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Personality, arousal theory and the relationship to cognitive ability as measured by inspection time and IQ

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Abstract

It has been suggested that the association between inspection time and intelligence test scores is mediated by personality/temperament (Howe, 1990). Personality, and in particular the trait of extraversion, has been implicated in IQ performance, and based on differential nervous system arousal, Robinson (1989) has proposed a quadratic relationship between extraversion and IQ. The aims of the present study were to investigate whether personality mediates the correlation between inspection time and IQ, and to test the prediction by Robinson that ambiverts (moderate neural arousal) would score higher on IQ tests than extraverts or introverts. 237 pairs of monozygotic and 297 pairs of dizygotic adolescent twins completed a line discrimination task to measure inspection time, the Multidimensional Aptitude Battery (IQ), and the Junior Eysenck Personality Questionnaire. Correlations between personality and cognitive measures were significant for the extraversion—IQ association, but not for any other personality dimensions, and hence no mediating role of personality in the inspection time—IQ relationship was indicated. A test of mean effects of extraversion on cognitive measures did not support Robinson's hypothesis, as introverts tended to outperform ambiverts rather than the reverse. A psychophysiological test of the association between personality and arousal was suggested for future research.
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Keywords: Extraversion; Inspection time; IQ; Junior Eysenck personality; Eysenck's arousal theory; Processing speed

1. Introduction

Inspection time is an elementary cognitive task which seeks to measure the speed of a single information process—perceptual speed. The most common variant of this task requires a decision

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as to which of two vertical lines is longer—the minimum stimulus duration at which a correct discrimination of the lines can be made is the inspection time. The significant correlation between inspection time and IQ is a consistent finding which reveals around 10% of overlapping variance (Deary & Stough, 1996; Grudnik & Kranzler, 2001). While this association has been theorised to reflect biological functions which are involved in neural speed/and or brain circuitry (Jensen, 1993; Vernon & Mori, 1992), it has been suggested that this shared variance might be due to factors such as personality or temperament (Howe, 1990).

In an early study, extreme scores on Manifest Anxiety or the Eysenck Personality Questionnaire (EPQ) conferred longer inspection times, indicating that personality and inspection time were related (Nettelbeck, 1973). Extraverts have also been shown to make more frequent use of strategies in the inspection time task (e.g., apparent motion cues) which can shorten their inspection time (Brebner & Cooper, 1986). In the first thorough test of Howe's (1990) hypothesis, partial correlations showed the relationship between visual inspection time and performance IQ to be unrelated to personality and temperament variables in 68 university students (Stough et al., 1996). The Strelau Temperament Inventory showed significant correlations for strength of excitation with performance IQ and inspection time, and for mobility with IQ, while the only significant correlations with the EPQ were for the lie scale with verbal IQ (−0.29) and Advanced Progressive Matrices (−0.26). Thus, stable aspects of personality (with the exception of lie) did not relate to intelligence, concordant with an earlier null finding of Eysenck (1971).

Rather than testing linear effects of personality on IQ, Robinson (1989) hypothesised a model of nervous system arousal that related extraversion to intelligence in a quadratic fashion. His model rested on the notion, first introduced by Eysenck (1967) and Eysenck and Eysenck (1985), that high scores on the extraversion scale were correlated with low levels of cortical arousal. Some psychophysiological support for this idea has been provided through studies of cortical activity and general autonomous physiological activity (Daruna & Karrer, 1984; Zuckerman, 1991), although null or negative findings have also been reported (Cahill & Polich, 1992; Ditraglia & Polich, 1991; Stenberg, 1994) perhaps due to task/measurement differences and variations in emotional arousal at the time of testing (Eysenck, 1994; Gale, 1986). In accordance with the Yerkes–Dodson law, proposing an inverted-U relationship between performance and arousal, at least at moderate task difficulty (Eysenck & Eysenck, 1985), Robinson (1989) proposed that the optimal functioning of neurophysiological processes involved in intelligence was under conditions of moderate arousal. Hence, ambiverts (those with moderate extraversion) were predicted to perform better on IQ tests. This prediction was tested by Stough et al. (1996), with results showing that the mean IQ score of ambiverts (120) was greater than introverts (109) and extraverts (112), but inspection time values did not differ. An earlier study of Robinson's theory in children (11–14 years) found no mean differences in IQ between introverts, ambiverts and extraverts, nor was the correlation between extraversion and IQ significant (Saklofske & Kostura, 1990). Psychoticism and lie scales were significantly correlated with IQ at 0.26 and −0.23, respectively. A recent study of 209 university students also failed to replicate a quadratic finding between extraversion and cognitive ability, but found a linear effect in which introverts showed superior verbal ability (Roberts, 2002). Roberts suggested that different ability tests require varied levels of arousal for optimal performance, so that, for example, introverts would perform best at tasks that elicit low arousal. The study additionally found significant correlations (∼0.20) between psychoticism and cognitive ability, and between neuroticism and spatial ability (−0.22).

