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The five factor model of personality and intelligence: A twin study on the relationship between the two constructs

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ABSTRACT

We assessed the association and underlying genetic and environmental influences among intelligence (IQ) and personality in adolescent and young adult twins. Data on intelligence were obtained from psychometric IQ tests and personality was assessed with the short form of the NEO five factor inventory (NEO-FFI).

IQ and personality data were available for 646 twins. There were an additional 1307 twins with NEO-FFI data, and 535 with IQ data. Multivariate genetic structural equation modeling was carried out.

Significant positive phenotypic correlations with IQ were seen for agreeableness ($r = 0.21$) and openness to experience ($r = 0.32$). A negative correlation emerged for neuroticism and IQ ($r = -0.10$). Genetic factors explained (nearly) all of the covariance between personality traits and IQ. Genetic correlations were 0.3–0.4 between IQ and agreeableness and openness. The genetic correlation between IQ and neuroticism was around −0.18. Thus, personality and IQ did not appear to be independent dimensions, and low neuroticism, high agreeableness and high scores on openness all contributed to higher IQ scores.

1. Introduction

Intelligence and personality are enduring and stable traits across situations and over time. They show substantial contributions of genetic factors to individual differences. Personality and intelligence are considered separate constructs (Maltby, Day, & Macaskill, 2007). The few studies that attempted to link them reported modest correlations. There are interesting hypotheses about how the two domains are conceptually and empirically related (Furnham, Moutafi, & Chamorro-Premuzic, 2005; Goff & Ackerman, 1992). Intelligence has been viewed as the cognitive part of the construct of personality (Brody, 1992; Cattell, 1941; Eysenck, 1997). Wechsler (1950) considered intelligence to be a manifestation of personality as a whole and argued that certain affective and motivational factors are integral parts of the construct of intelligence.

Several dimensional models have been suggested for personality. The five factor model (FFM) distinguishes five domains of personality: neuroticism, extraversion, openness to experience, agreeableness and conscientiousness (Costa & McCrae, 1992a). These traits show heritabilities from 30% to 60%, with openness to experience and extraversion commonly being the most heritable (Bouchard & Loehlin, 2001; Distel et al., 2009; Rettew, Rebollo-Mesa, Hudziak, Willemsen, & Boomsma, 2008).

Openness to experience tends to correlate highest with intelligence (Ackerman & Heggestad, 1997; Aitken Harris, 2004; Chamorro-Premuzic, Moutafi, & Furnham, 2005; Moutafi, Furnham, & Crump, 2006) and is associated with a wide class of intellectually oriented traits, such as curiosity, creativity, and willingness to explore new ideas (Goldberg, 1993). Results for other personality traits are less clear. Some studies reported negative associations between IQ and neuroticism (Austin, Hofer, Deary, & Eber, 2000; Kyllonen, 1997). Occasionally, extraversion has been reported to correlate (positively and negatively) with intelligence (Wolf & Ackerman, 2005), and this relation has been moderated by the nature of the test and the context (Bates & Rock, 2004; Matthews, 1997; Rawlings & Carnie, 1989; Robinson, 1985). Correlations of intelligence with conscientiousness have been small and negative (Furnham et al., 2005). Moutafi et al. (2006) hypothesized that conscientiousness is a trait that less intelligent individuals can possess to compensate in a competitive environment. Conscientiousness, in contrast, has been positively associated with academic performance (Chamorro-Premuzic & Furnham, 2003; Lievens et al., 2002). Agreeable people tend to be pleasant and accommodating in social situations and this trait is rarely associated with

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intelligence. However, one study found a small positive relation with scholastic achievement in adolescent males (Peterson, Pihl, Higgins, Seguin, & Tremblay, 2003). Altruistic behavior, which is a small aspect of the construct of agreeableness, was associated with higher IQ scores in younger children (Kohlberg, 1964; Krebs & Sturrup, 1982).

