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Separating narrow and general variances in intelligence-personality associations

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ABSTRACT

Recently, intelligence-personality associations (IPA) were found to be distorted due to failure to separate general and narrow variances of cognitive ability (Reeve, Meyer, & Bonaccio, 2006). In the present study, 248 students completed the NEO-FFI and a battery of nine intelligence tests, which comprised factors of general, abstract-fluid, verbal-crystallized and visuo-spatial intelligence. Average correlations were computed between personality trait scores and sets of ability scales without explicitly separating general from narrow variances of cognitive ability. Using factor analysis and regression residuals, mean correlations were computed for narrow intelligence factors and trait measures. Comparisons of the coefficients partially confirmed Reeve et al.'s (2006) findings; explanations and methodological implications for future research on IPA are discussed.

1. Introduction

Intelligence and personality were traditionally viewed as independent and separate entities (e.g., Eysenck, 1970; Webb, 1915; Zeidner, 1995). However, correlational studies established modest but consistent intelligence-personality associations (IPA; e.g., Ackerman & Heggestad, 1997; Chamorro-Premuzic & Furnham, 2006; Reeve et al., 2006), which are generally interpreted along two theoretical lines. The first one postulates a relationship at the measurement level, whereby personality traits affect one's intelligence test performance. For example, Chamorro-Premuzic and Furnham (2006) outlined that anxiety and stress-proneness hinder the effective use and exploitation of cognitive resources in maximal performance situations and thus, cause poor IQ test results. With reference to the trait dimension of extraversion–introversion, Revelle, Amaral, and Turriff (1976) demonstrated that arousing test conditions, such as restricted completion time and caffeine intake, reduced introverts' and enhanced extraverts' performance in a verbal ability task. That is, personality traits interact with situational factors of intelligence tests impacting on performance outcomes. The second line of interpretation posits that intelligence and personality are *conceptually* related, whereby personality traits determine *where*, *when* and *how* people apply and invest their cognitive abilities (e.g., Ackerman, 2000; Cattell, 1943; Chamorro-Premuzic & Furnham, 2006). That is, the application of intelligence will lead to knowledge attainment and expansion, and greater differentiation of cognitive abilities. Thus, IPA may be best understood within a developmental framework. For example, traits like typical intellectual engagement (Goff & Ackerman, 1992) and Openness to experience (e.g., Costa & McCrae, 1992) characterize individuals who seek cognitive stimulation and pursue manifold interests. Such behaviors constitute 'intellectual investment' and have been shown to be positively associated with crystallized intelligence, skills acquisition and knowledge attainment (e.g., Ackerman, Bowen, Beier, & Kanfer, 2001; Goff & Ackerman, 1992).

Recently, Reeve et al. (2006) highlighted a 'methodological problem that can obscure nature and magnitude' (p. 387) of IPA. Tests of mental ability share common variance, referred to as general intelligence factor *g* (Spearman, 1904), and also have specific variances which can be subsumed to 'narrow'[1] factors of intelligence. Reeve et al. (2006) suggested that shared and specific variances of ability factors must be separated to achieve an accurate understanding of IPA. The authors fitted a nested-factor model to extract *g* orthogonally to narrow factors of cognitive ability including crystallized intelligence (*gc*), quantitative reasoning (*gq*), visual-spatial ability (*gvs*) and cognitive speededness (*gs*) in a representative sample of more than 71,000 American high school students from the Project TALENT (PT) database.[2] Correlations of personality scales and orthogonal factors of intelligence, herein referred to as 'distinctive' coefficients, were compared to 'traditional' coefficients based on

[1] In line with Reeve et al. (2006), we will use the term 'narrow abilities' throughout this paper to refer to non-*g* ability factors.

[2] Project TALENT is a longitudinal study of a representative sample of 5% of all US high school students in 1960 with data on skills, abilities and aptitudes (see Tiedeman, 1972, for more details).

