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Personality differentiation by cognitive ability: An application of the moderated factor model☆

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ABSTRACT

The personality differentiation hypothesis holds that at higher levels of intellectual ability, personality structure is more differentiated. We tested differentiation at the primary and global factor levels in the US standardisation sample of the 16PF5 ($n = 10,261$; 5124 male; mean age = 32.69 years ($SD = 12.83$ years). We used a novel combined item response theory and moderated factor model approach that overcomes many of the limitations of previous tests. We found moderation of latent factor variances in five of the fifteen primary personality traits of the 16PF. At the domain level, we found no evidence of personality differentiation in Extraversion, Self-Control, or Independence. We found evidence of moderated factor loadings consistent with the personality differentiation for Anxiety, and moderated factor loadings consistent with anti-differentiation for Tough-Mindedness. As differentiation was restricted to a few personality factors with small effect sizes, we conclude that there is only very limited support for the personality differentiation hypothesis.

1. Introduction

Whilst very many studies have investigated the relation between intellectual ability and personality trait levels (e.g. Bartels et al., 2012; Chamorro-Premuzic et al., 2005; Murray et al., 2014), much less attention has been paid to the relation between intellectual ability and personality trait structure. An exception has been the work in the personality differentiation framework. The personality differentiation hypothesis originated with Brand, Egan and Deary (1994) who proposed that at higher levels of intellectual ability, personality structure is more differentiated. The authors proposed the hypothesis by way of analogy with the 'intelligence differentiation' hypothesis in cognitive ability (Spearman, 1927) and was based on the idea that more intelligent individuals have more specialised skills and interests which in turn become reflected in more differentiated personality structures.

Empirical studies have largely operationalised differentiation statistically as personality constructs having smaller variances and larger inter-correlations in individuals of lower cognitive ability. Several studies have reported a tendency for larger facet (Austin, Hofer, Deary & Eber, 2000; Harris, Vernon & Jang, 2005) or dimension variance (Austin, Deary & Gibson, 1997; De Fruyt, Aluja, García, Rolland, & Jung, 2006; Harris et al., 2005; Harris, Steinmayr, & Amelang, 2006; Myers & McCaulley, 1985; Shure & Rogers, 1963) in higher ability groups. Likewise, with the exception of only a few samples (e.g. Austin et al., 1997) or traits within studies, dimension inter-correlations have tended to decrease with ability level (Austin et al., 2002; De Fruyt et al., 2006; Blas & Carraro, 2011; Harris et al., 2006; Mõttus et al., 2007) though the effects are not large nor always statistically significant. This past work has led to a general perception that there is at least some support for the personality differentiation hypothesis.

In interpreting the above-mentioned evidence, it is important to consider the possibility that cognitive ability may not produce true differences in latent personality structure, but differences in the manner in which individuals interpret, understand and respond to personality items which could, in turn, impact on observed structure (Allik & McCrae, 2004;Watson, Deary & Austin, 2007). If, for example, personality items show differential reliability across the range of cognitive ability due to these or other measurement issues, then this could mask or mimic differentiation effects. That is, observed personality differentiation could be a measurement phenomenon rather than a latent structure phenomenon (e.g. see Murray, Dixon & Johnson, 2013).

The majority of previous personality studies has utilised observed scores which conflate trait and error variances making it difficult to differentiate between effects (or the absence of effects) due to differential measurement properties and differential latent structure across the range of cognitive ability. Although Brand et al., (1994) did not explicitly lay out any predictions regarding how personality differentiation should manifest in the latent variable models now commonly used to model and test hypotheses regarding personality

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structure, it would be reasonable to assume some parallels between personality differentiation and the intelligence differentiation hypotheses which served as its inspiration. The intelligence differentiation hypothesis proposes that *g* is less influential at higher levels of intellectual ability. This has been operationalized in factor models of intelligence as smaller factor loadings of specific intellectual skills (usually measured by subtest scores) for higher levels of *g* (Tucker-Drob, 2009; Molenaar, Dolan, & Verhelst, 2010). In personality, considering the relations between items and facets and between facets and global factors, this translates into the prediction that personality factor loadings will be reduced at higher levels of intellectual ability. That is, the personality factors interact with intellectual ability.

