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Personality and Individual Differences 40 (2006) 1189–1199

PERSONALITY AND INDIVIDUAL DIFFERENCES

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The heritability of conscientiousness facets and their relationship to IQ and academic achievement

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Received 9 August 2005; received in revised form 1 September 2005; accepted 7 October 2005
Available online 20 December 2005

Abstract

The heritability of conscientiousness has been one of the least explored of the NEO PI domains. Here we focus on the facet scales of the conscientiousness domain, estimating both their heritability and their correlations with measures of IQ and academic achievement (Queensland Core Skills Test; QCST) in a sample of adolescent twins and their non-twin siblings. Our findings confirmed positive associations between IQ and the facets of Competence and Dutifulness (ranging 0.11–0.27), with academic achievement showing correlations of 0.27 and 0.15 with these same facets and 0.15 with Deliberation. All conscientiousness facets were influenced by genes (broad sense heritabilities ranging 0.18–0.49) and unique environment, but common environment was judged unimportant. A multivariate genetic analysis including Competence, Dutifulness, IQ (verbal, performance) and QCST scores showed that common variance was primarily explained by a general additive genetic factor (loadings ranging 0.15–0.84). Future multivariate genetic analysis which incorporates Openness to Experience dimensions may improve the interpretation of these findings.

Keywords: Conscientiousness; IQ; Academic achievement; Twin study; Genetics; NEO PI-R

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0191-8869/$ - see front matter
doi:10.1016/j.paid.2005.10.013

1. Introduction

Conscientiousness, like other personality traits, is influenced partly by genes. However, there are conflicting findings (e.g., Jang, Livesley, & Vernon, 1996; Loehlin, McCrae, Costa, & John, 1998) on the influence of dominance genes (preferential expression of one parental gene, and including gene by gene interactions) and common environment. The genetic and environmental structure underlying intelligence is, on the other hand, well established, with its variation primarily composed of additive genetic effects (the sum of parental genes in influencing the offspring's trait). The notion that conscientiousness and intelligence may be related is not new (e.g., Pearson, 1906), but the empirical evidence is conflicting, with support for positive and negative correlations between conscientiousness and measures of intelligence (Ackerman & Heggestad, 1997). For academic achievement, positive correlations with conscientiousness have been consistently found (e.g., Busato, Prins, Elshout, & Hamaker, 2000; Lounsbury, Sundstrom, Loveland, & Gibson, 2003). This paper aims to further explore the associations between conscientiousness, IQ, and academic achievement, but within the framework of a classical twin design, which enables the estimation of genetic and environmental contributions to variance and covariance among the measures.

Conscientiousness has a moderate heritability (i.e., the proportion of variance due to genes; h^2). Loehlin (1992) analysed biological and adoptive parent–child and sibling/twin correlations reported from previous studies and showed that variation in conscientiousness could be explained by additive genes (0.22), gene by gene interactions (0.16), shared environment (0.07), and unique environment (0.55). The variance in NEO PI conscientiousness scores has been shown to consist of genetic dominance (explaining 29% of variance), shared environment (11%) and unique environment (60%) (Bergeman, Chipuer, Plomin, & Pedersen, 1993). An investigation of the NEO PI-R conscientiousness facet scores supported additive genetic and unique environmental effects for Competence ($h^2 = 0.44$), Dutifulness (0.44) and Achievement-Striving (0.42), while Order, Self-Discipline, and Deliberation were influenced by the common and unique environment (Jang et al., 1996). Although expansion of this study later showed additive genetic influence on Order and Self-Discipline (Jang, McCrae, Angleitner, Riemann, & Livesley, 1998). Furthermore, it was shown that after removing common variance between the facets, specific genetic effects (ranging 0.11–0.28) influenced all facets except Achievement-Striving and Deliberation. A multivariate analysis of facets confirmed the presence of a genetic general factor, a genetic factor loading on all facets but Deliberation, and specific genetic influences on most measures (Jang, Livesley, Angleitner, Riemann, & Vernon, 2002).