A few studies have focused on the question of common genetic and environmental influences on the association between personality and IQ. Aitken Harris, Vernon, and Jang (1998) reported moderate to large phenotypic and genotypic correlations, with especially large correlations for curiosity and achievement, using full-scale IQ and the personality research form E (PRF-E; Jackson, Procidanom, & Cohen, 1989). Pincombe, Luciano, Martin, and Wright (2007) found a genetic association between extraversion and IQ. However, a significant phenotypic correlation between the extraversion domain score and IQ was absent. Luciano, Wainwright, Wright, and Martin (2006) reported genetically mediated correlations for competence and dutifulness aspects of conscientiousness with IQ.

The present study investigates the association of psychometric IQ and the NEO-FFI personality scales in adolescent and young adult twins and examines genetic and environmental correlations between IQ and personality. Additional analyses explored differences between associations of verbal and performance intelligence with personality features.

2. Materials and methods

2.1. Participants and procedures

The data were obtained from the Netherlands twin register (NTR) (Bartels et al., 2007; Boomsma, Geus, et al., 2006). Data on intelligence and personality were collected in 3 laboratory studies (see Table 1). Additional personality data were collected by mailed surveys (Distel et al., 2009). The first sample (I) came from a longitudinal twin study on the genetic architecture of cognition (Bartels, Rietveld, Baal, & Boomsma, 2002; Boomsma & Van Baal, 1998; Hoekstra, Bartels, & Boomsma, 2007). A second sample (II) participated in a study on attention and cognition (Polderman et al., 2006) and a third sample (III) participated in an EEG study (Van Beijsterveldt, Molenaar, de Geus, & Boomsma, 1996). In each of these studies full-scale intelligence tests (FS-IQ) were administered. In addition, in samples II and III, the Raven standard progressive matrices (SPM) and the Raven advanced progressive matrices (APM) were administered. If twins participated at multiple ages, FS-IQ scores obtained at age 18 were analyzed. When data at 18 years were absent FS-IQ scores at age 12 were analyzed.

There were 646 twins with FS-IQ and NEO-FFI data; an additional 535 twins with full-scale IQ data and 1307 twins with NEO-FFI data. A total of 426 twins completed the Raven SPM at age 16 and 227 twins completed the Raven APM at ages 16–23 (see Table 1).

The 2488 twins came from 1289 families. There were 1143 MZ twins and 1345 DZ twins. For 1128 twins zygosity was based on DNA polymorphisms; 39 twins with unknown zygosity were excluded from the analyses; 424 twins were part of an opposite-sex twin pair. For the remaining twins, resemblance is based on survey information. Questions were completed by the twins or by their parents. Zygosity determination using these questionnaires is 93% (Rietveld et al., 2000).

2.2. Measures

At age 12 the Wechsler intelligence test for children (Wechsler et al., 2002) and at age 18, 11 subtests (6 verbal and 5 performance) of the Wechsler adult intelligence scale (Wechsler, 1997) were administered. From all these tests full-scale IQ scores and verbal and performance IQ scores were obtained (Hoekstra, Bartels, van, & Boomsma, 2009). At ages 15–17 the Raven advanced or standard progressive matrices test was part of the protocol. Raven is a non-verbal test that uses only figurative multiple-choice questions. The Raven test is a reliable measure of overall cognitive abilities, especially performance IQ and is less prone to cultural influences (Raven, 1960, 2000).

Personality traits were measured by the short version of the NEO (NEO-FFI: Costa & McCrae, 1992b). The NEO-FFI consists of 60 items that are rated on a five point scale (1–5: totally disagree, disagree, neutral, agree and totally agree) and gives a score for the

Table 1
Number of participants in the three IQ studies and the NEO-FFI survey study.

	Age 12	Age 16	Age 18	% Female			Age at NEO		
				12	16	18	12	16	18
Study I	–	–	WAIS: 370			54%			20.7
Study II	WISC: 353	–	APM: 227	53%		62%	17.7		18.0
Study III	–	SPM: 426	WAIS: 388		54%	54%		29.0	29.0
NEO-FFI	–	–	1307			65%			19.7

Note: SPM = Raven standard progressive matrices; APM = Raven advanced progressive matrices; WISC = Wechsler intelligence scale for children; WAIS = Wechsler adult intelligence scale.

Table 2
Means, standard deviations and twin correlations (95% CI) for the FFM personality traits and for IQ scores.