To ensure that any differences in factor loadings to not merely reflect differential reliability, one solution is to utilise a moderated factor model which allows moderation of item residuals to be modelled and thus explicitly models the differential reliability that might otherwise be mistaken for personality differentiation (Molenaar, Dolan, Wicherts, & van der Maas, 2010). The moderated factor model proposed by Molenaar et al. (2010) can be used to test for personality differentiation by evaluating whether the loadings in a factor model of personality are moderated by intelligence. The approach is conceptually similar to the multi-group CFA (MG-CFA) approaches to testing personality differentiation (see DeFruyt et al., 2006; McLarnon & Carswell, 2013) but it has the advantage that it allows intellectual ability to be modelled continuously rather than across discrete groups created using artificial dichotomisation. Further, the moderated factor model provides more easily interpretable indices of moderation because it directly estimates 'moderation parameters'. These parameters represent the linear change in loadings with a cognitive ability level. In spite of these advantages, the moderated factor model approach is yet to be applied to the personality differentiation. It was, therefore, the aim of the present study to apply the moderated factor model to evaluate personality differentiation in a large population representative sample of individuals who had completed an omnibus personality inventory, the Sixteen Personality Factor Questionnaire, Version 5 (16PF5) (Conn & Reike, 1994).

2. Methods

2.1. Sample & measure

We use the American standardisation sample of the 16PF5 (N = 10,261).[1] The standardisation sample was reviewed in 2002 based on the US census in 2000 to ensure it remained a representative of the general population of the USA with respect to a number of demographic variables including sex (5124 males, 49.9%), ethnicity (77.9% white, 10.8% black, 3.6% Asian), age (mean age = 32.69 years, SD = 12.83 years, range = 16 to 82) and geographic region. Conn and Rieke (1994) note that the educational level and years in education of the sample are greater than that of the US population.

2.1.1. Personality measures

In its current form, the 16PF5 comprises 15 personality scales, structured into five second order global factors, namely Extraversion (Self-Reliance (Q2), Warmth(A), Liveliness(F), Privateness(N), Social Boldness(H)); Anxiety (Tension(Q4), Apprehension(O), Emotional Stability(C), Vigilance(L)); Tough-Mindedness (Sensitivity(I), Openness to Change(Q1), Warmth(A), Abstractness(M)); Independence (Dominance(E), Social Boldness(H), Vigilance(L), Openness to Change(Q1)); and finally Self-Control (Abstractness(M), Rule Consciousness(G), Perfectionism(Q3), Liveliness(F)). Each of the primary personality scales consists of between 10 and 14 items with a three point response format, "No", "?" and "Yes", scored as 0, 1 and 2 respectively.

2.1.2. Intelligence measure (moderator)

In addition, the 16PF5 contains a 15 item Reasoning scale: a short cognitive ability measure assumed to tap verbal, numerical and logical abilities. It is designed to provide a quick measure of intelligence and correlates at $r = .61$ the Information Inventory (Altus, 1948) and at $r = .51$ with the Form A, Scale 2 Culture Fair Intelligence Test (CFIT; IPAT 1973a, 1973b). The test manual reports a Cronbach's alpha of .80 for the scale with 2 week and 2 month test–retest reliabilities of .71 and .70 respectively. Based on a sample of 2500 respondents, the Reasoning scale has been shown to have correlations with the primary factors of the 16PF ranging from r = −.27 (L: Vigilance) to r = .20 (Q1: Openness to Change) (Conn & Rieke, 1994, Appendix 5B). Investigations of differential item functioning by gender and ethnicity found no biasing by race or gender the exception of one item that functioned differently in a Hispanic sample (Conn & Rieke, 1994).