While genetic findings support substantial common variance between the diverse facets of the conscientiousness domain, the phenotypic correlations between individual conscientiousness facets and IQ may nevertheless differ. Ackerman and Heggestad's (1997) meta-analysis showed that while the NEO PI conscientiousness domain was positively and negatively, and often non-significantly, correlated with various measures of intelligence, Tellegen's achievement measure (a lower order factor of conscientiousness) demonstrated positive correlations of around 0.12 with almost all intelligence measures. In more recent studies (Moutafi, Furnham, & Crump, 2003, 2004) a negative association (−0.16 and −0.21) between conscientiousness and IQ has been reported, but the source of this association comes from a single NEO-PI facet, Order, and in the case of the Fifteen

Factor Questionnaire from a sub-factor defined by perseverance and order. Moutafi, Furnham, and Paltiel (2004) suggested that people lower in intelligence compensate by becoming more conscientious, whereas people higher in intelligence do not need to be conscientious to succeed in cognitive-related tasks.

In the only genetic study of the overlap between conscientiousness (Personality Research Form) and IQ (Multidimensional Aptitude Battery) a positive correlation (0.21) between Achievement and IQ was shown to be mediated equally by genes and unique environment, and a negative correlation (−0.14) between Order and IQ was mediated by genes and positively related influences of the unique environment (Harris, Vernon, & Jang, 1998). This study did not include a measure of academic achievement, which has been shown to be positively associated with conscientiousness (Blickle, 1996; Busato et al., 2000). For instance, Wolfe and Johnson (1995) report correlations of up to 0.38 between academic achievement (high school grades, scholastic aptitude test, university grade point average) and conscientiousness measures including Control, Organisation, and General Self-Efficacy. In the present study we therefore include an index of academic achievement in the analysis of the genetic and environmental covariance between conscientiousness facets and IQ measured in an adolescent sample of twins living in Brisbane, Australia.

2. Method

2.1. Participants

A twin and extended family design was used with the total sample of 730 families containing 650 families with IQ data, 484 families with academic achievement data, and 431 families with conscientiousness data. Table 1 outlines the sample size for each measure according to family

Table 1
Sample sizes of the various twin and sibling family configurations separately for IQ, academic achievement (QCST) and NEO PI-R data

		Twins pairs	Twin pair + 1 sibling	Twin pair + 2 siblings	Single twin + 1 sibling	Sibling–sibling	Total families
IQ	MZ	210	52	6	–	–	268
	DZ	288	71	12[a]	2	1	374
QCST	MZ	157	25	–	3	–	185
	DZ	166	37	5	10	3	221
NEO PI-R	MZ	64	26	1	7	5	103
	DZ	95	44	5	11[b]	8[c]	163

Note: The *N* for non-paired individuals (single twin/sibling) was 7 for IQ, 78 for QCST, and 165 for NEO PI-R. (These data were retained to improve mean, variance and inter-trait covariance estimates.)
[a] Includes 1 twin pair + 3 sibs.
[b] Includes 1 single + 2 sibs.
[c] Includes four pairs whose twin siblings were of unknown zygosity.

structure. Including non-paired family members there were a total of 484 families with IQ and academic achievement data, 351 families with IQ and NEO PI-R data, and 185 families with data on all measures. Exclusion criteria for study participation included history of significant head injury, neurological/psychiatric illness, substance dependence or current use of long term medications with central nervous system effects. Written informed consent was obtained from each participant and their parent/guardian prior to testing.

2.2. Procedure and materials

Data collection was performed in two stages within the context of an ongoing study of cognition in adolescent twins and their siblings (see Wright et al., 2001). Firstly, when the twins were aged 16 years (siblings were 17 on average) they came into the laboratory for testing on a battery of cognitive tasks, including the Multidimensional Aptitude Battery (MAB; Jackson, 1998), a measure of IQ. The shortened version of the MAB included three verbal subtests (information, arithmetic, vocabulary) and two performance subtests (spatial, object assembly). These subtests were chosen for maximal differentiation between verbal and performance scales, as the inter-scale correlations are only moderate.

In the second stage of the study, the NEO PI-R (Form S) was included in a questionnaire (see Wright & Martin, 2004) mailed out to 1406 participants when they were aged between 17 and 28 years (3 twin pairs and 2 individuals were inadvertently mailed questionnaires at 16). Responses were received from 56% of participants, their mean age being 20.2 (±2) years. The six facet scores (Competence, Order, Dutifulness, Achievement-Striving, Self-Discipline, Deliberation) of the conscientiousness scale were analysed. Complete responses of items for the conscientiousness facets ranged from 93.1% (Order) to 97.3% (Self-Discipline) of cases. In cases where a single item was missing per facet the score was replaced with the mean of that item dependent on sex. There are 269 families (with at least two siblings) for whom both IQ and NEO PI-R data are available.

