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Personality, cardiovascular, and cortisol reactions to acute psychological stress in the Midlife in the United States (MIDUS) study

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ABSTRACT

Recent research has suggested that diminished, as well as elevated reactivity to acute psychological stress is maladaptive. These differences in stress reactions have been hypothesized to relate to the Big Five personality traits, which are said to be biologically-based and stable across adulthood; however, findings have been inconclusive. This study sought to replicate the findings of the largest study conducted to date (Bibbey et al., 2013), with a sample of participants from the Midlife in the United States Study (MIDUS), aged between 35 and 84 years ($M = 56.33$, $SD = 10.87$). Participants ($N = 817$) undertook a standardized, laboratory-based procedure during which their cardiovascular and neuroendocrine reactivity to acute stress was measured. In contrast to Bibbey et al. (2013), associations between neuroticism and blunted reactivity did not withstand adjustment for confounding variables. Further, following adjustment for multiple tests, no significant positive association between agreeableness and HR reactivity was observed. Methodological differences between the studies, which may account in part for the contrasting findings, are discussed. Further conceptual replication research is needed to clarify associations between the Big Five personality traits and stress reactivity, across the lifespan.

1. Introduction

An estimated 17 million people die of cardiovascular disease (CVD) annually making it the number one cause of death globally (WHO, 2019) An increasing body of literature shows that above and beyond traditional risk factors (e.g. smoking, diet, and family history) psychological factors may contribute to CVD. In particular, the reactivity hypothesis posits that exaggerated or prolonged cardiovascular reactivity (CVR) to psychological stress may promote the development of CVD (Obrist, 1981; Phillips and Hughes, 2011; Sherwood et al., 2017). Indeed, prospective studies have found that that heightened reactivity to stress is associated with adverse cardiovascular outcomes including hypertension (Markovitz et al., 1998; Treiber et al., 2003), atherosclerosis (Treiber et al., 2003), and cardiovascular disease mortality (Carroll et al., 2012). However, recent research has shown that blunted or diminished responses to stress, while previously thought to be benign, are in fact associated with adverse health-related implications (Phillips and Hughes, 2011; Phillips, 2011). Alongside this line of research are studies implicating individual differences in personality in maladaptive responding to stress (Chida and Hamer, 2008).

An individual's personality, often described as biologically-based and stable across adulthood (McCrae et al., 2000), is inextricably linked to how they view the world and act within it. Accumulating evidence demonstrates that the “Big 5” personality traits (i.e., neuroticism, agreeableness, openness to experience, extraversion, and conscientiousness) are predictive of physiological stress responses (e.g., Bibbey et al., 2013; Gallagher et al., 2018). Individuals high in neuroticism demonstrate blunted heart rate (HR), and blood pressure reactivity to acute psychological stressors (Hughes et al., 2011; Jonassaint et al., 2009; Phillips et al., 2005) as well as blunted heart rate variability (HRV) (Čukić and Bates, 2015) and cortisol reactivity (Phillips et al., 2005). Importantly, while a meta-analysis of 71 studies found that neuroticism was associated with both diminished cardiovascular reactivity and recovery (Chida and Hamer, 2008), null findings have

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also been observed (e.g., Hutchinson and Ruiz, 2011). Further, lower levels of openness have been associated with blunted reactivity to stress in some studies (Oswald et al., 2006; Williams et al., 2009), and increased reactivity in others (Wirtz et al., 2007; Xin et al., 2017). Taken together, studies of associations between the personality traits and stress reactivity have clearly displayed mixed results. However, personality-reactivity studies to date are characterized by methodological issues, including small sample sizes, the predominance of young student samples, restricted range of trait scores, dichotomised trait variables, and the failure to statistically adjust for a range of possible confounding variables. Thus, large-scale studies in non-student populations are needed.

One population-based cohort study, conducted by Bibbey et al. (2013) using longitudinal data from the Dutch Famine Birth Cohort Study, addressed several of these methodological concerns. For this study, 352 middle-aged adults completed the Big Five Inventory to assess neuroticism, agreeableness, openness to experience, extraversion, and conscientiousness and subsequently completed a 15-minute CVR protocol. This included three stressors (the Stroop task, mirror tracing, and a speech task), lasting for 5 min each; cardiovascular and salivary cortisol responses were monitored throughout. After controlling for several potential confounds, higher neuroticism was associated with smaller cortisol, systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR reactions. A similar pattern was evident for those scoring low on agreeableness and openness. However, despite the scientific value of replication research (Button et al., 2013; Collaboration, 2015; Klein et al., 2018) these findings have yet to be replicated in a large-scale cohort.