2.2. Analysis strategy

2.2.1. Overview

Given the 3-level hierarchical structure of the 16PF5 (items, primary factors, global factors) the statistically most sound analysis would have been to fit a second-order moderated factor model to the item level personality data (i.e., a second-order item response theory model or discrete factor model subject to moderation). However, such a model has not yet been developed. In addition, for the present undertaking fitting such a model will be numerically challenging due to the large number of items (40 to 51 across global models), the large sample size, and the high dimensionality of the 16PF5. We therefore test for moderation at the primary and global factor level separately.

2.2.2. Primary factor level

As the primary factor level consists of item level categorical data, we adopted an item response theory approach. Our choice for a specific IRT model was guided by the recurrent finding that the middle '?' option of the 16PF response scale does not consistently perform as a middle response option (Murray, Booth & Molenaar, 2015; Stark, Chernyshenko, Drasgow & Williams, 2006). As tests on interaction effects in general (Loftus, 1978) and differentiation effects in particular (Murray et al., 2013) are sensitive to scaling of the measurement, we wanted to explicitly take the ordering of the response options (including '?') into account. Therefore, we adopted Bock's Nominal Response Model (NRM; Bock, 1972). In this model, each item category is associated with a loading parameter, unlike the discrete factor model where each *item* has a loading. This complicates the operationalisation of the differentiation effect in terms of moderated factor loadings. We therefore introduced the differentiation effect on the variance of the primary factor. That is, by making the primary factor variance an exponential function of the intelligence moderator, we could investigate whether the variance decreased for increasing levels of intelligence. Note that moderation of the factor variance has been proposed as an alternative but a comparable method to test for differentiation (Molenaar et al., 2010).

2.2.3. Global factor level

To assess differentiation at the global factor level, we used a two-step approach. First, we estimated factor scores for the primary factors using the NRM discussed above. Next, we fit a moderated first-order factor model to each of the global factors. Within this model, personality differentiation was operationalised as decreasing primary factor loadings at increasing levels of intellectual ability. Note that if the primary factors are differentiated (as tested using the methods discussed above), the primary factor scores will incorporate this effect.

[1]

This is desirable, as the presence of differentiation at the primary level may be the effect of differentiation at the global factor level.

2.2.4. Primary factor moderation analyses

In order to test moderation, two models were estimated per primary factor, a baseline model and a differentiation model. In the initial baseline model we estimated all item parameters. In addition, we included a main effect of the moderator on the latent factor in order to account for the simple linear association between the moderator and the primary factor under consideration (see Purcell, 2002; Molenaar et al., 2010). Next, in the differentiation model, we included an exponential function between the latent factor variance and the moderator. Subsequently, inferences about the presence of moderation were based on the Akaike Information Criterion (AIC: Akaike, 1987), Bayesian Information Criterion (BIC: Raftery, 1995) and sample size adjusted BIC (saBIC: Sclove, 1987) between the baseline and the differentiation model.[2] For all fit indices, smaller values indicate a better fitting model. We considered a difference to be practically significant if the difference in BIC between two models was >10 (Raftery, 1995). All models were estimated in *Mplus 7.4* (Muthén & Muthén) using marginal maximum likelihood estimation. Latent variable scaling and identification were achieved by fixing the first item loading to 1.

2.2.5. Global factor moderation analyses

For each global factor, we fit an NRM including all items proposed to measure the primary factors subsumed by that global factor. So, for example, for the global factor of Anxiety, we fit a MD-NRM with four correlated primary factors (Tension(Q4), Apprehension(O), Emotional Stability(C), Vigilance(L)), measured by 40 items.