The Queensland Core Skills Test (QCST) is a test of individual academic achievement that is sat by final year high school students wishing to enter tertiary education. The test is composed of four papers (a Writing Task, two Multiple-Choice papers, and Short Response questions) which tap a very broad range of scholastically acquired skills such as interpreting and explaining passages of prose, and understanding spatial and mechanical relationships. As the items of the QCST vary each year, the total score was standardised using the means and SD of the entire Queensland sample within each year, thus enabling integration of the data across eight years. For further detail of the QCST and its scoring procedure see Wainwright, Wright, Geffen, Luciano, and Martin (2005). The large number of single co-twins with QCST data was primarily due to academically less able students not sitting the QCST, with their mean IQ being lower than that of those who sat the test (Wainwright, Wright, Luciano, Geffen, & Martin, in press). Truncated selection of these data is inherently corrected for in the maximum likelihood multivariate analysis with IQ effectively serving as a proxy screen for sitting the QCST (Wainwright et al., 2005). The age range of subjects who sat for this test was 16–18 years (mean: 17.3 ± 0.39). A total of 161 families (with at least two siblings) had complete data for the QCST and NEO PI-R.

3. Results

3.1. Heritability of conscientiousness facets

All conscientiousness data were normally distributed, with only one or two outlying cases removed per facet; the mean and SD of the facet scores (Table 2) agreed with the college-aged norms (Costa & McCrae, 1992b). Structural equation models which tested assumptions of homogeneity of means and variances across twin birth order, zygosity (including comparison of twins versus non-twins), and sex were initially tested within a maximum likelihood framework (using the program Mx; Neale, Boker, Xie, & Maes, 1999). The chi-square test statistic was used to judge goodness of fit, and the effect of age on the means was also tested within these models. All variables, except Competence and Deliberation, showed grand mean differences between twins and non-twin siblings ($p < .01$) despite adjustments for age for all measures but Deliberation. The grand mean of siblings was lower than twins by 0.21 (Achievement-Striving) to 0.30 (Self-Discipline) of a SD. No other assumptions regarding homogeneity of means and variances were violated. Males scored significantly lower on Order (difference of 0.77), Achievement-Striving (0.72), and Deliberation (0.89).

Co-twin correlations were estimated from models in which means and variances were constrained equal across twin birth order and zygosity, but allowing separate twin and non-twin sibling means and including age and sex adjustments where significant. Co-twin correlations could be constrained equal across monozygotic (MZ) male and female groups, and similarly across dizygotic (DZ) male, female and opposite sex groups. Twin-singleton sibling and sibling–sibling correlations were equal to the DZ co-twin correlation, indicating that it was valid to treat these pairings as DZ co-twins. For all measures, except Order and Deliberation, MZ co-twin correlations were significantly larger than DZ co-twin correlations, suggesting the presence of genetic effects (Table 2). As the DZ correlations were less than half the size of the MZ correlations, models including non-additive genes rather than shared environment were fitted to the data.

The best fitting means and variance models for each measure were extended to include a model for the covariance between twins based on genetic theory. For MZ twins, the covariance was defined as additive genes (A) + dominance genes (D), whereas for DZ twins, the covariance

Table 2
Means and SD of the Conscientiousness facets, and accompanying MZ and DZ co-twin correlations

	Mean (SD)[a]	MZ correlation ($N = 91$ pairs)	DZ correlation ($N = 347$ pairs)[b]
Competence	19.8 (3.8)	0.38	0.08
Order	16.7 (4.5)	0.16	0.06
Dutifulness	20.5 (4.1)	0.40	0.13
Achievement-Striving	17.9 (4.3)	0.31	0.05
Self-Discipline	18.1 (5.1)	0.53	0.03
Deliberation	15.7 (4.3)	0.34	0.15

Age and sex corrected correlations are estimated by maximum likelihood.

[a] Total individuals $N = 774$–779.

[b] Twin–sibling and sibling–sibling correlations could be equated to the DZ correlation and are included in this estimate (183 twin–sibling pairs, 20 sibling–sibling pairs).

