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Michael J. Hogan, Roger T. Staff, Brendan P. Bunting, Ian J. Deary, and Lawrence J. Whalley

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Michael J. Hogan
National University of Ireland

Roger T. Staff
Aberdeen Royal Infirmary, NHS Grampian, Aberdeen, Scotland, United Kingdom

Brendan P. Bunting
University of Ulster

Ian J. Deary
University of Edinburgh

Lawrence J. Whalley
University of Aberdeen

The current study used data from the Aberdeen Birth Cohort, 1936, to investigate the hypothesis that the positive effects of the personality trait Openness on cognitive ability are mediated by activity levels. Results of latent growth modeling analysis revealed that higher Openness predicted better reading ability, inductive reasoning, and memory performance across three testing occasions when participants were aged 64–68 years. Higher Openness predicted higher activity levels, and higher activity levels in turn predicted higher reading ability, but not higher performance on measures of inductive reasoning, memory, and speed of processing. Overall, Openness and activity engagement appear related to preserved higher cognitive ability in older adults, with Openness having a direct effect on marker tests of fluid ability and with the combined influence of Openness and activity being particularly important for marker tests of crystallized intelligence.

Keywords: aging, cognition, Openness, personality

People who are high on Openness to experience are generally receptive to entertaining new and challenging facets of cultural life as well as personal thoughts and emotions (McCrae & Costa, 2003), and studies have reported a positive relationship between Openness to experience and performance on tests of intelligence (Ackerman & Heggestad, 1997; Gignac, Stough, & Loukomitis, 2004). Specifically, in a meta-analysis of studies that examined relationships between personality and intelligence, Ackerman and Heggestad (1997) found Openness correlated positively with general intelligence ($r = .33$) and crystallized intelligence ($r = .30$). Gignac, Stough, and Loukomitis (2004) similarly reported a positive correlation between Openness and general intelligence ($r = .43$).

Michael J. Hogan, Department of Psychology, National University of Ireland, Galway, Ireland; Roger T. Staff, Aberdeen Royal Infirmary, NHS Grampian, Aberdeen, Scotland, United Kingdom; Brendan P. Bunting, School of Psychology, University of Ulster, Londonderry, Ireland; Ian J. Deary, Department of Psychology, Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, George Square, Edinburgh, Scotland, United Kingdom; Lawrence J. Whalley, Institute of Applied Health Sciences, University of Aberdeen, Aberdeen, Scotland, United Kingdom.

Correspondence concerning this article should be addressed to Michael J. Hogan, Department of Psychology, National University of Ireland, Galway, Ireland. E-mail: michael.hogan@nuigalway.ie

Less is known about mechanisms through which Openness has a positive influence on intelligence test performance and ways in which relationships between Openness and intelligence change across the life course. One possibility is that Openness has a positive effect on levels of activity engagement, which in turn may facilitate the preservation of intellectual function in old age (Ball et al., 2002; Christensen, Henderson, Griffiths, & Levings, 1997; Jopp & Hertzog, 2007; Leibovici, Ritchie, Ledesert, & Touchon, 1996; Schwartzman, Gold, Andres, Arbuckle, & Chaikelson, 1987; Stanovich, West, & Harrison, 1995; Verghese et al., 2003; Willis et al., 2006). Furthermore, in line with Ackerman's theory of cognitive aging, which assumes that fluid intelligence cumulatively invested over time transforms into crystallized intelligence (or knowledge) and that the intensity of investment is determined by a person's Typical Intellectual Engagement (TIE; Ackerman, 1994, 1996; Ackerman & Heggestad, 1997; Goff & Ackerman, 1992), a related possibility is that any effects of Openness and TIE on maintenance of cognitive abilities in older adults are greater for intellectual abilities that belong to the domain of crystallized intelligence (Ackerman, 1994).

Gow, Whiteman, Pattie, and Deary (2005) examined the relationship among intelligence (assessed in the same individuals at ages 11 and 79), Openness to experience, and TIE, measured in later adulthood. Intelligence in childhood and late adulthood was significantly related to Openness and TIE. However, when initial ability (age-11 IQ) was controlled for, the associations among age-79 IQ, Openness, and TIE were nonsignificant. Gow and colleagues (2005) concluded that Openness, TIE, and late adulthood ability are related through the confounding effect of the lifelong stable trait of intelligence.

