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Personality and physiological reactions to acute psychological stress

Adam Bibbey [a,*], Douglas Carroll [a], Tessa J. Roseboom [b,c], Anna C. Phillips [a], Susanne R. de Rooij [b]

[a] School of Sport and Exercise Sciences, University of Birmingham, Birmingham, United Kingdom
[b] Department of Clinical Epidemiology and Biostatistics, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands
[c] Department of Obstetrics and Gynaecology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands

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ABSTRACT

Stable personality traits have long been presumed to have biological substrates, although the evidence relating personality to biological stress reactivity is inconclusive. The present study examined, in a large middle aged cohort ($N = 352$), the relationship between key personality traits and both cortisol and cardiovascular reactions to acute psychological stress. Salivary cortisol and cardiovascular activity were measured at rest and in response to a psychological stress protocol comprising 5 min each of a Stroop task, mirror tracing, and a speech task. Participants subsequently completed the Big Five Inventory to assess neuroticism, agreeableness, openness to experience, extraversion, and conscientiousness. Those with higher neuroticism scores exhibited smaller cortisol and cardiovascular stress reactions, whereas participants who were less agreeable and less open had smaller cortisol and cardiac reactions to stress. These associations remained statistically significant following adjustment for a range of potential confounding variables. Thus, a negative personality disposition would appear to be linked to diminished stress reactivity. These findings further support a growing body of evidence which suggests that blunted stress reactivity may be maladaptive.

1. Introduction

It is now commonly known that individuals vary markedly in the way their body reacts to stressful and challenging environmental exposures (Carroll, 1992). Consistent individual differences in stress reactivity have been observed in the hypothalamic–pituitary–adrenal (HPA) axis, as indexed by cortisol, and in the sympathetic–adrenal–medullary (SAM) system, as indexed by cardiovascular activity (Lovallo, 1997). It is also clear that these individual differences have implications for health and behaviour (Carroll et al., 2009; Chida and Steptoe, 2010). For example, greater cortisol and cardiovascular reactivity to acute stress has been associated with increased risk of cardiovascular disease (Carroll et al., 2011a; Chida and Steptoe, 2010; Hamer et al., 2010; Treiber et al., 2003). In contrast, however, recent evidence also implicates diminished cortisol and cardiovascular reactions in a range of adverse health and behavioural outcomes, such as smoking, alcohol dependence, obesity, and depression (Carroll et al., 2009, 2011b). What is less certain is whether individual differences in biological stress reactivity reflect consistent variations in basic human personality traits. Early research on Type A behaviour and stress reactivity proved inconclusive (Carroll, 1992), although there is evidence that one component of the Type A behaviour, hostility, is associated with greater cortisol and cardiovascular reactions to stress, e.g., (Smith et al., 2004). However, this is not a completely consistent finding (Carroll et al., 1997). There is, nevertheless, compelling theoretical reasons for expecting the variations in stress reactivity to map on to individual differences in personality traits; if personality, as has been proposed, affects stress perception (Connor-Smith and Flachsbart, 2007), cognitive stress theories and previous research would suggest it should also affect biological stress reactions (Carver and Connor-Smith, 2010; Dickerson and Kemeny, 2004; Lazarus, 1996).

Recent research on personality has frequently turned to the Big Five trait taxonomy which identifies five broad personality dimensions; neuroticism, agreeableness, openness, extraversion, and conscientiousness (McCrae and Costa, 1987). Each trait has demonstrated high stability for up to 45 year intervals (Soldz and Vaillant, 1999; Terracciano et al., 2006). Neuroticism refers to a tendency toward negative affectivity and an inclination toward impulsive behaviour. Agreeableness connotes a willingness to be helpful and trusting, and to possess a pro-social orientation towards others. Individuals high in openness to experience tend to be imaginative, creative, attentive to inner feelings, prefer variety, and are flexible in their thinking. Extraversion refers to the inclination to be energetic, sociable, and assertive, and conscientiousness encompasses organization, self-discipline, and determination (McCrae and John, 1992).

Higher neuroticism has been associated with lower cortisol stress reactivity (Kirschbaum et al., 1993; Oswald et al., 2006; Phillips et al., 2005) although it should be conceded that numerous studies reported no association between neuroticism and cortisol reactions to a range of stress exposures (Kirschbaum et al., 1992, 1995; Schommer et al., 1999; Verschoor and Markus, 2011; Wirtz et al., 2007). Nevertheless, in

* Corresponding author at: School of Sport and Exercise Sciences, University of Birmingham, Birmingham, B15 2TT, United Kingdom. Tel.: +44 121 415 8785; fax: +44 121 414 4121.
E-mail address: axb790@bham.ac.uk (A. Bibbey).

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support of the evidence suggesting higher neuroticism is linked to blunted physiological stress responses, a meta-analysis of 71 laboratory studies concluded that neuroticism, anxiety, and negative affect tended to be linked to attenuated cardiovascular stress reactivity (Chida and Hamer, 2008), with more recent studies reporting blunted heart rate (HR) (Hughes et al., 2011) and diastolic blood pressure (DBP) stress responses (Jonassaint et al., 2009) in highly neurotic individuals. Again, however, a number of studies have also reported no association between neuroticism and cardiovascular stress reactions (Hutchinson and Ruiz, 2011; Kirkcaldy, 1984; Schneider, 2004; Stemmler and Meinhardt, 1990; Williams et al., 2009). It is important to note that such null findings between neuroticism and physiological stress reactivity may well have been due to low power (Kirschbaum et al., 1995), restricted range (Schommer et al., 1999; Wirtz et al., 2007) or arbitrary categorization of neuroticism scores (Hutchinson and Ruiz, 2011), examination of anticipatory rather than stress reactions (Verschoor and Markus, 2011), insufficiently provocative stress exposures (Kirkcaldy, 1984; Williams et al., 2009), or a host of other methodological issues (Stemmler and Meinhardt, 1990). Therefore, due to these methodological flaws, evidence may well suggest that high levels of neuroticism are related to blunted biological stress reactivity.