Table 3
Genetic model fitting results including the proportions of additive genetic (A), genetic dominance (D), and unique environment (E) variance contributing to each trait and their 95% confidence intervals

	−2LL (df)	A	D	E
Competence	4248.92 (772)	0 (0, 0.40)	0.37 (0, 0.52)	0.63 (0.48, 0.81)
Order	4475.06 (767)	0.11 (0, 0.29)	0.07 (0, 0.34)	0.72 (0.66, 1)
Dutifulness	4343.48 (770)	0.15 (0, 0.47)	0.24 (0, 0.54)	0.61 (0.46, 0.78)
Achievement-Striving	4459.61 (771)	0 (0, 0.29)	0.28 (0, 0.45)	0.72 (0.55, 0.91)
Self-Discipline	4687.04 (773)	0 (0, 0.23)	0.49 (0.21, 0.62)	0.51 (0.38, 0.67)
Deliberation	4443.53 (772)	0.24 (0, 0.45)	0.10 (0, 0.48)	0.66 (0.52, 0.82)

was defined as $0.5A + 0.25D$. Unique environmental (E) sources of variance are unshared between co-twins so only contribute to trait variance. Parameter estimates for A, D and E were estimated by maximum likelihood, with the proportion of variance explained by each parameter shown in Table 3. The confidence intervals of A and D for all measures but Self-Discipline encompassed zero reflecting the low power to resolve the negative confounding of A and D (Martin & Eaves, 1977). Nonetheless, genetic influences on conscientiousness facets were apparent, with broad sense heritabilities ranging 0.18 (Order) to 0.49 (Self-Discipline).

3.2. Multivariate genetic modelling—conscientiousness, IQ and academic achievement

IQ and QCST scores were normally distributed, with a single outlier removed for verbal IQ. The IQ range of participants for whom NEO PI-R data were available was large, with verbal IQ scores ranging 81–143 (mean: 110 ± 11) and performance IQ scores ranging 68–151 (113 ± 16). The mean of the QCST data (0.31) was higher and the variance (0.95) lower than the twin sample from which they were drawn (0.20 ± 1). Correlations among the conscientiousness facets, IQ measures and QCST were inspected for significance (Table 4). The only conscien-

Table 4
Maximum likelihood derived correlations among conscientiousness facets, QCST scores, verbal and performance IQs, estimated under a model in which MZ and DZ co-twin correlations are free to vary, but correlations between traits are constrained equal between sexes, twin birth order, zygosity, and twin-singleton status

	C1	C2	C3	C4	C5	C6	QCST	VIQ	PIQ
Competence (C1)	1								
Order (C2)	0.43	1							
Dutifulness (C3)	0.53	0.39	1						
Achievement-Striving (C4)	0.58	0.53	0.51	1					
Self-Discipline (C5)	0.59	0.57	0.59	0.67	1				
Deliberation (C6)	0.44	0.37	0.46	0.35	0.40	1			
QCST	0.27	0.01^{ns}	0.15	0.09^{ns}	0^{ns}	0.15	1		
Verbal IQ	0.27	0.01^{ns}	0.13	0.06^{ns}	-0.01^{ns}	0.09^{ns}	0.81	1	
Performance IQ	0.15	-0.06^{ns}	0.11	-0.05^{ns}	-0.02^{ns}	0.09^{ns}	0.56	0.52	1

Note: Correlations are significant at $p < 0.05$; ns—not significant.
N range of individuals: Conscientiousness facets (772–776); Conscientiousness facets—QCST (463–465); Conscientiousness facets—IQ measures (546–557); VIQ-PIQ (1447); QCST—IQ measures (1038–1042).

tiousness facets to significantly correlate with both QCST and IQ scores were Competence and Dutifulness, with respective correlations for each ranging 0.15–0.27 and 0.11–0.15. These two variables were therefore included in a multivariate genetic analysis with QCST, verbal IQ, and performance IQ.

We have previously shown that the QCST and verbal IQ are influenced by common environment rather than non-additive genes (Wainwright et al., 2005), so a multivariate model was specified in which ACE components of variance contributed to QCST and IQ, but ADE components of variance contributed to Competence and Dutifulness. A model for the A factor structure was hypothesised to include a general factor, a conscientiousness group factor (with loadings on Competence and Dutifulness constrained equal for model identification), a cognitive group factor, and unique factors influencing each measure. A single C factor influencing IQ and QCST, and a single D factor influencing Competence and Dutifulness were further hypothesised. This model was compared (using the likelihood ratio test) to a fully saturated solution in the form of an atheoretical triangular decomposition of A, C, D and E (in this decomposition C loads only on IQ and academic achievement, and D loads only on Competence and Dutifulness).

Results showed that the hypothesised factor structure when compared to the triangular decomposition of genetic and environmental sources of covariance provided a good fit to the data, with a non-significant change in chi-square of 4.72 for five degrees of freedom. The additive genetic part of the model could be simplified by dropping the conscientiousness factor, the cognitive factor, and the unique influences on Competence and QCST, without significant loss in model fit ($\chi^2_6 = 1.83$, ns). Similarly, non-significant C, D and E path coefficients were removed (Fig. 1).