Models were estimated using marginal maximum likelihood estimation as implemented in the 'mirt' package (Chalmers, 2012) within the R statistical software (R Core Team, 2013). The maximum a posteriori (MAP) factor scores were obtained for each primary factor. Model fit was evaluated based on a root-mean square error of approximation (RMSEA), Tucker-Lewis index (TLI) and comparative fit index (CFI) using the generally recognised guidelines for fit of <0.05, >0.90 and >0.90 respectively (Schermelleh-Engel, Moosbrugger, & Müller, 2003).

Next, we fit a series of moderated factor models to the factor scores of the primary factors. For these first-order models, moderation of the factor loadings represents the primary test of differentiation, and provides evidence of a variation in the relationship between the global factors and their indicators at different levels of cognitive ability. Linear functions were used to model the relationship between the factor loadings and the moderator. In addition to the factor loadings, we also moderated the residual variances by specifying an exponential function between the residual variances and the moderator. Inclusion of moderated residuals in the model accounts for differential reliability that could be mis-attributed to personality differentiation if left un-modelled (Murray, Dixon & Johnson, 2013). Finally, to account for the main effect of the moderator (as discussed above), we also used a linear function between the intercepts and the moderator (See Molenaar et al., 2010).

Similarly as above, we first estimated a baseline model with moderation parameters on the factor loadings fixed to zero, and moderation parameters for the intercepts and residuals freely estimated (M1). We compared this model to a model (M2) in which the moderation parameters of the indicator intercepts, residuals and factor loadings were freely estimated. As above, the best fitting model was selected based on a number of model fit indices: AIC, BIC, saBIC and deviance information criteria (DIC: Spiegelhalter, Best, Carlin & van der Linde, 2002). We estimated the models in Mx (Neale, Boker, Xie & Maes, 2002). Latent variable scaling and identification were achieved as follows: for each global factor, the factor loading of the first indicator was constrained to be equal to 1 for moderator values of 0. In addition, the mean of the global factors were fixed to equal 0.

[2] The standard errors of the moderation parameters are likely wrong as they are based on the assumption of a symmetrical sampling distribution of the parameters, which is unlikely for interaction effects.

3. Results

3.1. Primary factor moderation

Model fit indices (see Table 1) suggested that moderation of factor variances was present for only five of the 15 primary scales. In the case of L, M, N, and Q1 the moderation parameter was positive, suggesting greater factor variance at higher levels of cognitive ability. In the case of Q4, the moderation parameter was negative, suggesting the opposite. The former is consistent with anti-differentiation and the latter with differentiation. Apprehension (O) shows an improvement in fit, but BIC change is only 7.95, and so does not meet our threshold for practical improvement of 10.

3.2. Primary factor scores

Table 2 contains the model fit indices for the NRM models for each of the five global factors. All models showed good levels of model fit by all indices, with the exception of the model for Tough-Mindedness that fell slightly below the desired cut-off for acceptable fit according to the CFI and TLI. Nevertheless, we conclude that the model fit is sufficient to justify the use of the primary factor scores obtained from these NRM models.

3.3. Moderation by reasoning ability

For Anxiety and Tough-Mindedness, the model including moderation of factor loadings (M2) displayed best fit (Table 3). For Independence, Self-Control and Extraversion, the inclusion of moderated factor loadings did not improve model fit uniformly according to all indices, and as a result, it was concluded that the baseline model provided the most parsimonious description of the data.

3.3.1. Anxiety

Fig. 1 plots the indicator factor loadings across different levels of cognitive ability. For all indicators with positive factor loadings (Emotional Stability(C)), the moderation effect was negative, and for those indicators with negative factor loadings (Tension (Q4), Apprehension (O), Vigilance (L)), the moderation effect was positive. Thus, for all indicators, as the level of cognitive ability increases, the relation between Anxiety and its indicators becomes weaker. This finding is consistent with the personality differentiation hypothesis. However, as is clear when one considers the scales of the two panels in Fig. 1, the moderation effects were generally small, and in the case of O, practically zero.