Given the inconsistency of empirical findings regarding the role of personality in cognitive performance, the aims of the present study were to (1) test whether any of the Junior EPQ personality dimensions mediate the relationship between inspection time and IQ, and (2) investigate Robinson's hypothesis of a quadratic relationship between extraversion and IQ. The study makes use of a large twin sample, providing substantial power to detect minor effects. Since the twin sample was an unselected sample of the population with wide IQ range (full scale: 77–148), the results may be considered more representative of the general population than previous studies which have sampled university students. The twin design further allows examination of whether significant relationships between personality and cognitive abilities are genetically or environmentally mediated. We have previously confirmed a genetic relationship between inspection time and IQ (Luciano et al., 2001a), and the possibility exists that covariation between personality and cognition may also be genetically influenced (e.g., Aitken-Harris, Vernon, Olson, & Jang, 1999).

2. Method

The sample of 1068 individuals comprised 237 monozygotic twin pairs (123 female, 114 male) and 297 dizygotic twin pairs (75 same-sex female, 70 same-sex male, 152 opposite-sex). They formed part of the Brisbane 'memory, attention and problem-solving' (or MAPS) study which has been collecting data since 1996, with the long term aim of finding genes for cognition (see Wright et al., 2001a). The age range of participants was between 15.4 and 18.2 years, with a mean of 16.2 years and standard deviation of ±0.3. Most participants were in their penultimate year of secondary school. Exclusion criteria for participation in the study included history of significant head injury, neurological or psychiatric illness, substance dependence or current use of long term medications with central nervous system effects. All participants had normal or corrected-to-normal vision (better than 6/12 Snellen equivalent). Written informed consent was obtained from each participant and their parent/guardian prior to testing.

The tests of inspection time and IQ were part of a psychometric battery, which also included a choice reaction time task (Luciano et al., 2001b) and two reading tests. This session lasted about 1.5 h during which the co-twin completed a testing session of similar duration which involved the measurement of event-related potentials during a delayed response task (Hansell et al., 2001; Wright et al., 2001b). The twins then swapped sessions and during the short rest interval the Junior Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975) was completed. The order of session testing was counterbalanced between twin pairs based on the birth order of the twins. A full description of the protocol is given in Wright et al. (2001a).

The Junior EPQ (Eysenck & Eysenck, 1975), which consists of 81 self-report items ('yes–no' responses) yields scores for the four higher order factors neuroticism, psychoticism, extraversion and lie (social desirability).

To measure IQ a shortened version of the computerised Multidimensional Aptitude Battery (MAB; Jackson, 1984, 1998) was used which included three verbal subtests, (information, arithmetic, vocabulary) and two performance subtests (spatial and object assembly). The five subtests were chosen to obtain maximal differentiation between verbal and performance scales, as the information, arithmetic and vocabulary subtests correlate only moderately with spatial and object assembly (Jackson, 1984). Multidimensional Aptitude Battery subtests had a multiple-

choice format and were timed at 7 min each. Participants were not penalized for guessing and were verbally encouraged by the research assistant to answer every item within the time period, in accord with the administration instructions of the manual (Jackson, 1984). Task specific instructions were provided on screen and scoring was computerized. The verbal and performance scaled scores were analyzed.

Inspection time was tested by a line discrimination task presented as a pseudo-computer game of choosing the longer of two worms to go fishing as previously described (Luciano et al., 2001a). The two lines of comparison were described as worms that would quickly burrow into the ground (i.e., appearance of masking stimulus). The participant's task was to identify the longer worm in an effort to catch the most fish by pressing the corresponding left or right arrow key on the keyboard. Feedback in the form of a fish appeared at the lower left-hand side of the screen following every five correct judgements. The importance of accuracy and not reaction time was stressed verbally by the experimenter prior to beginning the task.

Inspection time was estimated post hoc by fitting a cumulative normal curve (mean = 0) to accuracy as a function of stimulus onset asynchrony (SOA). It is commonly estimated via curve extrapolation so that performance at any desired accuracy level can be attained (Nettelbeck, 1987). The statistic of interest is the standard deviation of the curve, which is the SOA at which 84% accuracy is achieved. Participants whose data provided a poor fit to the cumulative normal curve ($R^2 < 0.95$) were excluded (33 participants, or 2.8% of the sample).