The other personality traits of the Big Five have received far less attention in this context. For agreeableness, null findings have been reported for cortisol (Oswald et al., 2006; Wirtz et al., 2007) and cardiovascular (Williams et al., 2009) stress reactivity. Openness has been reported to show a positive (Oswald et al., 2006), negative (Wirtz et al., 2007), and no (Schoofs et al., 2008) association with cortisol stress reactivity. In the one study we know of examining the relationship between cardiovascular stress reactivity and openness, a negative association emerged for blood pressure reactivity (Williams et al., 2009). Research on extraversion has generally yielded null outcomes for both cortisol (Kirschbaum et al., 1992; Schommer et al., 1999; Wirtz et al., 2007) and cardiovascular (Kirkcaldy, 1984; Vassend and Knardahl, 2005; Williams et al., 2009) stress reactivity. Finally, null findings also characterise the few studies that have examined conscientiousness and cortisol (Oswald et al., 2006; Wirtz et al., 2007) and cardiovascular (Williams et al., 2009) reactions to stress.

Previous research on personality and biological stress reactivity suffers from a number of limitations. Among them are small sample sizes (Kirschbaum et al., 1995; Oswald et al., 2006; Wirtz et al., 2007), the predominance of young student samples (Kirschbaum et al., 1992; Verschoor and Markus, 2011; Williams et al., 2009), restricted range of trait scores (Schommer et al., 1999; Wirtz et al., 2007), dichotomised trait variables (Kirkcaldy, 1984), and the failure to adjust statistically for a range of possible confounding variables (Williams et al., 2009; Wirtz et al., 2007). The aim of the present study was to re-examine, in a large middle aged cohort, the relationship between the Big Five personality traits and both cortisol and cardiovascular reactions to a comprehensive stress protocol comprising three acute psychological stress tasks. The nature of the study allowed us to adjust for a number of potential confounders. In addition, examination of the self reported stress task impact will also extend the previous literature, and possibly shed light on the psychological mechanisms linking the personality traits to physiological stress reactions. It was hypothesized that neuroticism would be negatively associated with both cortisol and cardiovascular stress reactivity. Given the paucity and inconsistency of previous research, we had no clear expectations regarding the size and the direction of any association between stress reactivity and the other personality traits that make up the Big Five.

2. Materials and methods

2.1. Participants

Participants were selected from the Dutch Famine Birth Cohort, which comprises 2414 men and women who were born in Amsterdam, The Netherlands, between November 1943 and February 1947. The selection procedures and subsequent loss to follow up have been described in detail elsewhere (Painter et al., 2005). The Dutch Famine Birth Cohort Study was designed to investigate the potential consequences of prenatal exposure to famine on health in later life. It might, therefore, be suggested that population characteristics may hamper generalization of the present analyses. However, this is very unlikely as health effects pertain in the group of people exposed to famine in early gestation (Roseboom et al., 2006). Only 8% of the total study sample and 9.5% ($N=37$) of the present sample were exposed to famine in early gestation. Nevertheless, we chose to exclude them to prevent any possible contamination. Seven hundred and twenty five of the sample attended a clinic assessment between 2002 and 2004, during which time cortisol and cardiovascular reactions to acute psychological stress were measured. In 2008–2009, participants were asked to complete a questionnaire package which included the Big Five Inventory (BFI) (Denissen et al., 2008). Six hundred and one participants returned the questionnaires. The effective sample size for the present analyses, i.e., cohort members who undertook stress testing and completed the Big Five, was 352 (190 women). The mean (SD) temporal lag between the questionnaire assessment and the stress session was 5.5 (0.6) years. Both arms of study were approved by the local Medical Ethics Committee and carried out in accordance with the Declaration of Helsinki. All participants gave written informed consent. The sociodemographic, anthropometric, health behaviour and medication status characteristics of the effective sample are shown in Table 1.

2.2. Psychological stress testing

The stress protocol has been described in detail elsewhere (de Rooij et al., 2006) and is illustrated in Fig. 1. In short, the stress testing was performed in the afternoon, about an hour after participants had eaten a light lunch. The protocol started with a 20-minute baseline period, followed by three 5-minute psychological stress tests (Stroop, mirror tracing, and speech); the inter-task interval was 6 min. The final task, the speech, was followed by a 30-min recovery period. The Stroop test was a single trial computerized colour–word conflict challenge. After a short introduction, participants were allowed to practice until they fully understood the requirements of the task. Errors and exceeding the response time limit of 5 s triggered a short auditory beep. In mirror tracing, a star had to be traced that could only be seen in mirror image (Lafayette Instruments Corp, Lafayette, IN, USA). Every divergence from the line of the star induced a short beep. In the speech test, participants were told to imagine being accused of pick-pocketing and instructed to give a 3-minute defence of the accusation, which was videotaped. They were given 2 min to prepare their defence. Participants were told that the number of repetitions, eloquence, and persuasiveness of their performance would be marked by a team of communication-experts and psychologists.