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average correlations between ability scales and personality measures. The ability scales were classified in correspondence to Carroll's (1993) model of intelligence for both analyses. The comparisons showed substantial differences in magnitude, which confirmed the hypothesis of 'misestimated' (p. 398) IPA. Reeve et al. (2006) concluded that traditional coefficients systematically under-estimated personality associations with *g* and *gs*, and over-estimated relations with *gc*, *gq* and *gvs*. This finding questions the validity of previous empirical evidence; the latter may have misguided contemporary theoretical rationales and experimental research of IPA.

Reeve et al.'s (2006) study constitutes a fundamental methodological contribution; however, the outdated personality measures, namely *ad hoc* re-conceptualizations of available self-report data rather than a normative instrument, did not allow for a conclusive interpretation of observed IPA. Specifically, the PT database included ten personality scales created in 1960 without reference to any commonly accepted model of personality. To demonstrate construct validity, Reeve et al. (2006) matched the scales' contents with facets of the NEO-PI-R (Costa & McCrae, 1992) and additionally, administered the original PT items along with the IPIP short form (Goldberg, 1999) to a sample of 219 college students. An exploratory factor analysis yielded a five factor solution, which was largely congruent with the content ratings of PT scales. Albeit these analyses provided 'sufficient construct validity evidence to make the focal analysis viable' (p. 396), Reeve et al. (2006) stressed that the employed personality measures are not adequate to provide compelling estimates of IPA.

The current study aims to extend Reeve et al.'s (2006) findings by establishing exact estimates of IPA using widely acknowledged and validated measures for personality. To this end, a sample of Spanish students ($N = 248$) completed a state-of-the-art battery of personality and intelligence measures, including nine ability tests and the NEO-FFI. Following Carroll's (1993) model, second stratum factors of abstract-fluid intelligence (*gf*), verbal-crystallized intelligence (*gc*), and visuo-spatial intelligence (*gvs*) were each operationalized by three mental ability tests; the third stratum factor *g* was an underlying agency comprised of all tests. Table 1 outlines details on the cognitive ability factors and the corresponding measures in this study.

In line with previous research (e.g., Ackerman & Heggestad, 1997), Neuroticism is expected to show a negative and extraversion a positive association with intelligence. Openness to experience is hypothesized to be positively correlated with intelligence, most strongly with *gc*, and Conscientiousness may show a small negative relationship with *g*. Akin to Reeve et al.'s (2006) observations, the traditional correlation coefficients are hypothesized to underestimate personality associations with *g* and *gf*, and to overestimate personality relations with *gc* and *gvs* when compared to distinctive correlation values.

2. Method

2.1. Sample

This study tested 248 Spanish undergraduate students (81% females) with a mean age of 20.1 years (SD = 2.4) ranging from 18 to 40 years, who participated to fulfill a part of their academic curriculum. They were assessed in groups of 10–20 in two testing sessions of one hour each. Two participants did not complete the questionnaires and were excluded from all analyses ($N = 246$; 47 males, 199 females).

2.2. Measures

Factors of *gf*, *gc* and *gvs* were each operationalized by a set of three tests including Raven's advanced progressive matrices (APM; Raven, 1938), rotation of solid figures (Yela, 1969), three tests from the primary mental ability battery (PMA; Thurstone, 1938) and four tests from the differential aptitude test battery (DAT; Bennet, Seashore, & Wesman, 1990). This intelligence test battery was previously employed by Colom, Abad, Quiroga, Shih, and Flores-Mendoza (2008). Note that screening versions (even numbered items) were used for the APM and the DAT subtests. For all tests except mental rotation from the PMA (see below), the score was the total number of correct answers.

Tests of gf: APM (Raven, 1938). The test showed grids of 3 rows $\times$ 3 columns with the lower right hand entry missing. Participants chose from eight alternatives the one that completed the 3×3 matrix figure. *Inductive reasoning* (PMA-R; Thurstone, 1938). Participants identified the correct letter from six alternatives inferring a rule underlying a presented sequence of letters. The test comprised 30 items. *Abstract reasoning* (DAT-AR; Bennet et al., 1990). Each of 40 abstract figures showed four patterns in correspondence to a given rule; participants chose the correct answer from five alternatives to complete the series.