3. Results

3.1. Associations among personality, inspection time and IQ

Maximum likelihood estimates of correlations between the personality measures, inspection time and verbal and performance IQs were obtained using the program, Mx (Neale, 2000). As a twin sample was used, participants were not independently related, so a model was specified in which co-twin correlations were estimated separately for monozygous and dizygous groups with intraindividual correlations between variables equated between co-twins and zygosity groups. A single mean and variance for twin 1 and twin 2 across zygosity was estimated and means were further adjusted for effects of age and sex. Later statistical testing (using the chi-squared, χ^2, difference test) showed within the limited age range of our sample that age did not significantly influence any of the measures, while sex differences were present for all measures except extraversion. Intraindividual correlations between variables were also compared between sex groups using the chi-squared difference test. Hence a model in which correlations were specified separately for females and males was compared to a model in which the correlations were equated between groups. The only correlation to show a difference between sexes was that between neuroticism and verbal IQ, which was significant for females but not males ($\chi^2_1 = 8.71$, $p < 0.01$). Whole sample correlations are presented in Table 1, although means are presented separately for females and males. The only significant correlations between the personality and cognitive measures were of extraversion with verbal and performance IQs, although they accounted for only 1% of variation. Hence, we found only weak evidence for an association between personality and IQ. Correlations between inspection time and IQ were significant and of moderate magnitude.

Table 1
Maximum likelihood correlations between Eysenck Personality Questionnaire scores, inspection time, verbal IQ and performance IQ

	P	E	L	N	IT	VIQ	PIQ	Mean (±SD)	
								Females (N = 515–548)	Males (N = 477–520)
Psychoticism	1							2.29 (1.98)	3.93 (2.43)
Extraversion	0.12*	1						19.43 (4.13)	19.50 (3.65)
Lie	−0.40*	−0.09	1					7.25 (3.58)	6.22 (3.34)
Neuroticism	0.18*	−0.17*	−0.14*	1				11.23 (4.47)	8.70 (4.58)
Inspection time	0.01	0.01	0.04	0.02	1			91.03 (43.93)	84.41 (50.31)
Verbal IQ	−0.05	−0.12*	−0.05	−0.06[a]	−0.27*	1		109 (11)	111 (12)
Performance IQ	−0.02	−0.11*	−0.04	−0.05	−0.36*	0.51*	1	109 (17)	114 (16)

Mean (and standard deviation) for the raw scores of each measure appear beside the correlations, separately for females and males.
* Significant, $p < 0.01$.
[a] Significant difference between female (−0.12) and male (−0.01) correlation.

3.2. Do introverts, ambiverts and extraverts differ on cognitive performance?

To test Robinson's hypothesis that cognitive performance is heightened under conditions of moderate arousal, mean differences between introverts and ambiverts and between ambiverts and extraverts were compared. Extraversion scores followed the same distribution in females and males. Group classification was based on whether scores fell below, within or above ±1 standard deviation from the mean (i.e., ambiverts scoring within 1 SD each side of the mean, introverts and extraverts, respectively, scoring below and above 1 SD from the mean). Hence, the respective range of scores for introverts, ambiverts and extraverts was 0–19, 20–22, and 23–24. The mean scores and standard deviations were highly similar to scores found in other studies, such as Brayne, Do, Green, and Green (1998) with a similar sample of adolescents from the same school district.

We tested whether there were differences in means of the three extraversion categories by modelling introversion and extraversion groups as deviations from the mean of the ambiversion group (since ambiverts were expected to score higher than introverts and extraverts) in Mx. First we fitted a model in which the two deviations for introverts and extraverts were estimated as free parameters; the effect for ambiverts was fixed at zero to ensure identification of the model. This model was then tested against one in which the deviation for the introversion group was fixed to zero, then alternatively, one in which the deviation for the extraversion group was fixed to zero. The difference in $-2 \times \log$ likelihood between each of these models is a χ^2 test with one degree of freedom. A main effect of sex was included in the model and a test of additional extraversion effects in males only was further examined. To account for the relatedness of individuals in the sample, MZ and DZ groups were separately specified so that the co-twin covariation between zygosity groups was free to vary (previous findings for inspection time and IQ confirm that MZ co-twin correlations are greater than DZ co-twin correlations). However, the mean effects of sex and extraversion were constrained equal across zygosity.

Table 2
Mean inspection time, verbal IQ and performance IQ according to extraversion category, separately for first born and second born twins

	Log inspection time (ms)		Verbal IQ		Performance IQ	
	Twin 1	Twin 2	Twin 1	Twin 2	Twin 1	Twin 2
Introverts ($N = 67$–73)	1.86	1.89	113	112	118	116
Ambiverts ($N = 314$–344)	1.91	1.90	109	109	111	110
Extraverts ($N = 103$–124)	1.86	1.90	110	110	112	110

The range of subjects in each twin group is provided for each of the extraversion categories.

We found a difference between introverts and ambiverts for verbal ($\chi^2_1 = 5.38$, $p = 0.02$) and performance IQ ($\chi^2_1 = 6.23$, $p = 0.01$), but not inspection time.