However, the influence of Openness and activity engagement on patterns of cognitive change in late adulthood has not been reported. In the current study, we examined the relationship among Openness to experience, activity engagement, and cognitive change over time (i.e., across three waves of the Aberdeen Birth Cohort, 1936 [ABC1936]) using latent growth modeling (LGM). We controlled for the effects of childhood intelligence (age 11 years) and other dimensions of personality in this analysis. Consistent with previous research and theory, we investigated five related hypotheses: (a) that Openness would predict higher scores on tests of cognitive ability (LGM intercept) in older adults; (b) that a positive relationship between Openness and cognitive ability (intercept) in older adults would be mediated in part by activity engagement; (c) that age-related cognitive decline (LGM slope), if present, would be lower in older adults who reported higher Openness and higher activity engagement and that the positive effect of Openness on the rate of cognitive decline would be mediated in part by higher activity engagement; (d) that the positive effects of high activity engagement on cognitive ability (LGM intercept and slope) would be greater for measures of crystallized intelligence (i.e., reading ability) when compared with measures of fluid intelligence (i.e., inductive reasoning, memory, and speed of processing); and (e) that the positive effects of Openness and activity on cognitive ability (LGM intercept and slope) would be significant even after controlling for individual differences in childhood intelligence and individual differences in Neuroticism, Agreeableness, Conscientiousness, and Extraversion.

Methods

Participants

Adults from the local community who were born in 1936 were recruited between 2000 and 2001. All had participated in the Scottish Mental Survey of 1947 when approximately 95% of children born in 1936 and at school in Scotland on June 1, 1947 were tested using the Moray House Test (MHT; Scottish Council for Research in Education, 1949). Participants were assessed across three testing occasions from 2000 to 2005 when aged 64–68 years. Data for 406 participants were included in the current analysis (see Whalley et al., 2011, for a detailed description of the sample).

Psychometric Testing

Each of the cognitive tests was measured on three different occasions; personality and activity measures were obtained on the first testing occasion.

The MHT (Scottish Council for Research in Education, 1949) was used to measure childhood intelligence. It was concurrently validated ($r = .80$) against the Terman-Merrill Form L of the Binet test on a subsample of 1,000 participants of the Scottish Mental Survey of 1932. Its stability coefficient from age 11 to 77 years is .63 (Deary, Whalley, Lemmon, Crawford, & Starr, 2000).

The National Adult Reading Test. The National Adult Reading Test (NART; Nelson, 1982) was used as a measure of verbal ability and crystallized intelligence. Word pronunciation ability is coded and scores range from 0 to 50. Sample words include aeon, abstemious, and equivocal.

Raven's Standard Progressive Matrices. Raven's Standard Progressive Matrices (RPM; Raven, Court, & Raven, 1977) were used as a measure of nonverbal reasoning. Participants were allowed 20 min on the test, the items of which involve identifying the correct piece that completes an abstract pattern. The number of correctly completed items comprised the score.

The Digit Symbol subtest of the Wechsler Adult Intelligence Scale–Revised. The Digit Symbol (DS) subtest of the Wechsler Adult Intelligence Scale–Revised (Wechsler, 1981) was used as an indicator of speed of information processing (Salthouse, 1996). The test involves participants substituting symbols for numbers according to an explicit code.

The Rey Auditory Verbal Learning Test. The Rey Auditory Verbal Learning Test (AVLT; Lezak, 1995, pp. 438–446) assessed memory performance. Participants were given five trials to learn a list of 15 words. The sum of the scores from each part of the test was used as the total AVLT score.

Personality. We used the 120-item Neuroticism-Extraversion-Openness Inventory Personality Inventory (Costa & McCrea, 1992) to measure five traits: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to experience.

TIE. Following Delenbach and Zimprich (2008), we used 18 items from the TIE scale (Goff & Ackerman, 1992).

Results

Missing Data Analysis

A theory-based approach to missing data was taken using full information maximum likelihood as the method of estimation. Furthermore, analysis using listwise deletion methods ($N = 331$) did not markedly differ from the results of our measurement and structural models reported below; thus, here we report results based on full information maximum likelihood. The proportion of data present at testing times 1, 2 and 3 for (a) NART were 99, 74, and 66%; (b) RPM 98, 75, and 66; (c) DS 95, 75, and 67%; and (d) AVLT 98, 75, and 67%. Descriptive statistics are reported in Table 1. For NART, DS, and AVLT, those who provided data on two testing occasions had a significantly higher baseline than those who only provided data at testing time 1 ($p < .05$ for all three comparisons), and those who provided data on three testing occasions had a significantly higher baseline for all four cognitive outcomes when compared with those who provided data for less than three testing occasions ($p < .05$ for all four comparisons).