Saliva samples were collected using Salivettes (Sarstedt, Rommelsdorf, Germany) at seven time points during the protocol: at 5 and 20 min in the baseline period; at 6 min after completion of the Stroop; at 6 min after completion of the mirror-drawing test; and

Table 1
Characteristics of final sample at clinic assessment ($N=352$).

Variable	M/N	SD/%
Age (years)	58.23	0.95
Sex (female)	190	52.5
Socio-economic status (ISEI-92)	51.29	13.64
Body mass index (kg/m^2)	28.76	4.90
Alcohol (units of per week)	9.83	15.01
Current smoker	74	20.5
Anti-hypertensive medication	96	26.5
Anti-depressant or anxiolytic	45	12.4

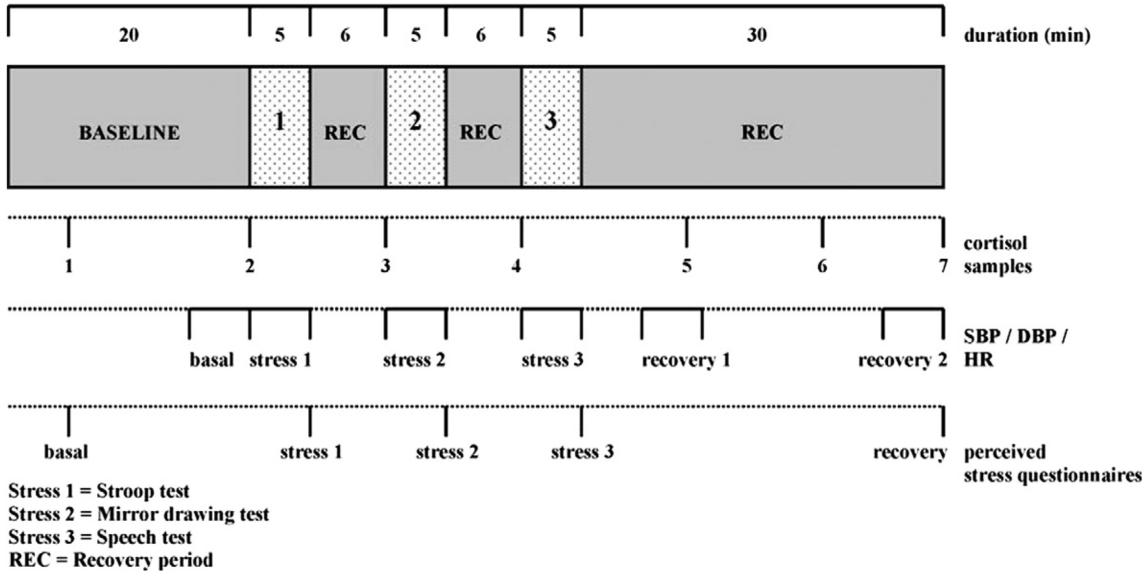

Fig. 1. Schematic representation of the psychological stress protocol.

at 10, 20 and 30 min after completion of the speech test. Salivary cortisol concentrations were measured using a time-resolved immunofluorescent assay (DELFIA) (Wood et al., 1997). The assay had a lower detection limit of 0.4 nmol/l and an inter-assay variance of 9–11% and an intra-assay variance of less than 10%. Continuous blood pressure (BP) and HR recordings were made using a Finometer or a Portapres Model-2 (Finapres Medical Systems, Amsterdam, Netherlands). There were no differences in measurements between the two instruments. We designated four 5-minute periods as the key measurement periods: baseline (15 min into the baseline period), and the 5 min each of Stroop, mirror-tracing, and speech (including preparation time) exposure. We calculated mean systolic blood pressure (SBP), DBP, and HR for each measurement period. A questionnaire was completed after each of the stress tasks which included questions on stress task commitment, perceived stressfulness, stress task difficulty, and perceptions of control. Answers for each item were given on a 7-point scale with scores ranging from 1 (not at all) to 7 (very much); thus, overall item scores could range from 3 to 21.

2.3. Personality

We used a Dutch validated translation of the BFI (Denissen et al., 2008). The BFI is based on an established and well-validated model of personality. The inventory comprised five scales with a variable number of items to be self-rated on a 5-point Likert scale ranging from strongly disagree to strongly agree (John and Srivastava, 1999). The five scales include: neuroticism (8 items, scores range from 8 to 40), extraversion (8 items, scores range from 8 to 40), agreeableness (9 items, scores range from 9 to 45), conscientiousness (9 items, scores range from 9 to 45) and openness to experience (10 items, scores range from 10 to 50). In the present study, Cronbach's α was 0.86 for neuroticism, 0.80 for extraversion, 0.75 for agreeableness, 0.77 for conscientiousness and 0.81 for openness, indicating good internal consistency for all scales.

2.4. Other study parameters

In the 2002–2004 study, height was measured twice using a fixed or portable stadiometer and weight twice using Seca and portable Tefal scales. Body mass index (BMI) in kg/m^2 was computed from the averages of the two height and weight measurements. A standardized interview was performed in which information was obtained about socio-economic status (SES), lifestyle, and use of medication. Alcohol consumption was represented as the number of units of alcohol consumed per week and smoking behaviour was characterised as current, ex-, and never smoker. Medication status (antihypertensive, antidepressant, and anxiolytic use) was determined by questioning followed by medication check. Two binary variables were derived: taking versus not taking anti-hypertensive medication, taking versus not taking either anti-depressant or anti-anxiolytic medication. We defined current SES according to International Socio-Economic Index (ISEI)-92, which is based on the participant's or their partner's occupation, whichever status is higher (Bakker and Sieben, 1997). Measured values on the ISEI-92 scale ranged from 16 (low status, e.g. a cleaning person) to 87 (high status, e.g. a lawyer).