	Open	Agr	Neu	Cons	Ext	IQ	PIQ	VIQ	SPM	APM
Mean	36.12	43.80	30.51	43.96	43.35	106.08	107.61	104.18	49.37	19.75
SD	5.55	4.86	7.71	5.91	5.78	15.47	17.67	15.70	6.11	6.32
MZ	0.51	0.38	0.51	0.46	0.48	0.84	0.75	0.83	0.57	0.67
	(0.44–0.57)	(0.29–0.45)	(0.44–0.57)	(0.38–0.53)	(0.41–0.54)	(0.81–0.87)	(0.69–0.79)	(0.80–0.86)	(0.44–0.68)	(0.54–0.76)
DZ	0.28	0.12	0.19	0.21	0.16	0.50	0.52	0.41	0.48	0.18
	(0.19–0.35)	(0.03–0.20)	(0.11–0.28)	(0.13–0.29)	(0.07–0.25)	(0.42–0.58)	(0.44–0.60)	(0.32–0.50)	(0.32–0.60)	(−0.05–0.38)

Note: Open = openness; Agr = agreeableness; Neu = neuroticism; Cons = conscientiousness; Ext = extraversion; IQ = full-scale IQ; SPM = Raven standard progressive matrices; APM = Raven advanced progressive matrices; PIQ = performance IQ; VIQ = verbal IQ; MZ = monozygotic; DZ = dizygotic.

Table 3
Estimates of phenotypic and cross-twin-cross trait correlations (with their 95% CI) for IQ scores with the 5 FFM personality traits.

	Phenotypic correlations					MZ/DZ cross- twin cross trait correlations				
	Open	Agr	Neu	Cons	Ext	Open	Agr	Neu	Cons	Ext
IQ	0.32* (0.25–0.40)	0.21* (0.13–0.28)	−0.10* (−0.18–0.01)	0.02 (−0.07–0.10)	0.00 (−0.01–0.08)	0.30 (0.21–0.37)/ 0.23 (0.13–0.32)	0.21 (0.12–.29)/ 0.13 (0.03–0.22)	−0.10 (−0.29–0.00)/ −0.04 (−0.14–0.06)	0.04 (−0.6–0.13)/ −0.02 (−0.13–0.08)	0.00 (0.10–0.08)/ 0.00 (−0.10–0.10)
PIQ	0.24* (0.15–0.31)	0.18* (0.10–0.25)	−0.05 (−0.13–0.04)	0.01 (−0.08–0.09)	−0.03 (−0.11–0.05)	0.20 (0.11–0.29)/ 0.20 (0.10–0.30)	0.18 (0.08–0.26)/ 0.11 (0.01–0.20)	−0.05 (−0.14–0.05)/ 0.00 (−0.10–0.10)	0.03 (−0.07–0.13)/ −0.03 (−0.13–0.07)	−0.05 (−0.14–0.04)/ −0.04 (−0.14–0.06)
VIQ	0.33* (0.26–0.40)	0.19* (11–0.26)	−0.12* (−0.20–0.04)	0.02 (−0.06–0.11)	0.03 (−0.05–0.11)	0.30 (0.22–0.38)/ 0.19 (0.10–0.29)	0.17 (0.08–0.25)/ 0.11 (−0.1–0.20)	−0.12 (−0.21–0.03)/ −0.06 (−0.16–0.04)	0.03 (−0.07–0.12)/ −0.01 (−0.12–0.09)	0.03 (−0.06–0.12)/ 0.04 (−0.06–0.13)
SPM	0.27* (0.13–0.38)	0.21* (0.07–0.34)	−0.03 (−0.19–0.13)	−0.10 (−0.27–0.07)	−0.02 (−0.17–0.14)	0.28 (0.13–0.43)/ 0.15 (−0.02–0.31)	0.05 (−0.13–0.22)/ 0.12 (−0.05–0.28)	0.02 (−0.17–0.21)/ 0.04 (−0.14–0.22)	0.00 (−0.21–0.20)/ −0.10 (−0.28–0.10)	−0.02 (−0.21–0.17)/ −0.04(−0.24–0.15)
APM	0.30* (0.18–0.40)	0.16* (0.04–0.28)	−0.03 (−0.16–0.09)	−0.02 (−0.13–0.10)	−0.03 (−0.15–0.09)	0.23 (0.10–0.35)/ 0.13 (−0.04–0.28)	0.13 (0.00–0.27)/ 0.09 (−0.08–0.25)	−0.04 (−0.18–0.11)/ 0.05 (−0.11–0.21)	−0.12 (−0.25–0.02)/ 0.04 (−0.12–0.19)	0.07 (−0.06–0.21)/ 0.01 (−0.14–0.17)