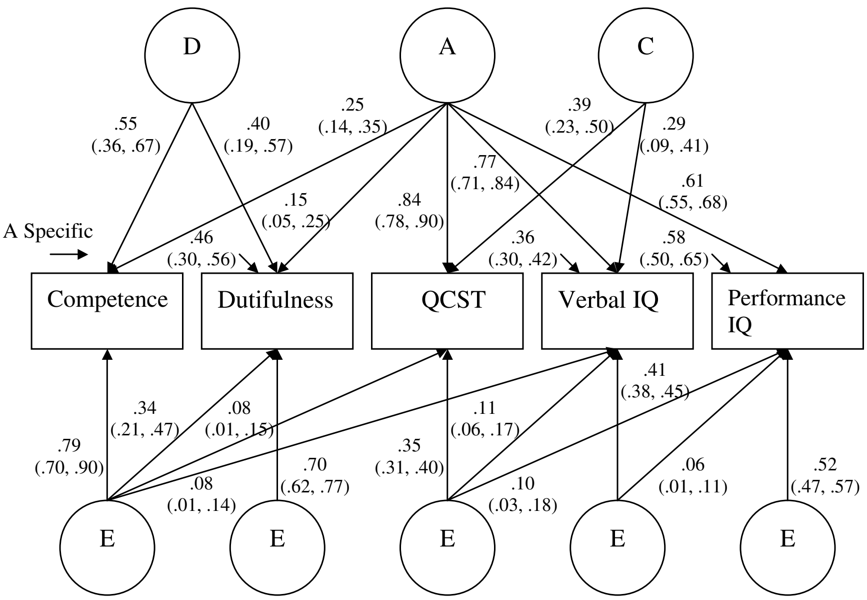

Fig. 1. Standardised path diagram depicting the genetic (A—additive; D—dominance) and environmental (C—common; E—unique) covariance between Competence, Dutifulness, academic achievement (QCST), and IQ (verbal, performance). Ninety five percent confidence intervals on the point estimates are shown in brackets.

The covariance among variables was explained by a number of genetic and environmental factors. A general A factor explained between 2% (for Dutifulness) and 70% (for QCST) of variance in the measures. The D factor explained 30% of variance in Competence and 16% of variance in Dutifulness, and the C factor explained 15% of variance in QCST and 8% of variance in verbal IQ. Three E factors showed common effects among various measures: the first factor influenced all measures except performance IQ, the second factor influenced the cognitive measures only, and the third factor influenced verbal and performance IQ. The relationship between Competence and Dutifulness with QCST and verbal IQ was mediated to a larger extent by A than E, while the association between Competence and Dutifulness with performance IQ was solely mediated by A. Factors with specific influences included: an A factor influencing Dutifulness (explaining 21% of variance); an A factor influencing verbal IQ (13%); an A factor influencing performance IQ (34%); an E factor influencing Dutifulness (49%); and an E factor influencing performance IQ (27%).

4. Discussion

This study investigated the heritability of the conscientiousness facets from the NEO PI-R and their covariation with measures of IQ and academic achievement. Significant positive correlations were observed between the facets of Competence and Dutifulness with the IQ and academic achievement measures, and the Deliberation facet was shown to positively correlate with academic achievement. All conscientiousness facets were heritable, and a multivariate genetic analysis of Competence, Dutifulness, verbal IQ, performance IQ and academic achievement confirmed that their shared variance stemmed primarily from a genetic general factor.

Heritabilities of the conscientiousness facets mostly fell within the range previously reported (e.g. Jang et al., 2002), although the heritabilities for Achievement-Striving and Order were much lower, perhaps resulting from the comparatively young age of our sample. While there was insufficient power in the univariate analyses to detect non-additive gene effects for most measures, the upper confidence interval on D suggested the potential for substantial non-additive gene influences. In the more powerful multivariate analysis, a significant common dominance genetic factor influenced Competence and Dutifulness accounting for up to 30% of trait variance. Non-additive genetic effects have previously been reported for conscientiousness (Bergeman et al., 1993; Loehlin, 1992), although it is not clear whether these represent epistasis or dominance. Another possibility is that the low DZ correlation instead reflects a sibling contrast effect in that high conscientiousness in one sibling lowers conscientiousness in the other sibling. The equality of variances between MZs, DZs and singletons in our study suggests that contrast effects are not present, but modelling of this effect in a larger sample is necessary to exclude this possibility (Carey, 1986; Neale et al., 1999). The absence of common environmental effects on conscientiousness was implicated in our data, agreeing with past research that has showed either low or non-significant effects from the common environment (Jang et al., 2002; Loehlin et al., 1998). It may be that the overwhelming effect of non-additive genes cancels out any shared environmental effect, or simply that familial socialisation does little to shape conscientiousness.