Tests of gc: Verbal reasoning (DAT-VR; Bennet et al., 1990). Participants completed 40 analogies, whereby the first and the last word of the sentence were missing. From five possible alternatives, the correct pair of words had to be selected. *Numerical reasoning* (DAT-NR; Bennet et al., 1990). Participants were presented with mathematical equations with one missing variable. The correct solution was chosen from five alternatives. *Vocabulary* (PMA-V; Thurstone, 1938). This synonym test consisted of 50 words, which had to be individually evaluated in their meaning against four alternative words.

Tests of gvs: *Rotation of solid figures* (Yela, 1969). Each item included a model figure with five alternatives. Participants evaluated which alternative could be rotated within a three-dimensional space to fit the model figure. *Mental rotation* (PMA-E; Thurstone,

Table 1
Factors of cognitive ability according to Carroll's (1993) hierarchical model of intelligence.

Factor name	Description	Tests
g General factor of intelligence	A fixed amount of 'mental energy' that underlies all intellectual activity albeit to different extents	Summed composite score of *gf*, *gc*, and *gvs* scales*
gf Abstract-fluid intelligence	Problem solving, abstract reasoning, ability to learn new things; irrespective of previous knowledge or education	Raven's matrices Abstract reasoning (DAT) Reasoning (PMA)
gc Verbal-crystallized intelligence	Knowledge, information, inductive reasoning based on prior learning experiences	Verbal reasoning (DAT) Numerical reason (DAT) Vocabulary (PMA)
gvs Visual-spatial intelligence	Ability to mentally rotate objects, orientation in space, visual perception of space	Solid figures Mental rotation (PMA) Spatial relation (DAT)

Note: PMA refers to Thurstone's (1938) primary mental ability battery; DAT refers to Bennet et al.'s (1990) differential ability test battery.
* Corresponding tests are outlined in the cells below.

1938). Items included a model figure with six alternatives: some were rotated versions of the model figure, others were mirror imaged. Only the rotated figures had to be identified. The score was the total number of correct responses (appropriately selected figures – simply rotated) minus the total number of incorrect responses (inappropriately selected figures – mirror imaged). *Spatial relations* (DAT-SR; Bennet et al., 1990). Items were composed of an unfolded figure with four folded alternatives. Participants chose the folded alternative that matched the unfolded model.

NEO-FFI (Aluja, García, & García, 2002). The Big Five personality traits were assessed with the Spanish standardization version. The measurement comprised 60 items tapping Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to experience. The items were rated on a five point scale, ranging from 'strongly disagree' to 'strongly agree'.

2.3. Analyses

In line with Reeve et al.'s (2006) method of a 'miniature meta-analysis' (p. 369), average correlations were computed between the Big Five personality traits and sets of three ability scales (see Table 1 for classifications). For *g*, average correlations were calculated between all intelligence tests and the personality scales. Herein, these mean correlations are referred to as traditional coefficients.

To obtain distinctive coefficients, Reeve et al. (2006) fitted a nested-factor model, which separated shared and unique variances of cognitive ability factors, for each sex separately and conducted a multi-group confirmatory factor analysis. The comparatively small sample (especially regarding male participants) in the present study made such a model mathematically intractable. Instead, we conducted two separate sets of analyses to confirm the hypothesized structure of cognitive ability across sexes on one hand, and to compute intelligence scores which did not share any variance on the other.

First, a structural equation model (SEM) examined the ability scores for invariance of the covariance–variance structures across sexes (Vandenberg & Lance, 2000). Hereby, variances and covariances of the observed intelligence test scores were constrained to be equal across sub-samples of males and females; this ensured that subsequent factor models of intelligence were justifiably fitted to the overall sample without disregarding sex differences. In a second step, confirmatory factor analysis (CFA) was applied to prove the adequacy of a hierarchical factor model in the overall sample corresponding to Carroll's (1993) three strata model (Fig. 2). Subsequently, the hypothesized nested-factor model was fitted in line with Gustafsson and Balke (1993), as shown in Fig. 1.

