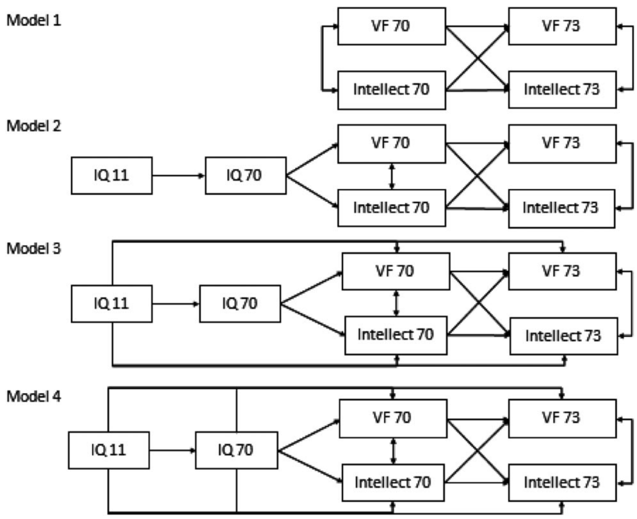

Figure 1. Models of childhood IQ, verbal fluency (VF), and Intellect from age 11 to 73 years.

using full information maximum likelihood estimation (Arbuckle, 1996) under the assumption of data missing at random to the complete sample ($N = 1,091$), as well as to a subsample omitting all cases with any missing data ($n = 715$), and to a subsample omitting all cases with missing data and a Mini Mental State Exam score of 24 or below ($n = 706$). This latter subsample excluded participants likely to be suffering from cognitive impairments. Model fit was assessed with the $\chi^2(df)$ test, 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 0.90 and 0.95 or above, respectively (Hu & Bentler, 1999). RMSEA values of .08 and below are considered acceptable (Browne & Cudeck, 1993).

Results

The study variables' correlations were positive and of moderate to large magnitude (see Table 1; also for descriptives). IQ at ages 11 and 70 had almost identical correlations with verbal fluency and Intellect at ages 70 and 73. In line with our hypothesis, verbal fluency and intellect showed significant contemporaneous and cross-lagged intercorrelations.

In the first model, $\chi^2(0) = 0.00$, CFI = 1.000, TLI = N/A, RMSEA = N/A, Intellect and verbal fluency were significantly correlated at age 70 ($r = .25$, $p < .001$) but not at age 73 ($r = .05$, $p > .05$). Both variables had high stability coefficients from age 70 to age 73 ($r = .80$ for verbal fluency and $r = .73$ for Intellect). Verbal fluency at age 70 had a significant positive effect on Intellect at age 73, but Intellect at age 70 was only marginally related to verbal fluency at age 73. The second model had a comparatively poor fit, $\chi^2(6) = 58.53$; CFI = 0.980; TLI = 0.929; RMSEA = .090, 90% CI [.070, .111], which was significantly improved in the third model when direct paths between IQ at age 11 and intellect and verbal fluency at age 73 were added, $\chi^2(2) = 5.74$; CFI = 0.999; TLI = 0.985; RMSEA = .041, 90% CI [.000, .083]. IQ at age 11 was highly predictive of IQ at age 70, accounting for 48% of its variance. In addition, IQ at age 11 had significant direct effects on Intellect (.20 and .06) and verbal fluency (.18 and .08) at ages 70 and 73 ($p < .05$). In the fourth model, $\chi^2(0) = 0.00$, CFI = 1.000, TLI = N/A, RMSEA = N/A, which allowed for direct effects of IQ at age 70 on verbal fluency and Intellect at age 73, IQ at age 11 was no longer significantly associated with the variables at age 73 ($p > .05$; see Figure 2). Instead, IQ at age 70 was significantly associated with verbal fluency at ages 70 and 73 and with Intellect at age 70 ($p < .05$) but not at age 73 ($p > .05$). IQ at age 70 partially mediated the effects of IQ at age 11 on verbal fluency and Intellect at age 70 (Sobel's test was significant at $p < .001$ for verbal fluency and $p < .01$ for Intellect), but not on verbal fluency and Intellect at age 73 (Sobel's test with $p = .09$). Verbal fluency at age 70 had a significant effect on Intellect at age 73, whereas Intellect at age 70 was not significantly associated with verbal fluency at age 73. The corresponding coefficients were both small and not significantly different. Overall, the model accounted for 66% and 58% of the variance in verbal fluency and Intellect at age 73, respectively. The model parameters changed negligibly when omitting cases with missing data points, as well as those with a Mini Mental State Exam score of 24 points or lower.