Measurement Models

In agreement with Delenbach and Zimprich's (2008) study, a four-factor structure of TIE (Reading, Problem-Solving, Abstraction, and Interest) was consistent with a single, second-order factor (Activity), χ^2 $(df = 97, N = 331) = 129.78$, $p = .015$, confirmatory fit index (CFI) = 0.973, root mean square error of approximation (RMSEA) = .032 (90% confidence interval [CI], .015–.046).

Table 1
Means and SDs of Cognitive, Personality, and Activity Engagement Variables

	Time 1 *Mean* (*SD*)	Time 2 *Mean* (*SD*)	Time 3 *Mean* (*SD*)
NART	33.54 (7.31)	34.87 (7.78)	33.45 (7.51)
AVLT	54.73 (12.17)	58.41 (13.42)	57.84 (13.72)
RPM	37.27 (8.12)	37.61 (8.09)	37.30 (8.23)
DS	45.38 (10.84)	45.95 (11.27)	45.57 (11.32)
Extraversion	26.97 (5.80)		
Neuroticism	17.51 (7.59		
Openness	24.25 (5.78)		
Agreeableness	33.03 (5.15)		
Conscientiousness	35.45 (5.78)		
Activity Engagement	67.87 (12.02)		

Structural Models

A series of four latent growth curve models were used to examine the extent to which Openness to experience, Neuroticism, Agreeableness, Conscientiousness, and Extraversion directly and indirectly (via activity engagement) affected measures of (a) reading performance, measured using the NART; (b) inductive reasoning, measured using RPM; (c) speed of processing, measured using the DS; and (d) memory, measured using the AVLT. Each model controlled for the effects of childhood intelligence in the analysis. For each of the four models, we first fitted an unconditioned baseline model that included no exogenous variables in the prediction of intercept and slope parameters. The results of these models informed our decision as to whether or not to include paths from the exogenous variables to the respective slope and intercept of cognitive outcome measures, specifically, depending on whether or not there was significant variance in the slope and intercept parameters. Analysis of mean change over time revealed no significant decline in cognitive ability in adulthood for any of the cognitive outcomes. Variance in the intercept was significant for all cognitive outcomes. For all cognitive outcomes except RPM's, the slope variance was notably significant.

The conditioned models provided an adequate description for the data for reading performance (NART) χ^2 (df = 8, N = 424) = 6.11, p = .635, goodness-of-fit index (GFI) = 0.973, CFI = 1.00, RMSEA = 0.000 (90% CI, 0.000–0.047); inductive reasoning (RPM) χ^2 (df = 16, N = 421) = 13.818, p = .612, GFI = 0.966, CFI = 1.00, RMSEA = 0.000 (90% CI, 0.000–0.039); speed of processing (DS) χ^2 (df = 8, N = 406) = 10.237, p = .332, GFI = 0.993, CFI = 0.999, RMSEA = 0.018 (90% CI, 0.000–0.061); and memory (AVLT) χ^2 (df = 9, N = 410) = 11.002, p = .276, GFI = 0.990, CFI = 0.998, RMSEA = 0.023 (90% CI, 0.000–0.063). The estimates and significance levels for paths in these models are presented in Table 2. We now describe how the hypotheses fare within the models.

Consistent with hypothesis 1, higher Openness predicted better overall performance on three of the four ability tests—NART, AVLT, and RPM (see Table 2a).

Consistent with hypothesis 2, the positive relationship between Openness and reading ability was mediated in part by activity engagement. However, the positive effects of Openness on AVLT and RPM were direct and not mediated by activity engagement (see Table 2, b and d).

We found no evidence to support the hypothesis that age-related cognitive decline is lower in older adults who reported higher Openness and higher activity engagement (see Table 2, c and e).

Consistent with hypothesis 4, the positive effects of high activity engagement on cognitive ability intercept were greater for measures of reading ability when compared with measures of inductive reasoning, memory, and speed of processing (see Table 2d).

Consistent with hypothesis 5, the positive effects of Openness on cognitive ability intercept were significant even after controlling for individual differences in childhood intelligence and individual differences in Neuroticism, Agreeableness, Conscientiousness, and Extraversion (see Table 2a).