3.3.2. Tough-Mindedness

In the case of Tough-Mindedness (Fig. 2), one indicator (Warmth A) shows a similar pattern to the indicators of Anxiety, specifically, that the factor loading becomes weaker as ability level increases. However, the opposite effect is seen for the remaining three indicators (Sensitivity (I), Openness to Change (Q1), Abstractness (M); note lines for I and Q1 are almost entirely overlapping). Here, as ability level increases, factor loadings become stronger. This is the opposite effect to what would have been predicted by the personality differentiation hypothesis.

4. Discussion

We used a combined IRT and moderated factor model approach in a large standardisation sample of an omnibus personality inventory, the 16PF5, in order to test the personality differentiation hypothesis. We found very limited support for the differentiation hypothesis. There

Table 1
Model fit statistics and parameter estimates for the first order NRM models assessing moderated latent factor variances.

	AIC	BIC	saBIC	Parameter estimates from moderation models					
				Main effect	p-Value	Intercept variance	p-Value	Moderation variance	p-Value
A baseline	167,663.23	167,988.85	167,845.85						
A moderation	167,660.85	167,993.71	167,847.53	0.029	<.001	0.771	<.001	0.016	.107
C baseline	140,969.76	141,266.44	141,136.15						
C moderation	140,971.30	141,275.22	141,141.75	−0.019	.001	0.687	<.001	0.005	.513
E baseline	153,436.92	153,733.60	153,603.30						
E moderation	153,438.96	153,742.88	153,609.41	−0.004	.476	0.475	<.001	0.001	.917
F baseline	165,475.71	165,772.39	165,642.09						
F moderation	165,473.82	165,777.74	165,644.27	0.017	<.001	−0.339	.003	0.014	.074
G baseline	170,039.14	170,364.76	170,221.76						
G moderation	170,038.30	170,371.16	170,224.98	0.053	<.001	0.342	<.001	0.012	.110
H baseline	150,075.98	150,372.66	150,242.37						
H moderation	150,074.50	150,378.41	150,244.94	0.028	<.001	1.379	<.001	0.013	.105
I baseline	186,189.90	186,515.53	186,372.52						
I moderation	186,184.85	186,517.71	186,371.53	−0.021	<.001	0.346	<.001	0.018	.017
L baseline	161,133.51	161,430.19	161,299.90						
L moderation	161,115.88	161,419.80	161,286.33	0.172	<.001	0.850	<.001	0.031	<.001
M baseline	170,741.06	171,066.69	170,923.68						
M moderation	170,715.52	171,048.38	170,902.20	−0.045	<.001	0.689	<.001	0.037	<.001
N baseline	158,223.58	158,520.26	158,389.97						
N moderation	158,162.44	158,466.36	158,332.89	0.045	<.001	0.784	<.001	0.055	<.001
O baseline	163,933.76	164,230.44	164,100.14						
O moderation	163,918.58	164,222.49	164,089.02	−0.071	<.001	1.683	<.001	0.029	<.001
Q1 baseline	236,207.04	236,619.50	236,438.36						
Q1 moderation	236,133.51	236,553.20	236,368.89	−0.045	<.001	−1.786	<.001	0.063	<.001
Q2 baseline	155,771.68	156,068.36	155,938.07						
Q2 moderation	155,767.61	156,071.52	155,938.05	−0.066	<.001	1.329	<.001	0.017	0.022
Q3 baseline	155,469.66	155,766.34	155,636.05						
Q3 moderation	155,471.55	155,775.47	155,642.00	0.064	<.001	0.158	.145	0.002	.774
Q4 baseline	157,838.30	158,134.98	158,004.69						
Q4 moderation	157,817.79	158,121.71	157,988.24	−0.053	<.001	0.828	<.001	−0.031	<.001

was no evidence for moderation of factor loadings for the domains of Extraversion, Independence and Self-Control. Moderation of factor loadings was found for Anxiety and Tough-Mindedness, but only in the case of Anxiety was this moderation consistent with the personality differentiation hypothesis.