Open = openness; Agr = agreeableness; Neu = neuroticism; Cons = conscientiousness; Ext = extraversion; IQ = full-scale IQ; SPM = Raven standard progressive matrices; APM = Raven advanced progressive matrices; PIQ = performance IQ; VIQ = verbal IQ.
* Significant correlation.

traits neuroticism, agreeableness, conscientiousness, extraversion and openness to experience. For each trait 12 items are summed to obtain a total score.

2.3. Genetic modeling

Monozygotic (MZ) twins share (nearly) 100% of their genes, while dizygotic (DZ) twins share on average 50% of their segregating genes. This allows statistical modeling of twin data to attribute phenotypic variance to genetic and environmental components: $V_{(P)} = V_{(A)} + V_{(D)} + V_{(C)} + V_{(E)}$. Additive genetic variance ($V_{(A)}$) is the variance that results from the additive effects of alleles at each contributing genetic locus. Dominant or non-additive genetic variance ($V_{(D)}$) is the variance that results from the non-additive/interactive effects of alleles at contributing genetic loci. Shared environmental variance ($V_{(C)}$) is the variance resulting from environmental events that act to make twins similar. Unique environmental variance ($V_{(E)}$) is the variance that results from environmental effects that make twins different and also includes measurement error. The higher the agreement between MZ twins in their phenotypes compared to DZ twins, the more variance in a trait can be attributed to genetic components. In the classical twin design, $V_{(D)}$ and $V_{(C)}$ cannot both be estimated and estimation of $V_{(D)}$ and $V_{(C)}$ requires large sample sizes (Posthuma & Boomsma, 2000). Since there is limited evidence for $V_{(D)}$ for IQ and thus for the covariance between IQ and any other phenotype and also little evidence for $V_{(C)}$ for personality and thus for the covariance between personality with any other phenotype, model fitting focused on estimating $V_{(A)}$ and $V_{(E)}$.

2.4. Statistical analysis

Genetic analyses were carried out in Mx (Neale, Boker, Xie, & Maes, 2006). Means, standard deviations and univariate twin correlations were estimated in saturated models. Phenotypic (within person) correlations between IQ and personality traits and cross-twin-cross-trait correlations were estimated in a multivariate saturated model. To determine to what extent IQ scores and personality traits shared genetic influences, bivariate genetic models were fitted to the data for the personality traits that showed significant phenotypic correlations with intelligence. All analyses were performed for Full IQ, verbal and performance IQ. RAVEN-IQ was included since it is assumed that it measures fluid intelligence and to investigate whether the associations with personality were specific for fluid intelligence. FS-IQ (WISC and WAIS) assesses both fluid and crystallized intelligence. Based on the twin correlations and the cross-twin cross-trait correlations, genetic model fitting started with a full ACE model. Significance of shared environmental influences on the covariance was tested by fixing this estimate to zero.

3. Results

The upper part of Table 2 provides the means and standard deviations for the personality traits and the IQ measures. The lower part of Table 2 shows the twin correlations for each trait. All MZ correlations were larger than the corresponding correlations for DZ twins. The left part of Table 3 shows the estimates of phenotypic (within person) correlations for personality and IQ scores. The correlations between IQ scores and the FFM personality traits were lowest for extraversion and conscientiousness and highest for openness to experience, followed by a modest positive correlation with agreeableness and a negative correlation with neuroticism.

Phenotypic correlations with IQ scores were close to zero for extraversion and conscientiousness. Genetic bivariate models were

Table 4
Percentage of the covariance between Personality and IQ accounted for by genetic and environmental factors.