In summary, although higher Openness predicted better performance on three of the four tests of cognitive ability, the relationship between Openness and reading ability was mediated in part by activity engagement; however, the positive effects of Openness on ability were significant even after controlling for childhood intelligence, Neuroticism, Agreeableness, Conscientiousness, and Extraversion.

Discussion

We investigated the relationship among Openness, activity, and cognitive performance in a sample of 406 older adults who participated in three waves of data collection as part of the ABC1936 study of cognitive aging and dementia. We found evidence in favor of four of the five hypotheses proposed. Specifically, higher Openness predicted better performance on three of the four tests of cognitive ability included in the study; the positive relationship between Openness and reading ability was mediated in part by activity engagement; the positive effects of high activity engagement on cognitive ability were greater for measures of reading ability when compared with measures of inductive reasoning, memory, and speed of processing; and the positive effects of Openness on ability were significant even after controlling for individual differences in childhood intelligence, Neuroticism, Agreeableness, Conscientiousness, and Extraversion.

The results of the current study do not concur with the results of Gow, Whiteman, Pattie, and Deary (2005), who found that when childhood ability was controlled for, the association of age-79 IQ, Openness, and TIE was nonsignificant. Conversely, the results of the current study suggest instead that reading, inductive reasoning, and verbal memory performance in late adulthood may be better

Table 2
Estimates and Effect Sizes for Models Predicting Four Cognitive Outcomes

	NART *Estimate (SE)*	RPM *Estimate (SE)*	DS *Estimate (SE)*	AVLT *Estimate (SE)*
(a) Direct effects from the exogenous measures to the intercept				
Openness	0.14* (.06)	.20** (.07)	.07 (.10)	.37** (.12)
Agreeableness	0.06 (.06)	.09 (.07)	.16 (.10)	.17 (.12)
Conscientiousness	0.00 (.053)	.05 (.06)	.25** (.09)	.11 (.11)
Extraversion	−0.20** (.06)	−.10 (.06)	.10 (.10)	.05 (.11)
Neuroticism	−0.12* (.04)	−.21** (.05)	−.07 (.08)	.07 (.09)
Childhood Intelligence	0.41** (.02)	.36** (.03)	.42** (.04)	.33** (.05)
(b) Direct effects from the exogenous measures to activity				
Openness	1.00** (.09)	1.00** (.09)	1.01** (.09)	1.00** (.09)
Agreeableness	−0.40** (0.10)	−.40** (.10)	−.37** (.10)	−.41** (.10)
Conscientiousness	0.34** (0.09)	.35** (.09)	−.37** (.10)	.36** (.09)
Extraversion	0.10 (0.10)	.09 (.10)	.11 (.10)	.10 (.10)
Neuroticism	−.04 (0.08)	−.04 (.08)	−.04 (.08)	−.04 (.08)
Childhood Intelligence	0.14** (0.05)	.17** (.04)	.16** (.04)	.18** (.04)
(c) Direct effects from the exogenous measures to the slope				
Openness	−.02 (.06)		.11 (.08)	−.04 (.11)
Agreeableness	.00 (.06)		.04 (.07)	−.01 (.09)
Conscientiousness	−.01 (.05)		−.09 (.07)	.06 (.09)
Extraversion	.11* (.06)		.05 (.07)	.07 (09)
Neuroticism	.05 (.04)		.02 (.05)	−.12 (.06)
Childhood Intelligence	−.04* (.02)		−.01 (.03)	.02 (.04)
(d) Direct effect from activity to the intercept				
Activity → intercept	0.07* (.03)	0.00 (.03)	0.03 (.05)	−.05 (.06)
(e) Direct effect from activity to the slope				
Activity → slope	.02 (.03)	.00 (.03)	−.02 (.04)	.04 (.05)

* $p < .05$. ** $p < .01$.

maintained in the context of higher Openness, irrespective of levels of childhood intelligence. One major difference between the current study and the study by Gow and colleagues (2005) was that they used the same test (the MHT) to measure childhood intelligence and intelligence at age 79 years. It may be that Openness did not emerge as a significant predictor of cognitive ability in later adulthood in their model because of the stronger shared variance between MHT performance at age 11 years and MHT performance at age 79 years.

Nevertheless, for all four cognitive outcomes in the current study the most significant predictor of a higher score on the initial testing occasion (intercept) was higher childhood intelligence. Higher childhood intelligence had a direct effect on higher cognitive performance and an indirect effect on higher cognitive performance that was mediated by higher activity levels.