2.5. Statistical analyses

Baseline cortisol was calculated as the mean of the two cortisol concentration measurements during the baseline period. The cortisol concentrations of the fifth and sixth samples, i.e., those taken 10 min and 20 min following stress exposure, were used to determine cortisol stress reactivity. These were the peak cortisol values in the present study and these time lags also characterise peak response in other stress research (for review see: Dickerson and Kemeny, 2004). These values were averaged and baseline cortisol subtracted to yield the stress reactivity values. Baseline cardiovascular activity was the average of values recorded in the 5-minute period 15 min into the baseline. SBP, DBP, and HR measures were averaged across each of the three stress tasks, and the mean of these three averages then determined. Cardiovascular stress reactivity was defined in each case as the difference between the overall stress mean value and baseline for each of the three cardiovascular variables. We calculated a total perceived task commitment score by adding the scores on the questionnaires performed after each stress task.

We applied linear regression analyses to analyse the associations between personality traits and stress reactivity. For all five personality traits, we first tested an unadjusted model, followed by a model adjusting for sex, age and SES and, finally, a model which additionally adjusted for alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline cortisol/cardiovascular activity (as appropriate). In the adjusted models, a hierarchical approach was followed in which the covariates were entered at Step 1 and the

Table 2
Mean (SD) cortisol and cardiovascular activity at baseline and following, and in the case of cardiovascular during, stress task exposure.

	Cortisol nmol/l	HR bpm	SBP mm Hg	DBP mm Hg
Baseline	4.70 (3.22)	73.63 (10.11)	128.36 (19.80)	67.09 (11.78)
Stress	6.32 (4.48)	81.87 (13.65)	160.31 (26.20)	80.19 (11.98)

All stress measures were significantly different from baseline for each variable, $p<.001$.

personality variables individually at Step 2. Correlation analyses were run to determine the associations between each of the personality traits as well as their association with self reported stress task impact variables.

3. Results

3.1. Physiological stress reactions

Summary baseline and stress task physiological data are presented in Table 2. Cortisol concentrations increased following stress task exposure, F (1,266) = 41.64, $p<.001$, $\eta^2=.135$. The stress tasks also reliably perturbed SBP, F (1,351) = 1302.48, $p<.001$, $\eta^2=.788$, DBP, F (1,351) = 314.62, $p<.001$, $\eta^2=.473$, and HR, F (1,350) = 110.56, $p<.001$, $\eta^2=.240$.

3.2. Big Five personality traits

The summary personality trait statistics are presented in Table 3. Neuroticism was negatively associated with the other four traits which were all positively related to each other. Although highly significant, the correlation coefficients were generally small to moderate in size.

3.3. Personality and self reported stress task impact

The summary statistics for stress task impact are reported in Table 4. The stress tasks were regarded as moderately stressful and difficult, and participants did not perceive themselves as being particularly in control. However, they regarded themselves as being strongly committed to the tasks. Those scoring high in neuroticism perceived the stress tasks as more stressful, r = .26, $p<.001$, and more difficult, r = .32, $p<.001$. They also regarded themselves as less in control, r = −.30, $p<.001$. There was no association between neuroticism and stress task commitment. Those scoring high on openness and extraversion, in contrast, found the tasks less stressful, r = −.14, $p=.01$ and r = −.16, $p=.002$ respectively, and less difficult, r = −.23, $p<.001$ and r = −.20, $p<.001$ respectively. They also felt in greater control, r = .24, $p<.001$ and r = .16, $p=.002$ respectively. Neither openness nor extraversion was associated with commitment to the stress task. No other associations of note emerged from these analyses.

3.4. Personality and cortisol stress reactivity

In the unadjusted regression, neuroticism and cortisol reactivity were negatively associated whereas agreeableness and openness were positively associated with cortisol reactivity. No associations with cortisol reactivity emerged for extraversion and conscientiousness. The regression models for neuroticism, agreeableness, and openness are summarized in Table 5. In regression models adjusting for sex, age, and SES, high neuroticism, low agreeableness, and low openness continued to be related to low cortisol reactivity. In models that additionally adjusted for alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline cortisol activity, similar outcomes emerged. In addition the associations emerging from these fully adjusted models are illustrated in Fig. 2 where tertiles of personality trait are plotted against cortisol stress reactions. Fig. 2 indicates that whereas high neuroticism was associated with low reactivity, low agreeableness and openness were associated with low reactivity. In the fully adjusted models, sex and baseline cortisol were also associated with cortisol reactivity; women and those with higher cortisol baseline concentrations exhibited lower cortisol stress reactions.

Table 4
Self reported impact of the stress task.

Variable	Mean (SD)
Commitment	14.80 (4.10)
Stressfulness	11.09 (4.05)
Difficulty	14.38 (3.54)
Control	10.20 (3.61)

Answers for each item given on a 7-point scale with scores ranging from 1 (not at all) to 7 (very much); thus, overall item scores could range from 3 to 21.

3.5. Personality and cardiovascular stress reactivity

As was the case with cortisol reactivity, HR reactivity was consistently associated with neuroticism, agreeableness and openness. The unadjusted regression model revealed that high neuroticism, low agreeableness, and low openness were related to low HR reactivity. The associations for neuroticism, agreeableness, and openness withstood adjustment for sex, age and SES, and for the additional variables included in the fully adjusted model. These outcomes are summarized in Table 6. Again, conscientiousness and extraversion were not related to HR reactivity. Fig. 3 illustrates these associations from the fully adjusted regression models, by plotting tertiles of neuroticism, agreeableness and openness against HR reactivity.