In addition to the model χ^2 test (Jöreskog, 1969), incremental goodness-of-fit indices including comparative fit index (CFI), Bentler–Bonett normed fit index (NFI) and the Tucker–Lewis index (TLI), as well as the root-mean-square error of approximation (RMSEA) were chosen indicators of goodness-of-fit. CFI, NFI and TLI indicate an adequate model fit at values of .90 and .95 or above (Hu & Bentler, 1999). For RMSEA, values of .08 and below are considered acceptable (Browne & Cudeck, 1993).

To separate variances of intelligence factors, a *g*-factor was extracted from the mental test battery using principal axis factoring, which only reflected the battery's common variance. The factor *g* was regressed from the intelligence test scores and standardized residuals were saved. For narrow intelligence factors, distinctive correlations were computed by averaging correlations of sets of residual ability scores with a given personality scale. For the general intelligence factor, correlations of personality scales and the first unrotated component *g*', which comprises common as well as unique error variances, were computed.

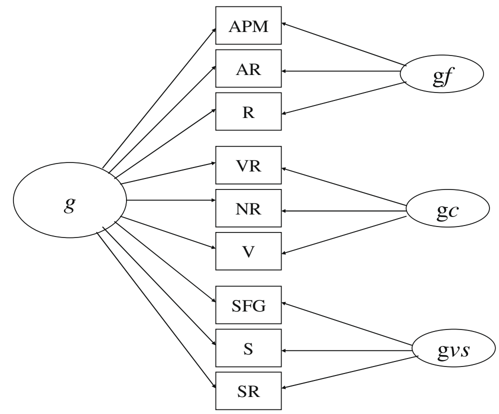

Fig. 1. Hypothesized nested-factor model with orthogonal factors of intelligence. *Note*: Error variances have been omitted to sustain graphical clarity. *Key*: APM = Raven's matrices; AR = abstract reasoning; R = inductive reasoning; VR = verbal reasoning; NR = numerical reasoning; V = vocabulary; SFG = rotation of solid figures; R = mental rotation; SR = spatial rotation.

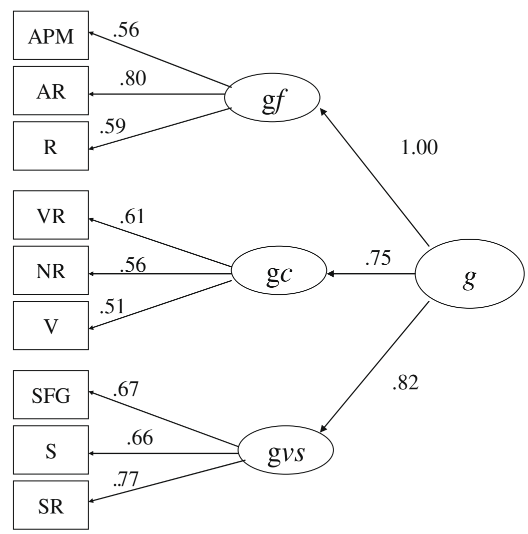

Fig. 2. Hierarchical factor model of intelligence. *Note*: All paths are significant at $p < .01$. Error terms have been omitted to sustain graphical clarity. For key, please see Fig. 1.

3. Results

3.1. Descriptives

Table 2 shows the descriptive statistics of cognitive ability and personality for men and women. Women had higher scores on Neuroticism, Extraversion, Agreeableness and Conscientiousness compared to men with medium effect sizes; these findings are in line with common norms (i.e., McCrae, Terracciano, et al., 2005). With regard to cognitive ability measures, women performed better on the reasoning (PMA) test but men exceeded in rotation of solid figures with a medium effect size.