	Openness $h^2 = 0.52$ (0.46–0.57)	Agreeableness $h^2 = 0.36$ (0.28–0.43)	Neuroticism $h^2 = 0.50$ (0.43–0.56)
% of the covariance accounted for by additive genetic factors			
Full-scale IQ $h^2 = 0.71$ (0.56–0.86)	0.93 (0.79–1.06)	0.99 (0.76–1.25)	1.01 (0.32–1.8)
Performance IQ $h^2 = 0.48$ (0.31–0.66)	0.94 (0.69–1.19)	1.02 (0.67–1.43)	–
Verbal IQ $h^2 = 0.83$ (0.69–0.86)	0.92 (0.79–1.05)	0.92 (0.64–1.21)	1.02 (0.59–1.57)
SPM $h^2 = 0.16$ (0.03–0.55)	1.09 (0.64–1.71)	0.40 (−1.30–1.19)	–
APM $h^2 = 0.65$ (0.40–0.75)	0.77 (0.43–1.09)	0.78 (0.04–1.46)	–
% of the covariance accounted for by environmental factors			
Full-scale IQ	0.07 (−0.06–0.21)	0.01 (−0.25–0.24)	−0.01 (−0.82–0.68)
Performance IQ	0.06 (−0.19–0.32)	−0.02 (−0.43–0.33)	–
Verbal IQ	0.08 (−0.5–0.21)	0.08 (−0.21–0.36)	−0.02 (−0.57–0.41)
SPM	−0.09 (−0.71–0.36)	0.60 (−0.19–2.30)	–
APM	0.23 (−0.09–0.57)	0.22 (−0.46–0.96)	–

Note: IQ = full-scale IQ; SPM = Raven standard progressive matrices; APM = Raven advanced progressive matrices; h^2 is the proportion of the variance explained by additive genetic factors.

Table 5
Genetic and environmental correlations between openness, agreeableness, neuroticism, and IQ.

	Openness	Agreeableness	Neuroticism
Additive genetic correlation			
Full-scale IQ	0.48 (0.34–0.63)	0.42 (0.25–0.61)	−0.18 (−0.35–0.02)
Performance IQ	0.41 (0.22–0.62)	0.44 (0.21–0.70)	–
Verbal IQ	0.47 (0.34–0.59)	0.32 (0.16–0.48)	−0.20 (−0.35–0.06)
SPM	1.0 (0.35–1.0)	0.29 (−0.92–1.0)	–
APM	0.41 (0.19–0.63)	0.30 (0.01–0.59)	–
Environmental correlation			
Full-scale IQ	0.08 (−0.07–0.22)	0.00 (−0.15–0.15)	0.00 (−0.15–0.16)
Performance IQ	0.04 (−0.10–0.18)	−0.01 (−0.15–0.13)	–
Verbal IQ	0.10 (−0.05–0.24)	0.04 (−0.10–0.19)	0.01 (−0.15–0.17)
SPM	−0.05 (−0.29–0.19)	0.22 (−0.06–0.46)	–
APM	0.17 (−0.06–0.38)	0.09 (−0.13–0.29)	–

IQ = full-scale IQ; SPM = Raven standard progressive matrices; APM = Raven advanced progressive matrices.

therefore considered only for intelligence and openness to experience, intelligence and agreeableness, and intelligence (only FIQ and VIQ) and neuroticism. All corresponding cross-twin correlations between the FFM personality traits and IQ scores were stronger in MZ twins compared to DZ twins, with some small exceptions (see right part of Table 3). In Table 4 the proportion of covariance explained by genetic and environmental factors is given. Genetic and environmental correlations between the traits are displayed in Table 5. For all three bivariate models there was no significant deterioration of the fit after removing the C influences on the covariance and on the variance of personality (all p-values >0.05).

Table 4 shows that the shared variance in openness to experience and IQ scores was mainly accounted for by additive genetic influence (ranging from 77 to 100%). The genetic correlations between openness and the IQ scores ranged from 0.41 to 1.0. The largest proportion of the covariance between intelligence and agreeableness was explained by the same genetic influences (ranging from 39% to 100%) with a genetic correlations ranging from 0.29 to 0.44. The covariance between neuroticism and intelligence was also mainly explained by genetic influences (100%) with genetic correlations ranging from −0.18 to −0.20.