Neuroticism was the only personality trait that was consistently associated with SBP and DBP reactivity. A summary of the outcomes for regression analysis involving neuroticism, agreeableness, and openness is provided in Table 7. In the unadjusted models, neuroticism was negatively associated, whereas openness was positively associated with SBP reactivity. Agreeableness, extraversion, and conscientiousness were not related to SBP reactivity. In the models adjusting for sex, age and SES, neuroticism was still negatively associated with SBP reactivity but the association between openness and SBP reactivity was attenuated to non-significance. The negative association between neuroticism and SBP reactivity was still evident in the fully adjusted regression model. As illustration, Fig. 4 plots tertiles of neuroticism against SBP reactivity for the fully adjusted model. In the unadjusted regression model, the model that adjusted for sex, age and SES, and the fully adjusted model,

Table 3
Association among the Big Five personality traits.

Characteristic		Extraversion	Agreeableness	Conscientiousness	Openness
	Mean (SD)				
Neuroticism	20.33 (5.75)	−.45	−.33	−.25	−.36
Extraversion	28.11 (5.11)		.29	.39	.44
Agreeableness	33.54 (4.79)			.26	.19
Consciousness	33.99 (4.76)				.26
Openness	34.62 (5.88)				

All correlations between personality traits were statistically significant, $p<.001$.

Table 5
Regression models for neuroticism, agreeableness, conscientiousness and cortisol reactivity.

	β	t	*p*	R^2
Neuroticism and cortisol reactivity				
Unadjusted model	−.19	3.20	.002	.035
Adjusted 1	−.14	2.30	.02	.018
Adjusted 2	−.14	2.27	.02	.016
Agreeableness and cortisol reactivity				
Unadjusted model	.15	2.49	.01	.021
Adjusted 1	.16	2.75	.006	.025
Adjusted 2	.16	2.73	.007	.023
Openness and cortisol reactivity				
Unadjusted model	.19	3.31	.001	.037
Adjusted 1	.15	2.51	.01	.021
Adjusted 2	.13	2.21	.03	.015

Adjusted model 1 = adjustment for sex, age and SES; Adjusted model 2 = additional adjustment for alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline cortisol.

Table 6
Regression models for neuroticism, agreeableness, conscientiousness and HR reactivity.

	β	t	*p*	R^2
Neuroticism and HR reactivity				
Unadjusted model	−.20	3.89	<.001	.042
Adjusted 1	−.19	3.55	<.001	.034
Adjusted 2	−.15	2.65	.008	.019
Agreeableness and HR reactivity				
Unadjusted model	.12	2.21	.03	.014
Adjusted 1	.12	2.15	.03	.013
Adjusted 2	.11	2.05	.04	.012
Openness and HR reactivity				
Unadjusted model	.17	3.15	.002	.028
Adjusted 1	.14	2.63	.01	.020
Adjusted 2	.11	2.00	.05	.011

HR = heart rate; Adjusted model 1 = adjustment for sex, age and SES; Adjusted model 2 = additional adjustment for alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline HR.

high neuroticism scores were related to low DBP stress reactivity. The fully adjusted association is illustrated in Fig. 4. None of the other personality characteristics were related to DBP stress reactivity.

In these fully adjusted models, smoking was also associated with SBP, DBP, and HR reactivity; current smokers exhibited smaller reactions. BMI was also associated with HR reactivity; those with higher BMI values were characterised by smaller HR reactions.

4. Discussion

The present study examined, in a large middle aged cohort, the relationship between the Big Five personality traits and both cortisol and cardiovascular reactions to acute psychological stress. Individuals scoring higher on neuroticism and lower on agreeableness and openness had smaller cortisol stress reactions. These associations remained statistically significant following adjustment for a range of potential confounders: sex, age, SES, alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline cortisol activity. Neuroticism was also negatively associated with SBP, DBP, and HR stress reactivity, and these associations also survived full statistical adjustment. Agreeableness and openness were positively associated with HR reactivity in all the regression models tested. Extraversion and conscientiousness were not related to either cortisol or cardiovascular stress reactivity. Thus, it would appear that a negative constellation of personality traits, i.e., higher neuroticism, but lower agreeableness and openness, was associated with diminished stress reactions both of the cardiovascular system and the HPA axis.

The low cortisol reactivity observed in individuals with high neuroticism scores is in accordance with findings from previous research (Kirschbaum et al., 1993; Oswald et al., 2006; Phillips et al., 2005). Similarly, the present observation that low cardiovascular stress reactivity characterises those with high neuroticism scores is also not without precedent (Hughes et al., 2011; Jonassaint et al., 2009). Indeed, from a recent meta-analysis of 71 laboratory studies, it was concluded that neuroticism, anxiety, and negative affect were associated with blunted rather than exaggerated cardiovascular reactions to acute stress (Chida and Hamer, 2008). The current study, then, adds further weight to the proposition that neuroticism is characterised by blunted reactions to acute stress exposure. As previously suggested, null findings for cortisol (Kirschbaum et al., 1992, 1995; Schommer et al., 1999; Verschoor and Markus, 2011; Wirtz et al., 2007) and cardiovascular (Hutchinson and Ruiz, 2011; Kirkcaldy, 1984; Schneider, 2004; Stemmler and Meinhardt, 1990; Williams et al., 2009) stress reactivity may well have been due to a variety of limitations including low power (Kirschbaum et al., 1995), insufficiently provocative stress exposures (Kirkcaldy, 1984; Williams et al., 2009), arbitrary categorization (Hutchinson and Ruiz, 2011) or restricted range (Schommer et al.,