In contrast to Robinson's hypothesis the effect in both variables was for introverts to score higher than the ambiverts (see Table 2) and this effect was the same in females and males. Although not significant, there was a trend for introverts to outperform ambiverts in inspection time.

4. Discussion

The present findings provided little evidence for an association between personality and cognitive ability (inspection time and IQ), the only significant correlation—between extraversion and IQ—explaining just 1% of variance. Hence, there was no indication that personality mediates the observed correlation between inspection time and IQ. Robinson's (1989) hypothesis that ambiverts, who display moderate arousal levels, should outperform introverts and extraverts on the cognitive indices was also not supported.

The correlations between personality dimensions and cognitive measures derived in this study were based on a representative sample of the general population—one of the largest samples used to date. A low but significant negative correlation was demonstrated between extraversion and IQ (verbal and performance) so that introverts tended to score higher than extraverts. While this finding has not received much support from other studies using the Junior Eysenck Personality Questionnaire (Eysenck & Cookson, 1969; Saklofske, 1985), Eysenck originally hypothesised a negative relationship between extraversion and intelligence for individuals in secondary school, with more able students gradually becoming more introverted. As extraversion explained 1% of variance in IQ in our study and since this association is not consistently replicated in other studies, this effect must be considered trivial. While our twin sample allowed us to investigate the genetic and environmental contributions to the observed covariance no genetic analysis was undertaken as the correlation was so low. No other personality dimension significantly correlated with the Multidimensional Aptitude Battery scales, agreeing with some previous findings in which different IQ tests, like the Ravens Progressive Matrices and WAIS-R, were used (Eysenck, 1971; Saklofske & Kostura, 1990).

No significant correlation between any personality dimension with inspection time was found in the present study, supporting previous results of Bates and Eysenck (1993) and Stough et al. (1996), and providing no evidence that personality traits mediate the inspection time—IQ rela-

tionship. However, it is possible that a specific temperament factor such as achievement motivation, which may not be effectively captured by the Eysenckian personality dimensions, plays some role in the variation of cognitive scores or its covariation with inspection time (Howe, 1990).

The second aim of this study was to test Robinson's (1989) arousal theory, which predicts that ambiverts whose function at an intermediate level of arousal will show enhanced cognitive performance. Although this hypothesis was supported by Stough et al. (1996) using the Raven and WAIS-R IQ tests, it was not supported in the present investigation; instead introverts scored higher than ambiverts on verbal and performance IQ. Similarly, for inspection time, no mean differences between introverts, ambiverts and extraverts were found, consistent with Stough et al. (1996) and further invalidating Robinson's hypothesis. The present findings replicate those of Roberts (2002), who showed no evidence of a quadratic relationship between extraversion and ability, and a trend for introverts to perform better on verbal and performance IQ than extraverts and ambiverts.

While it is possible that moderate arousal levels are not the optimal levels for successfully completing simple or complex cognitive tasks, it may be that, in contrast to Eysenck and Eysenck's (1967, 1985) arousal theory, extraversion is not linked to nervous system arousal. Psychophysiological studies have provided both positive (Daruna & Karrer, 1984; Tran, Craig, & McIsaac, 2001; Wilson & Languis, 1990) and negative (Cahill & Polich, 1992; Ditraglia & Polich, 1991; Stenberg, 1994) support for the arousal hypothesis. These contradictory results may be arguably due to the differential responses and coping strategies of extraverts and introverts according to specific task demands and situational variables (Gale, 1986). For instance, test anxiety can influence an individual's cortical arousal level and can thus obscure the effects of extraversion (Eysenck, 1994). Hence, further examination of the extraversion–cortical arousal association is required and future directions of the present study will include a more effective test of Robinson's hypothesis, by introducing a psychophysiological correlate of actual arousal levels of the introverted, ambiverted and extraverted groups. It may be helpful to investigate the relationship of extraversion and electrophysiological indices in a twin sample since the genetic and environmental contributions to this relationship can be addressed, including the overlap due to random/situational events not shared by twin pairs.

In summary, a mediating role of the personality dimensions measured by the Junior Eysenck Personality Questionnaire between inspection time and IQ was not observed (in a large, representative sample of 16 year olds), but should be further investigated with specific temperament factors not captured by the Eysenck personality factors. In addition, Robinson's hypothesis of a quadratic relationship between extraversion and IQ, whereby moderately aroused ambiverts should obtain superior IQ scores was not supported. Instead, introverts outperformed ambiverts and extraverts in verbal and performance IQ, raising questions about the influence of differential task and situational demands on the personality types. In future investigations, the specific relationship between extraversion and cerebral arousal should be established by psychophysiological means, as there is doubt to whether extraversion is indeed an index of nervous system arousal.

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