To foreclose sex differences in the structure of the proposed factor model of ability, an omnibus test examined invariance of variance–covariance matrices, whereby covariances of ability scores were constrained equal across groups. The fit indices (χ^2 (41) = 55.10, $p > .05$; NFI = .916; TLI = .958; CFI = .976; RMSEA = .037, confidence interval (CI) of 90% of .00–.06) supported the invariance of the matrices; thus, further factor models were legitimately fitted to the overall sample. A hierarchical CFA recognized *g* and *gf* as identical factors (χ^2 (25) = 63.19, $p < .001$; NFI = .897;

Table 2
Means (SD), *F*-tests and *t*-tests for all variables across sexes.

	Men		Women		t^{a}	F^{b}	d^{c}
Neuroticism	20.30	(7.57)	24.24	(8.37)	2.95*	0.59	−.49
Extraversion	29.23	(7.84)	32.21	(7.14)	2.52*	1.09	−.40
Openness	31.43	(6.25)	31.60	(6.49)	0.17	0.11	−.03
Agreeableness	27.02	(6.15)	30.35	(5.02)	3.90*	1.56	−.59
Conscientiousness	26.91	(6.20)	29.45	(7.33)	2.19*	2.75	−.37
Raven's	10.94	(2.67)	10.89	(2.43)	−0.11	1.73	.02
PMA-R	17.45	(5.16)	18.99	(4.28)	1.90*	5.21*	−.32
DAT-AR	13.09	(3.72)	12.86	(3.53)	−0.39	0.16	.06
PMA-V	30.36	(6.54)	28.89	(6.14)	−1.46	0.081	.23
DAT-VR	13.32	(2.96)	12.39	(3.05)	−1.89	0.05	.31
DAT-NR	11.43	(3.01)	10.66	(3.34)	−1.44	1.04	.24
SFG	9.21	(4.15)	6.99	(3.14)	−3.45*	6.12*	.66
PMA-E	25.85	(9.27)	25.11	(10.64)	−0.44	2.08	.07
DAT-SR	14.34	(5.42)	14.34	(4.15)	0.00	2.87	.00

* $p < .05$.
[a] Mean comparison across sexes.
[b] Variance (Levene's) test across sexes.
[c] Cohen's *d*. Negative values indicate higher means for women.

TLI = .905; CFI = .934; RMSEA = .079, CI of .06–.10, Fig. 2). A subsequent nested-factor model distinguished orthogonal factors of *g*, and *gc* and *gvs* with a superior fit compared to the previous hierarchical model (χ^2 (21) = 33.99, $p < .05$; NFI = .944; TLI = .961; CFI = .977; RMSEA = .050, CI of .01–.08; Fig. 3). Note, that tests of *gf* did not share unique residual variance separate from *g*; therefore, only ability tests of *gc* and *gvs* were individually regressed onto *g*-factor regression scores.

The observed correlation coefficients of either computation method were low and did not exceed .25. For men, the traditional analyses showed the highest coefficients for Agreeableness, which was negatively linked to all sets of ability tests with values ranging from −.16 to −.25. An exception was *gf*, whose highest (also negative) association was with Openness to experience. Across personality traits, *gvs* was most strongly associated with personality. In the distinctive analysis, Agreeableness remained the strongest negative correlate across ability scales but its link with *gc* and *gvs* reduced substantially (from −.25 to −.14, and from −.19 to −.06, respectively) whilst its association with *g* increased (from −.16 to −.24). On average, *g* became the highest correlate across personality traits in the distinctive analysis. Fisher's *z*-transformation did not suggest significant changes in coefficients' magnitude across computation methods ($p > .05$, in all cases). Reeve et al. (2006),