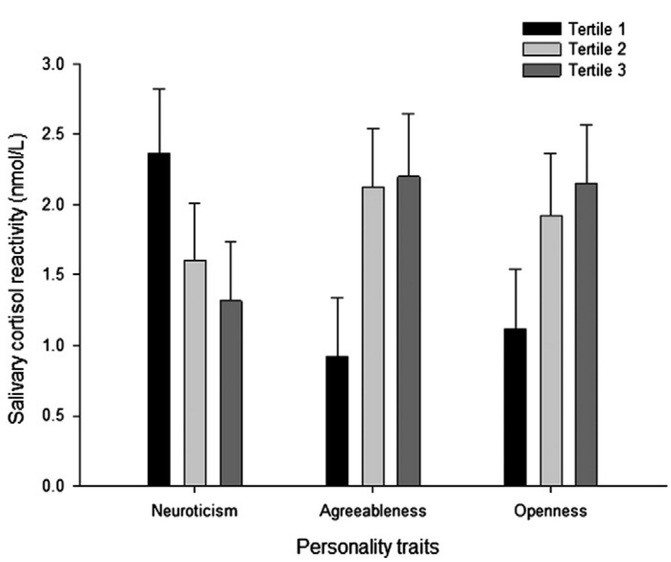

Fig. 2. Mean (SE) salivary cortisol reactivity by tertiles of neuroticism, agreeableness and openness.

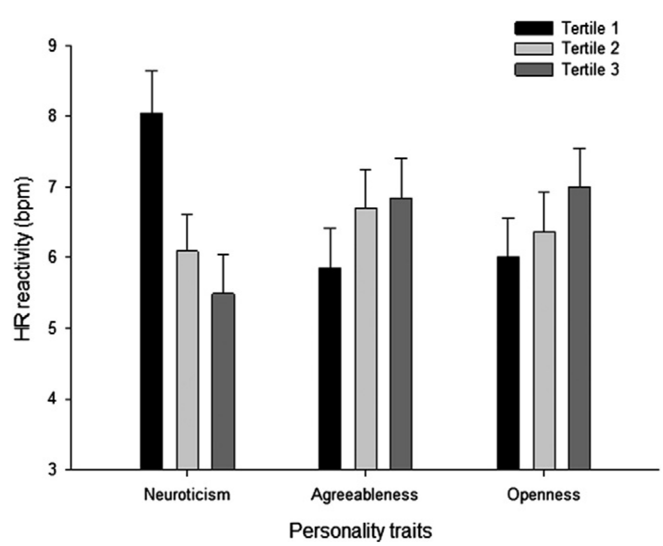

Fig. 3. Mean (SE) heart rate reactivity by tertiles of neuroticism, agreeableness and openness.

Table 7
Regression models for neuroticism, agreeableness, conscientiousness and SBP and DBP reactivity.

	β	t	*p*	R^2
Neuroticism and SBP reactivity				
Unadjusted model	−.16	2.99	.003	.025
Adjusted 1	−.13	2.40	.02	.016
Adjusted 2	−.12	2.18	.03	.014
Agreeableness and SBP reactivity				
Unadjusted model	.08	1.58	.12	.007
Adjusted 1	.08	1.49	.14	.006
Adjusted 2	.09	1.53	.13	.007
Openness and SBP reactivity				
Unadjusted model	.11	1.98	.05	.011
Adjusted 1	.07	1.32	.19	.005
Adjusted 2	.08	1.32	.19	.005
Neuroticism and DBP reactivity				
Unadjusted model	−.15	2.88	.004	.023
Adjusted 1	−.15	2.73	.007	.021
Adjusted 2	−.14	2.43	.02	.017
Agreeableness and DBP reactivity				
Unadjusted model	.09	1.63	.11	.008
Adjusted 1	.08	1.38	.17	.006
Adjusted 2	.08	1.34	.18	.005
Openness and DBP reactivity				
Unadjusted model	.10	1.94	.06	.008
Adjusted 1	.09	1.54	.12	.007
Adjusted 2	.08	1.42	.16	.014

SBP = systolic blood pressure; DBP = diastolic blood pressure; Adjusted model 1 = adjustment for sex, age and SES; Adjusted model 2 = additional adjustment for alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived commitment to the stress task, and baseline SBP/DBP activity (as appropriate).

1999; Wirtz et al., 2007) of neuroticism scores (Hutchinson and Ruiz, 2011), examination of anticipatory rather than stress reactivity (Verschoor and Markus, 2011), or a range of other methodological issues (Stemmler and Meinhardt, 1990).