4. Discussion

Intelligence as measured by IQ was positively associated with openness to experience and agreeableness. Neuroticism correlated negatively with FIQ and VIQ. The associations between openness to experience and intelligence here were in accordance with previous studies (Ashton, Lee, Vernon,Jang, K.L., & Jang, 2000; Chamorro-Premuzic & Furnham, 2008; Gignac, Stough, & Loukomitis, 2004). Individuals who possess this trait might learn faster and be more willing to change their beliefs (Ashton et al., 2000; Sadowski & Cogburn, 1997). Moderate phenotypic correlations between agreeableness and IQ were also of interest. Earlier studies reported small correlations between intelligence and agreeableness (Ackerman & Heggestad, 1997; Kyllonen, 1997). There have been a few studies on altruistic behavior in young children that found a positive relation with IQ (Kohlberg, 1964; Krebs & Sturrup, 1982). Questions that define agreeableness in the NEO-FFI cover family conflicts and trust in other people. However, there is also a question on the willingness to cooperate. According to the Vygotskian hypothesis (described in Moll & Tomasello, 2007) unique aspects of human cognition are driven by social cooperation. The cooperative attitudes of the subjects scoring high on agreeableness could therefore be the shared underlying factor in the relationship with IQ.

To investigate if correlations were specific to fluid intelligence as measured in the RAVEN standard progressive matrices test or specific to verbal intelligence, verbal and performance IQ scores obtained from the full-scale IQ sample were analyzed. Openness to experience and agreeableness correlated with both RAVEN tests and IQ tests. For neuroticism we see no significant correlations with PIQ and the APM or SPM tests.

We conclude that openness to experience and agreeableness were associated with intelligence. There is no evidence for an association of IQ with the other FFM personality traits. Our study has some limitations. We only obtained data from adolescents and young adults. A study by Baker and Bichsel (2006) criticized the general use of younger adults and carried out a study in older individuals. They found that openness was no longer an important trait at an older age and hypothesized that this factor was only important in young adulthood. Another possible limitation is that for part of the sample the IQ and personality tests were not administered at the same time. However, previous studies have indicated that within person correlations over time are substantial for personality (Marshall, F., Rolland, & Bagby, 2005; McCrae & Costa, 1994), and intelligence (Mortensen, et al., 2003). Finally, this study did not have enough power to detect genetic non-additive (dominance) effects, although compared to earlier studies the number of participants was large.

An important finding was that the association between openness to experience and IQ seems to result from largely shared genetic factors. Terraciano et al. (2010) showed an association ($p = 3 \times 10^{-5}$) of openness to experience with rs10251794, an intronic single nucleotide polymorphism (SNP) in the gene *CNTNAP2*, which encodes for a member of the neurexin family that has been linked with autism and cognitive impairment. Agreeableness was associated with rs6832769 ($p = 9 \times 10^{-6}$) in *CLOCK*. These results might also suggest new pathways involved in cognition. However, the meta-analysis of GWA studies on NEO scales by de Moor et al. (2010) did not replicate these SNPs, but reported genome-wide significant results for openness to experience near the *RASA1* gene on 5q14.3 (rs1477268 and rs2032794, $p = 2.8 \times 10^{-8}$ and $p = 3.1 \times 10^{-8}$, respectively). For conscientiousness a genome-wide hit was seen in the brain-expressed *KATNAL2* gene on 18q21.1 (rs2576037, $P = 4.9 \times 10^{-8}$). A gene-based test confirmed the association of *KATNAL2* to Conscientiousness. However, in silico replication did not show significant associations of these top SNPs with openness and conscientiousness, although the direction of effect of the *KATNAL2* SNP on conscientiousness was consistent in all replication samples. The *RASA1* gene codes for a GTPase-activating protein involved in intracellular signaling and cellular proliferation and differentiation. The gene is highly expressed in the bone marrow and bone, but also in the brain.

To summarize, our results confirm the association between openness to experience and intelligence and show a high genetic correlation between these traits. A challenging task for further research is to identify genes involved in both traits. Furthermore, an interesting correlation has been found between agreeableness and intelligence, also influenced by shared genetic factors. This correlation has rarely been found in previous studies and could potentially be an object for further research.

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