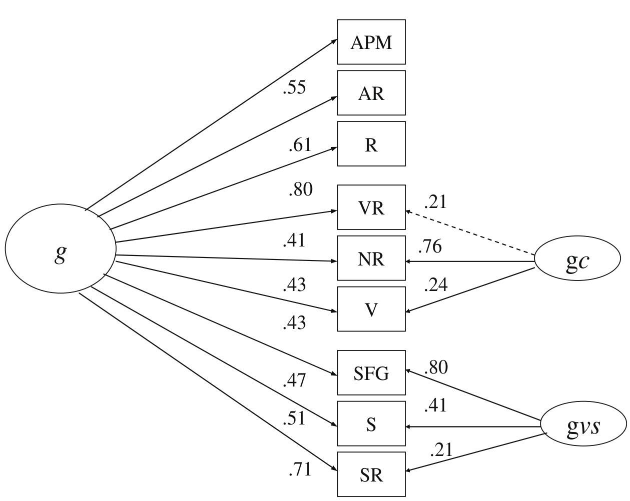

Fig. 3. Nested-factor model of intelligence. *Note*: Paths that were not significant ($p > .05$) are represented by dashed lines. Error terms have been omitted to sustain graphical clarity. For key, please see Fig. 1.

whose large sample size effectively caused even meaningless changes to be significant, evaluated changes in coefficients by their actual size, whereby a value of .05 'seemed reasonably large' (p. 397) relative to the magnitude of typical IPA. Applying the same reference standard, there were seven changes in coefficients' magnitude for men in the present study. Specifically, negative associations of *g* and Agreeableness and Conscientiousness increased from the traditional to the distinctive analysis (from −.16 to −.24, and from −.04 to −.09). The association of *gc* and Agreeableness reduced, whereas the correlation of *gc* and Openness to experience increased (from −.25 to −.14, and from .04 to .11, respectively). The greatest difference across computation methods in magnitude was observed for *gvs* and its association with Agreeableness with a difference of .13 from −.19 to −.06.

For women, the traditional analysis showed the strongest associations for ability and Neuroticism (negatively). Overall, *gvs* was most strongly linked to personality compared to the other sets of ability scales. In the distinctive analysis, *g*'s negative association with personality increased and became the highest correlate of personality overall. For *gc* and *gvs*, no consistent pattern of change could be observed across computation methods. In line with the results from the male sample, no correlation coefficient change reached significance using Fisher's *z*-transformation ($p > .05$, in all cases) but five changes of .05 or greater were observed. Specifically, correlations of *g*, *gc* and *gvs* with Neuroticism changed from −.07 to −.12, from −.02 to .05, and from −.11 to −.03, respectively. Also, *gvs*' association with Extraversion and Conscientiousness showed a difference of .05 across computation methods. Changes of direction in correlation coefficients were observed across computation methods in both samples; this was in agreement with Reeve et al.'s (2006) results (Tables 3 and 4).

4. Discussion

The current results confirm Reeve et al.'s (2006) observation that intelligence-personality associations (IPA) are distorted when shared and unique variances in cognitive ability are not sufficiently differentiated. Previously, Reeve et al. (2006) concluded that traditional coefficients systematically underestimated personality associations with *g* and *gs*, and overestimated relations with *gc*, *gq* and *gvs*. In the current study, associations of personality traits and *g* were consistently underestimated in the traditional analysis compared to the distinctive method. Also, changes were observed in personality correlates of *gc* and *gvs*; however, the inconsistent nature of these did not lend itself to support the hypothesis of a systematic overestimation of IPA.

Estimates of correlations between personality traits and cognitive ability are typically low; for example Reeve et al.'s (2006) coefficients did not exceed .20. In line with previous research (e.g., Zeidner, 1995), the present study found small and almost trivial coefficients. An exceptions may be the negative association of Agreeableness with *gc* in males. To date, there is no evidence suggesting a substantial or consistent association of Agreeableness and factors of intelligence (Ackerman & Heggestad, 1997). Correlational evidence of IPA may be interpreted in terms of personality affecting intelligence test performance, or with regard to one's application of and investment in cognitive ability. It is difficult, however, to find a rational explanation for the reported correlation of Agreeableness and *gc* within either line of thought. Future research is needed to ensure that the present observation is not specific to the employed sample.

In line with the hypothesis, Neuroticism and Conscientiousness were largely negatively associated with composites and orthogonal factors of intelligence across sexes. Contradicting the hypothesis, Extraversion was also negatively related to intelligence, which

Table 3
Correlation coefficients from 'traditional' and 'distinctive' analyses for men.