Discussion

The current study contributes to understanding the role of investment personality traits for cognitive development in old age. In line with our hypotheses, intellect and verbal fluency were highly stable between the ages of 70 and 73 years. Similarly, as we already showed in this sample elsewhere, IQ at age 11 was a strong predictor of IQ at age 70 (e.g., Gow et al., 2011). Beyond that, childhood IQ had significant direct effects on Intellect and verbal fluency at ages 70 and 73. However, after including IQ at age 70 in the model, the association of childhood IQ with verbal fluency

Table 1
Descriptives and Correlations Among Study Measures

Measure	*n*	Min.	Max.	*M*	*SD*	α	1	2	3	4	5
1. IQ age 11	1,028	1	74	49.00	11.80	—	—				
2. IQ age 70	1,079	9	76	64.23	8.80	—	.69	—			
3. Verbal fluency age 70	1,087	10	83	42.42	12.54	.88	.38	.41	—		
4. Verbal fluency age 73	865	6	90	43.18	12.94	.89	.38	.39	.81	—	
5. Intellect age 70	948	5	40	23.83	5.68	.74	.29	.26	.24	.24	—
6. Intellect age 73	852	5	40	23.74	5.93	.78	.28	.27	.28	.27	.76

Note. α = internal consistency coefficient. IQ scores were not recorded on item level; thus, no concurrent α can be computed for them. All correlations are significant at $p < .001$.

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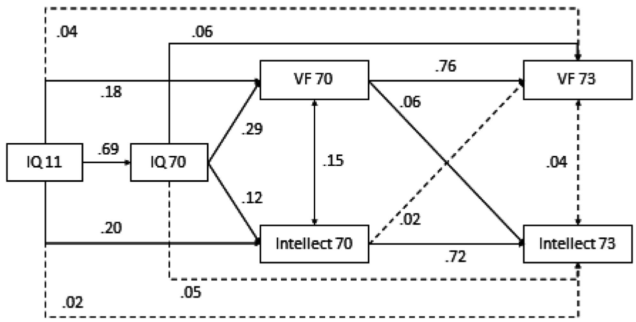

Figure 2. Fully adjusted model of investment and cognition in the Lothian Birth Cohort 1936 from age 11 to 73 years. Error terms have been omitted to sustain graphical clarity. Nonsignificant paths are dashed ($p >$ .05). VF = verbal fluency.

and Intellect at age 73 became nonsignificant, contradicting our hypotheses. That is, IQ at age 11 was associated with verbal fluency and Intellect at age 70 beyond IQ at age 70, but these effects did not persist for age 73. By comparison, IQ at age 70 was significantly related to verbal fluency and Intellect at both ages 70 and 73.

Intellect was associated with concurrent verbal fluency at the age of 70 years, but the effect did not extend to age 73. That is, Intellect was significantly associated with verbal fluency, after adjusting for general IQ in childhood and at age 70, but not in the long term. Conversely, better verbal fluency at age 70 was significantly associated with higher intellect at age 73, even though the effect size was small. This finding suggests that it is better verbal fluency that precedes investment tendencies, perhaps because people with higher verbal abilities are more capable of following intellectual pursuits (e.g., reading books, going to the theater). Thus, cognitive development in old age appears to be more in line with preserved differentiation rather than differential preservation.

On the one hand, our results are in line with the Gow et al. (2005) conclusions that the investment–cognition link in old age is largely accounted for by child- and adulthood IQ. On the other hand, our findings contradict von Stumm and Deary's (2012) report of a significant positive effect of investment on verbal fluency. They examined a later and longer period of aging from age 79 to age 87, and also used a different investment trait measure, namely Typical Intellectual Engagement, which may constitute a more precise measure of investment than intellect, at least if it is assessed in its entirety (Hogan et al., in press; von Stumm & Ackerman, 2013). That said, it is also possible that we failed to detect a significant contribution of Intellect on verbal fluency in old age because we lacked data for more sophisticated statistical models (i.e., latent growth curve with a third assessment wave).

In conclusion, intellect and verbal fluency marginally influenced each other's development in old age, but they composed weakly associated entities that are highly stable. Their contemporaneous correlation reduced after adjusting for child- and adulthood IQ. Thus, a predisposition to seek out and engage in cognitively stimulating activity was associated with better concurrent cognitive ability but had no enduring effects on cognitive performance 3 years later.

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