The diminished cortisol stress reactivity shown by individuals low on openness is in line with the results of some (Oswald et al., 2006) but not all (Schoofs et al., 2008; Wirtz et al., 2007) previous research. To the best of our knowledge the present study is the first to demonstrate that openness is positively associated with HR reactivity, with one previous study reporting no association (Williams et al., 2009). Further, in contrast to previous research which failed to find an association with cortisol (Oswald et al., 2006; Wirtz et al., 2007) or cardiovascular reactivity (Williams et al., 2009), low agreeableness in the present study was associated with attenuated cortisol, as well as HR, stress reactions. Again, previous null findings in the field (Oswald et al., 2006; Schoofs et al., 2008; Wirtz et al., 2007) may be attributed to low power and other methodological issues. The absence of an association between extraversion or conscientiousness and cortisol (Kirschbaum et al., 1992; Oswald et al., 2006; Schommer et al., 1999; Wirtz et al., 2007) or cardiovascular (Kirkcaldy, 1984; Vassend and Knardahl, 2005; Williams et al., 2009) stress reactivity is a common outcome. It is proposed that emotionally relevant stressors may be required to reveal any effects of extraversion (Jonassaint et al., 2009), with effects for conscientiousness dependent upon the degree of control afforded during stress exposure (Hogan and Ones, 1997).

The reason that HR reactivity is more broadly associated with personality than blood pressure reactivity may reflect the fact that the former more closely reflects β-adrenergic activation. Sympathetic nervous system blockade studies indicate that cardiac reactivity closely reflects β-adrenergic activation, with indices of cardiac reactivity more sensitive to β-adrenergic blockade than blood pressure reactivity (Sherwood et al., 1986; Winzer et al., 1999). Although it has been proposed that β-adrenergic and HPA axis activation can be dissociated under some circumstances (Dickerson and Kemeny, 2004; Frankenhaeuser, 1982), substantial evidence demonstrates that they frequently co-vary, such that variations in the magnitude of β-adrenergic system reactions to acute stress, as indexed by cardiac reactivity, predict subsequent variation in HPA axis reactions, as indexed by cortisol reactivity (al'Absi et al., 1997; Bosch et al., 2009; Cacioppo, 1994).

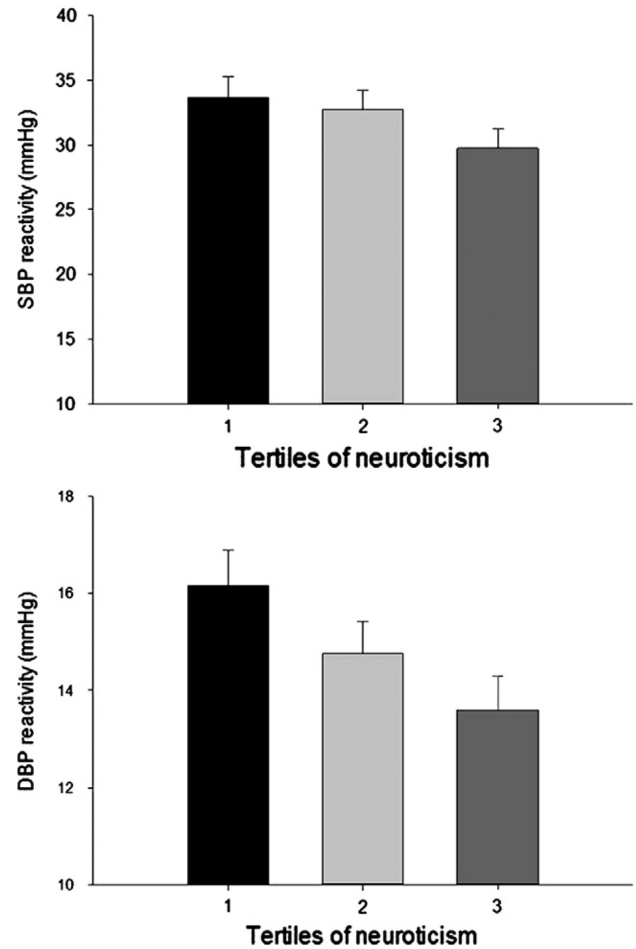

Fig. 4. Mean (SE) systolic and diastolic blood pressure reactivity by tertiles of neuroticism.

Examination of the associations between personality and the self reported stress task impact may also shed light on potential psychological mechanisms linking personality traits to physiological stress reactivity. Regarding neuroticism there would appear to be a paradox. Despite higher neuroticism being associated with greater perceptions of task stressfulness and difficulty, and lower feelings of control, those high in neuroticism exhibited blunted biological stress reactions. Previous research reporting attenuated cortisol and cardiovascular stress reactions in individuals exposed to high levels of chronic stress (Kudielka et al., 2009; Melamed et al., 2006) may help explain the blunted acute stress reactions in the context of greater threat perception in highly neurotic individuals (Schneider et al., 2012). Personality is proposed to be an enduring trait (Soldz and Vaillant, 1999; Terracciano et al., 2006). Thus, neurotic individuals will experience maladaptive psychological states, high subjective stress and low feelings of control, each time they encounter acute stress. Over time, this would amount to something similar to the experience of chronic stress and contribute to blunted physiological stress reactivity as a result of "allostasis": a down-regulation of the HPA axis and autonomic nervous system that impairs the physiological stress reactions to the acute challenges of daily life (McEwen, 1998, 1999). In support, the current findings emerged in a middle aged sample, one where there was presumably scope for prolonged personality effects on stress experience and, thus, on subsequent "allostasis". It is important to note here that studies examining young student samples are prominent among those reporting no association between neuroticism and reactivity (Kirschbaum et al., 1992; Verschoor and Markus, 2011; Williams et al., 2009).