Thus, our results do not support the personality differentiation by cognitive ability hypothesis. Previous results, primarily framed in terms of Brand et al.'s (1994) personality differentiation hypothesis have been somewhat mixed with regards to the strength of the evidence for the moderation of personality structure by cognitive ability, however, this may be at least partly attributable to the fact that the majority of previous studies has used observed scores which do not separate out changes in variance and inter-correlations with ability level that are due to measurement issues versus the latent constructs. Further, studies which have taken these issues into account using latent variable models have done so within the traditional multi-group CFA measurement invariance framework which has required the discretisation of the cognitive ability continuum into low and high ability groups (e.g. Mclarnon & Carswell, 2013). The current analysis is the first to utilise a method specifically tailored to testing differentiation hypotheses and which allows continuous moderation of personality structure by cognitive ability. Therefore, the models reported in the current study arguably provide the clearest tests of moderation of personality structure by cognitive ability to date.

Table 2
Model fit for the multi-dimensional NRM models.

	RMSEA (95% CI)	CFI	TLI
Anxiety	.045 (.044 to .045)	.95	.95
Tough-Minded	.046 (.046 to .047)	.87	.86
Independence	.035 (.035 to .036)	.94	.93
Self-Control	.043 (.042 to .043)	.93	.92
Extraversion	.045 (.044 to .045)	.94	.93

We would also question the strength of the theoretical basis for the personality differentiation hypothesis. Originally developed by analogy with the intelligence differentiation hypothesis, there has been little attempt to develop it in its own right. For example, no mechanism by which personality differentiation should occur has been articulated nor any predictions as to how to test any hypothesised mechanisms delineated. Thus, although it is now possible to conduct more sophisticated tests of the hypothesis, if the personality differentiation is to be taken seriously as a description of the interplay between cognitive ability and personality development there will also be a need to develop a more convincing theoretical basis alongside the application of these tests.

Whilst the findings in the current study are not favourable for the personality differentiation hypothesis, three developments on the

Table 3
Model fit indices for the moderated factor models for the global scales of the 16PF5.

	AIC	DIC	BIC	saBIC
Anxiety				
M1: baseline model	−22,893.85	−122,175.39	−159,873.92	−94,689.68
M2: free loadings	**−22,997.45**	**−122,216.39**	**−159,911.25**	**−94,733.36**
Tough-Mindedness				
M1: baseline model	4648.90	−108,404.02	−146,102.55	−80,918.31
M2: free loadings	**2443.54**	**−109,495.90**	**−147,190.76**	**−82,012.87**
Independence				
M1: baseline model	**1422.62**	**−110,017.15**	**−147,715.69**	**−82,531.44**
M2: free loadings	1428.79	−110,003.27	−147,698.13	−82,520.25
Self-Control				
M1: baseline model	**−6010.64**	**−113,733.78**	**−151,432.32**	**−86,248.07**
M2: free loadings	−6009.30	−113,722.32	−151,417.17	−86,239.29
Extraversion				
M1: baseline model	**−16,777.74**	**−146,799.45**	**−193,922.62**	**−112,442.31**
M2: free loadings	−16,793.89	−146,794.03	−193,912.60	−112,440.24

Note: Values in bold font represent the best fitting models.