In addition to the positive effects of childhood intelligence, Openness and activity on reading ability (intercept), better reading ability was predicted by higher Conscientiousness, lower Neuroticism, and lower Extraversion. The effects of Neuroticism and Extraversion were not significantly related to activity level; hence, their effect on reading scores was largely direct, but the effect of Conscientiousness on reading ability was entirely indirect via activity levels. Finally, higher childhood intelligence and lower Extraversion predicted smaller slope in the reading ability model.

Ackerman's theory of cognitive aging assumes that fluid intelligence cumulatively invested over time transforms into crystallized intelligence (or knowledge) and that the intensity of investment is determined by TIE (Ackerman, 1994, 1996; Ackerman & Heggestad, 1997). At the same time, our results suggest that this intensity of investment may be a function of higher Openness and higher Conscientiousness because Openness and Conscientiousness predicted higher activity levels. Nevertheless, the positive effects of Openness on performance over and above childhood intelligence and activity levels in the current study suggests that there may be some unique effects of Openness on cognitive ability in late adulthood. It is important to note that the positive effects of Openness on AVLT and RPM were direct and not mediated by activity engagement.

It is important to note that the construct of Openness to experience measures the tendency to fantasize, an aesthetic sensitivity, awareness of one's emotions, preference for novelty, intellectual curiosity, and preference for nontraditional values (McCrae & Costa, 2003). As such, Openness is broader in scope than TIE (Ackerman, 1996), which measures an individual's intellectual curiosity and preference to engage in cognitively demanding or challenging leisure tasks and activities, such as reading, problem-solving, and abstract thinking. The artistic imagination and aesthetic, independent, and nonconforming aspects of Openness (De Raad, Hendriks, & Hofstee, 1992; Johnson, 1994) may be critical drivers of broader patterns of cognitive activity and experience that help to sustain higher levels of cognitive complexity throughout adulthood. This is consistent with research by Parisi, Stine-Morrow, Noh, and Morrow (2009), who have reported a positive relationship between self-reported measures of alertness to novelty and intellectual complexity and performance on tests of fluid intelligence.

The current study also revealed that higher Neuroticism predicted worse overall performance on tests of reading and inductive reasoning, consistent with the idea that anxiety and negative emotion may impair performance in older adult samples (Deptula, Singh, & Pomara, 1993). More generally, this pattern of higher Openness to experience and lower Neuroticism associated with better crystallized and fluid ability in late adulthood suggests that a broader personality profile is associated with higher cognitive-emotional complexity and better overall performance on challenging cognitive tasks (Labouvie-Vief, Gruhn, & Studer, 2010).

Here we did not identify a significant decline in cognitive ability over the observed period. One possibility is that not enough time passed for a decline to be detected and/or that the influence of test familiarity obscured a decline. Another possibility is that this may have been attributable to withdrawal from the study (detailed in Whalley et al., 2011); that is, those that declined during the follow-up period do not return for testing (i.e., therefore, are not missing at random). Although full maximum likelihood was used as the method of estimation approach to account for missing data, this assumes that any missing data are related to other observed or latent variables in the model. Nevertheless, it may be the case that the pattern of missingness in the data was nonrandom and not predictable from the variables in the analysis.

The implications of our results are as follows. Overall, Openness and activity engagement appear related to preserved higher cognitive ability in older adults, with Openness having a direct effect on marker tests of fluid ability and with the combined influence of Openness and activity being particularly important for marker tests of crystallized intelligence. Given that we did not observe significant cognitive decline in our sample, further research and follow-up on the Aberdeen cohort is needed to clarify if higher Openness and higher levels of activity engagement predict slower rates of cognitive decline. Further empirical and theoretical work is also needed to better understand the mechanisms through which Openness positively influences cognitive ability. To the extent that Openness is amenable to experimental manipulation, researchers can begin to investigate specific mechanisms through which Openness influences cognitive ability. This research may also have implications for the future development of cognitive training programs for older adults. For example, the preference for novelty that is a defining feature of Openness may be akin to what Ellen Langer has described as mindfulness, or "noticing novelty, drawing novel distinctions," a process that is amenable to experimental manipulation and positively related to cognitive performance in some situations (Chanowitz & Langer, 1981). Experimental insights can be used to inform future longitudinal research that examines, for example, the neuroscientific basis of the link between Openness to experience and cognitive ability across the life span. This work will help researchers to derive a more comprehensive theory explaining the link between Openness and both fluid and crystallized intelligence.

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