A dissociation between subjective and physiological stress reactions was also apparent for openness. Those scoring higher in openness reported the stress tasks as less stressful and difficult, and reported greater feelings of control, despite displaying higher cortisol and HR reactions. This dissociation may have been due to greater emotional suppression in highly open individuals as attention to inner feelings is a proposed component of openness (McCrae and John, 1992). Accordingly, individuals high in openness may have been attempting to avoid a vulnerable emotional state marked by feelings of stress, difficulty, and lack of control, as indicated in their subjective task ratings. Indeed, emotional suppression has been linked to greater physiological stress reactivity (Gross, 2002). Conversely, as greater openness to experience would suggest a propensity to relish and enjoy a variety of tasks (McCrae and John, 1992), in this case the stress tasks, highly open individuals may have experienced the more adaptive affective responses. A recent review suggests that there is often a dissociation between affective and physiological stress reactions (Campbell and Ehlert, 2012). The results of the present study add further support and suggest that the drivers of subjective stress reactions are different from those that drive physiological stress reactivity.

Given their implications for health and behaviour, it is important to identify the factors which contribute to the individual variation in the magnitude of HPA axis and cardiovascular stress reactivity (Bale, 2006; Uchino et al., 2007). Greater cortisol reactivity to acute stress has been associated with coronary artery calcification (Hamer et al., 2010), potentially increasing cardiovascular disease risk (Girod and Brotman, 2004); with hypercortisolism possibly also involved in the pathogenesis of mood and anxiety disorders (Holsboer, 2000; Susman et al., 2010; Young et al., 2000) and increased inflammatory disease susceptibility (Mason, 1991). Similarly, large magnitude cardiovascular stress reactions have been associated with cardiovascular disease pathology, such as hypertension, markers of systemic atherosclerosis, and left ventricular hypertrophy, e.g., (Carroll et al., 2011a; Chida and Steptoe, 2010; Treiber et al., 2003).

However, recent evidence indicates that attenuated cortisol and cardiovascular stress reactions are also associated with a range of adverse health and behavioural outcomes (Carroll et al., 2009, 2011b). Blunted cortisol and cardiovascular stress reactions have shown cross-sectional and prospective associations with lower self-reported health (de Rooij and Roseboom, 2010; Phillips et al., 2009), obesity (Carroll et al., 2008; Phillips et al., 2012), tobacco, alcohol, and substance dependence along with addiction risk (for a review see: Lovallo, 2007), and more recently exercise dependence (Heaney et al., 2011), risk of re-offending in delinquents (De Vries-Bouw et al., 2011), and disordered eating behaviour (Ginty et al., 2012). Further, depressed individuals have shown diminished cortisol (de Rooij et al., 2010; Taylor et al., 2006; Young et al., 2000) and cardiovascular (de Rooij et al., 2010; Phillips et al., 2011; Salomon et al., 2009; Schwerdtfeger and Rosenkaimer, 2011) reactions to stress. On the basis of such results, it has been hypothesized that blunted physiological reactivity to stress may be a peripheral marker of dysregulation in the brain systems that support motivation (Carroll et al., 2009, 2011b; Lovallo, 2011). The present finding that negative personality characteristics are associated with blunted stress reactivity is certainly in keeping with this hypothesis. After all, such characteristics have been linked to many of the adverse health and behavioural outcomes associated with blunted stress reactivity e.g., depression (Bienvenu et al., 2004), poor self-reported health (Vassend and Skrondal, 1999), obesity (Sutin et al., 2011), disordered eating and exercise dependence (Bamber et al., 2000; Bulik et al., 2006; Cassin and von Ranson, 2005), and tobacco, alcohol, and substance dependence or addiction risk (Martin and Sher, 1994; Munafo et al., 2007; Terracciano and Costa, 2004; Terracciano et al., 2008). Dysregulation of the neural systems that support motivation have been proposed to play a role in all of these outcomes (Carroll et al., 2009, 2011b; Lovallo, 2011), as well as in determining personality (Cremers et al., 2010; DeYoung and Gray, 2009).

The present study is not without its limitations. First, personality traits and physiological stress reactivity were measured on average 5.5 years apart. However, these traits have been found to demonstrate high temporal stability across 45 years (Soldz and Vaillant, 1999; Terracciano et al., 2006). Second, personality assessments relied on self-report and, accordingly, the social desirability of reporting a positive constellation of personality traits may have influenced our findings. However, this seems unlikely. Self-reported traits have proved to be strong predictors of actual behaviour and have shown high correlations with personality ratings provided by spouses, peers and experts (Fleeson and Gallagher, 2009; McCrae, 1991). Third, it is not possible to determine causality or direction of causality from observational analyses, and confounding by some unmeasured variable can never be wholly discounted (Christenfeld et al., 2004). Nevertheless a strength of the current study was that we were able to adjust statistically for an extensive range of potential confounders, many more than previous studies. Fourth, the observed effect sizes were small. The effect sizes were nonetheless comparable though to those observed for other variables known to affect cortisol and cardiovascular stress reactivity (Carroll et al., 2012; de Rooij and Roseboom, 2010; Phillips et al., 2012). Finally, it is unclear whether or not the observed associations between personality factors and reactivity are independent of one another. The five personality traits measured were correlated, although imperfectly so, and it is probably best to view personality as an intersecting constellation of traits rather than as a set of independent factors (Digman, 1997).

In conclusion, the present analyses indicated that cortisol and HR stress reactivity were negatively associated with neuroticism, but positively associated with agreeableness and openness. High neuroticism scores were also negatively associated with diminished blood pressure reactivity. As such, the results provide further support to the notion that blunted cortisol and cardiovascular reactivity may be maladaptive and may reflect dysregulation of the neural systems supporting motivated behaviour.

Conflict of interest

The authors have no conflict of interest: they have no financial or personal relationships with other people or organizations that could inappropriately influence their work.

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The sponsors had no role in design of the study; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

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