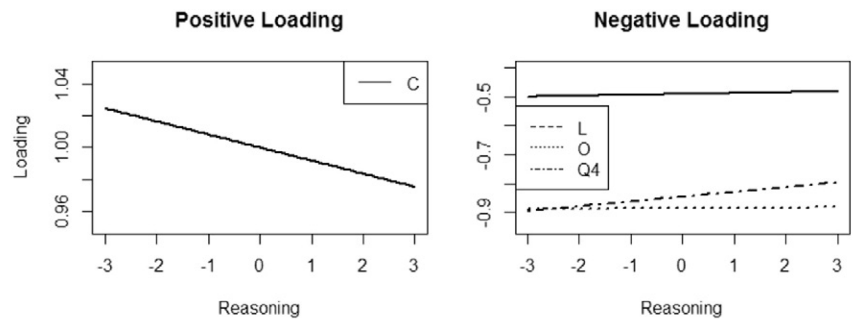

Fig. 1. Estimated factor loadings for Anxiety indicators as a function of reasoning ability. C = Emotional Stability; L = Vigilance; O = Apprehension; Q4 = Tension. Moderation parameters for factor loadings were: C = −0.0082, L = 0.0030, O = 0.0009, and Q4 = 0.0164.

current study may prove useful contributions to work in this area. First, although the models applied here represent an advantage over previous studies, as we noted earlier, a more ideal test of differentiation would make use of the full hierarchical structure of personality inventories and fit second-order moderated models based on item level data. As this is currently not possible yet, we relied on an analysis in separate steps to test for differentiation; however, such second-order models would be welcomed to provide a more specific test of differentiation.

Second, a primary limitation in the current study was the use of the 16PF5 Reasoning scale as a measure of cognitive ability. Using the Reasoning scale in the current study allowed us to utilise a large standardisation sample of an omnibus personality measure. However, to the extent that the Reasoning scale does not capture all aspects of cognitive ability, the results of the current study are limited. That is, if the Reasoning scale is not an adequate measure of, say, fluid ability, then it is possible that stronger moderation of fluid ability may be observed with a different estimate of the cognitive ability of participants. We suggest that the most likely consequence of this is a reduction in power to detect differentiation, rather than any systematic bias producing spurious moderation. Given the generally small moderation effects found in the current analysis, replication of these results with a more comprehensive measure of cognitive ability would be beneficial.

Lastly, we had only self- and not informant reports of personality. Combining self- and other-reports to assess differentiation would provide a more robust test of the hypothesis. Finally, given that our sample was all drawn from the same Western educated society, it is possible that it was too homogeneous to detect differentiation effects or that differentiation is more related to education or other cultural variables than cognitive ability. Previous studies have suggested that differentiation may be detectable when considering societies that differ dramatically in cultural set-up e.g. when comparing urbanised with forager-horticulturist societies (Gurven et al., 2013).

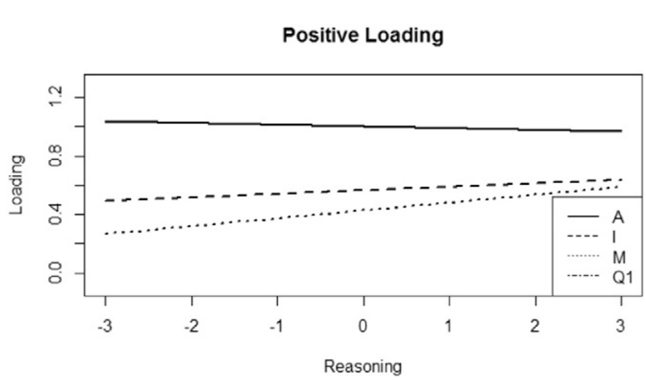

Fig. 2. Estimated factor loadings for Tough-Mindedness indicators as a function of reasoning ability. A = Warmth; I = Sensitivity; M = Abstractness; Q1 = Openness to Change. Moderation parameters for factor loadings are: A = −0.0119, I = 0.0242, M = 0.0538, and Q1 = 0.0277. Lines representing Q1 and I are overlapping.

5. Conclusion

In the current study, we found little evidence for the moderation of personality trait variance using moderated factor models. Only the global domain on Anxiety showed evidence of factor loading moderation consistent with the differentiation hypothesis. Moderated factor models overcome the key limitations of previous studies of personality variance moderation, thus arguably providing a more valid test of hypotheses predicting personality variance moderation than has been possible to date.

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