	Traditional coefficients				Distinctive coefficients		
	g[a]	*gf*[a]	*gc*[a]	*gvs*[a]	*g*[b]	*gc*[c]	*gvs*[c]
Neuroticism	−.01	−.07	−.01	.03	−.04	.02	.07
Extraversion	−.07	.00	−.09	−.12	−.10	−.03	−.05
Openness	−.05	−.14	.04	−.04	−.08	.11	.02
Agreeableness	−.16	−.03	**−.25**	−.19	−.24	−.14	−.06
Conscientiousness	−.04	−.02	.00	−.10	−.08	.05	−.06

Note: Significant coefficients ($p < .05$) are in bold.
[a] Average correlations of sets of ability tests.
[b] *g*-factor extracted from the test battery using PCA.
[c] Average correlations of residual scores from sets of ability tests.

Table 4
Correlation coefficients from 'traditional' and 'distinctive' analyses for women.

	Traditional coefficients				Distinctive coefficients		
	g[a]	*gf*[a]	*gc*[a]	*gvs*[a]	*g*[b]	*gc*[c]	*gvs*[c]
Neuroticism	−.07	−.09	−.02	−.11	−.12	.05	−.03
Extraversion	−.05	−.07	−.04	−.03	−.07	−.01	.02
Openness	.00	−.06	.04	.02	.00	.05	.03
Agreeableness	−.01	.02	−.04	.00	.00	−.04	.00
Conscientiousness	−.03	.00	−.02	−.09	−.06	.02	−.04

[a] Average correlations of sets of ability tests.
[b] *g*-factor extracted from the test battery using PCA.
[c] Average correlations of residual scores from sets of ability tests.

may be due to the specific characteristics of the NEO measure of Extraversion (see Wolf & Ackerman, 2005, for a detailed review). Finally, Openness to experience was inconsistently and weakly related to intelligence across sexes, in contrast to previous research findings (e.g., Bates & Shieles, 2003; Kyllonen, 1997). In males, the correlation between *gc* and Openness changed considerably from traditional to distinctive analysis (from .04 to .11) but no such movement was observed in females or for any other intelligence-Openness association.

The current study differs most notably in two aspects from Reeve et al.'s (2006) investigation. On one hand, a state-of-the-art battery of personality was implemented to overcome Reeve et al.'s (2006) *ad hoc* re-conceptualization of available self-report data. On the other, the presently implemented set of statistical analyses enabled a consistent approach to measurement error. Reeve et al. (2006) did not correct ability scales for measurement error when computing traditional correlations. However in the distinctive analysis, structural equation modeling required the estimation of error variances and thus, reported coefficients were disattenuated. In the present study, neither average correlations of regression residuals, which were used to derive distinctive factors of intelligence, nor traditional correlations of ability scales were corrected for measurement error. In addition, traditional and distinctive *g*-factors were uncorrected for measurement error and therefore, their associations with personality are directly comparable.

The present study also suffers from some limitations. The sample consisted of students who show a limited range of intelligence and personality; thus, reported correlations may be slightly underestimated. The small number of tested men warrants a cautious interpretation of the results, especially with regard to the negative Agreeableness-*gc* association. In addition, the sample size negatively affects the power of this study to detect significant changes between traditional and distinctive correlation coefficients. Finally, the employed battery of ability scales did not allow examination of the effects of variances on IPA in additional second stratum factors like *gf* and *gs*.

Overall, this study found small effects of separating variances of cognitive ability factors on IPA; in particular, traditional coefficients systematically underestimated relations between *g* and personality traits compared to distinctive coefficients. For other ability scales, changes in coefficients' values and direction across computation methods were evident but less conclusive.

The current results somewhat challenge the adequacy of correlational evidence as statistical methodology to examine IPA. Although modest associations have been repeatedly reported, such analyses seem to contribute sparsely to the understanding of intelligence in relation to personality. Future research must explore other means of assessing IPA in order to clarify the effects of personality on intelligence test performance and to empirically validate effects of intellectual investment traits on adult intellect.

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