Consistent with some previous studies (e.g., Lounsbury, Welsh, Gibson, & Sundstrom, 2005) but not others (e.g., Allik & Realo, 1997), positive rather than negative correlations were supported between several conscientiousness facets and cognitive measures. For the most part correlations were non-significant in line with another study of NEO PI-R conscientiousness facet scores (Moutafi et al., 2003). Correlations were estimated partialling out the effects of age and sex on conscientiousness facets and IQ, and our sample was much more representative of the population than other studies which have focussed on university or other samples (e.g., job applicants) restricted for IQ range. The previous, significant negative correlation reported between the Order factor and fluid ability (Moutafi et al., 2003, 2004) may stem from sampling bias as it has recently been shown that samples of average to high IQ participants show increased variability in conscientiousness scores than samples of low to average IQ (Harris, Vernon, & Jang, 2005). Alternatively, it may be that our correlation (−0.06) between Order and performance IQ (most reflective of fluid ability) is attenuated because participants lacked motivation to perform to the best of their ability on the IQ test. Chamorro-Premuzic and Furnham (2004) suggest that in such a situation, conscientious participants take the task more seriously than those low in conscientiousness (presumedly higher in intelligence), who achieve lower scores than had they been motivated to perform well. The positive correlation we observed between Deliberation and the QCST but not IQ may stem from increased motivation to score optimally on the QCST than on the IQ test resulting in increased deliberation of QCST items for those high in this personality scale.

A multivariate genetic analysis showed that the relationship between Competence, Dutifulness, IQ and academic achievement was primarily mediated by a genetic general factor. This factor may be interpreted as a general ability (*g*) factor as it explained more variance in the cognitive measures than in Competence and Dutifulness. Jensen (1998) claims that personality measures do not influence *g*, and this has been somewhat validated in factor analytic studies of the NEO PI (McCrae, 1994; McCrae & Costa, 1997), which makes our finding of a genetic *g* factor difficult to interpret. Although it is possible that Competence (of which 'intelligent' is a strongly correlated adjective, Costa & McCrae, 1992b) partly acts as a self-report measure of intelligence and for this reason the genetic overlap occurs. A self-report confound for Dutifulness seems less likely, although the facet has been related to 'distractibility' from the Adjective Check List (Costa & McCrae, 1992b), and may thus report on attention which arguably contributes to *g*. Alternatively, as Cattell (1957) believed, *g* influences the development of conscientiousness, and hence the shared genetic variance through *g*; although it is unclear why this was not shown for the other conscientiousness facets. Up to 27% of the correlation between Competence and Dutifulness with the QCST and verbal IQ was due to the unique environment: events such as teacher encouragement and socialisation with academically minded peers might enhance both one's conscientiousness and academic achievement and verbal IQ in a directional or reciprocal manner. It is interesting that these factors do not influence performance IQ which, unlike verbal IQ, tends to measure a more fluid ability that is not reliant on prior knowledge and so is less amenable to improvement through increased studying, care and attention to test items, or other upshots of increased Competence and Dutifulness.

In summary, we found that NEO PI-R conscientiousness facets were generally not good predictors of IQ or academic achievement, explaining at most 7% of shared variance. Positive correlations between Competence and Dutifulness with the cognitive measures were shown to be influenced primarily by a common additive genetic factor. Future multivariate genetic analysis could be extended to include measures of Openness to Experience, which along with conscientiousness and psychometric intelligence have been hypothesised to form an intellect factor (Costa & McCrae, 1992a).

Acknowledgements

We would like to thank the twins and their parents for participating, the QSA for use of their data, Marlene Grace and Ann Eldridge for participant recruitment and IQ data collection, and the following people for NEO data collection and database administration: Alison Mackenzie, Kim Eldridge, Romana Leisser, Daniel Park and David Smyth. We kindly acknowledge financial support from the H.J. Eysenck Memorial Fund to Dr. Luciano (also supported by ARC postdoctoral fellowship DP0449598), Beyond Blue, and ARC grants A79600334, A79906588, A79801419.

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