Further, while the Bibbey et al. study evaluated cortisol, HR, and blood pressure, associations between personality and HRV merit further attention. Decreased HRV is associated with a number of risk factors for CVD (see Thayer et al. (2010)) and has been conceptualized as reflecting individual differences in self-regulation abilities including the capacity to respond flexibly to external demands, such as acute stress (e.g., Thayer and Lane, 2009). In particular, resting high-frequency HRV (HF-HRV), an index of cardiac vagal regulation, has been positively associated with personality characteristics such as extraversion and agreeableness, and inversely associated with neuroticism (Oveis et al., 2009); however, large-scale studies evaluating personality and HF-HRV reactivity are lacking.

Therefore, the aim of the present study was to conduct a conceptual replication of the Bibbey et al. (2013) study using data from the Midlife Development in the United States 2 (MIDUS 2) study, and evaluate HF-HRV in the same sample.

2. Materials and methods

2.1. Study overview and design

The original MIDUS survey (MIDUS 1), conducted in 1995 and 1996, investigated the psychological, behavioural, and social factors contributing to the overall health and well-being of English-speaking American adults. Data were collected using telephone interviews and self-administered questionnaires. In 2004, participants were contacted to take part in a follow-up study, MIDUS 2 (see http://midus.wisc.edu/midus2/project1/ and http://midus.wisc.edu/midus2/project4/ for detailed information on methods). The original study consisted of 7108 respondents, and the retention rate for MIDUS 2 was 75% when controlling for mortality. MIDUS 2 participants were invited to complete an additional biological assessment, known as the Biomarker Project. The present study uses data from the longitudinal study subsample who completed MIDUS 2 and who participated in the Biomarker Project ($N = 1054$), approximately 2 years later, to examine the extent to which the personality scores (quantified in MIDUS 2) predict cardiovascular and cortisol responses to stressors, collected for the Biomarker Project.

2.2. Participants

Biomarker Project participants ranged in age from 35 to 86 years ($M = 58.04$, $SD = 11.62$); 55% were women ($N = 477$) and there were no significant sex differences in age, $t(1052) = 1.68$, $p = .09$. Of 1054 participants, 970 completed the psychophysiology session. These were younger than non-completers ($M = 57.79$, $SD = 11.57$ years vs. $M = 60.93$, $SD = 11.92$ years; $p = .02$) but did not differ in personality (all $ps \geq .09$).

Complete relevant biomarker data were available for 854 participants. We excluded the first 26 participants who completed an extended version of the stressors (before the overall protocol was shortened; see Ryff et al., 2011). Missingness was relatively high for use of anti-depressants/anxiolytics (15%) and for occupational class (26%; the measure of socio-economic status [SES] used by Bibbey et al., 2013). A missing indicator was computed for medication and standardized scores for education were used as a proxy for SES for participants missing occupational class. Participants with missing data on other study variables were excluded. The final sample size for analysis was 817. Over three-quarters (76.3%) of the sample reported at least one chronic health condition during data collection for MIDUS 2. Given chronic health conditions were, in effect, normative for this group these participants were not excluded.

2.3. Psychological stress testing

Participants were admitted for a 2-day overnight hospital stay, including a standardized, psychophysiological laboratory-based protocol after breakfast on the second day. The session ran for approximately 90 min and has been outlined in detail elsewhere (Ryff et al., 2011). In brief, participants provided baseline saliva samples shortly after arrival at the laboratory, then the cardiovascular equipment was calibrated and participants completed practice trials for the stress tasks. They then sat quietly for an 11-minute formal resting baseline period, after which they undertook the first cognitive stress task. This was followed by a 6-minute recovery period and then the second cognitive stress task.

The stressors were the Stroop colour/word interference task, and a mental arithmetic task, both of 6 min duration, presented in random order. For the Stroop task, a word was presented on a computer screen, either of a congruent or incongruent colour (e.g., the word "yellow" written in yellow letters versus the word "yellow" written in blue letters). Participants used a keypad to respond to the answer that corresponds to the colour of the letters, not the colour name. Participants were informed that "the computer will score your responses for speed and accuracy. If you don't respond quickly enough, it will score your response as incorrect and present a new problem."

The Morgan and Turner Hewitt (MATH; Turner et al., 1986) mental arithmetic task required participants to complete a number of addition and subtraction problems. A problem was presented on the screen, followed by an 'equals sign' and an answer. Participants pressed a key (corresponding to yes or no) to indicate whether the answer was correct. Problem difficulty varied across five levels, ranging from problems of 1-digit ± 1-digit numbers (level 1) to 3-digit ± 3-digit numbers (level 5). The task always began at level 3; incorrect responses were followed by a problem of lower difficulty (maintained thereafter at level 1 till a correct response was given); correct responses were followed by a problem of higher difficulty. Participants were informed that "If you don't respond quickly enough, the computer will count your answer as wrong and will present another problem to you." Total number of problems presented varied based on the participant response times. Participants rated their stress levels verbally on a scale from 1 (*not stressed at all*) to 10 (*extremely stressed*) at baseline, and once during each stressor.

2.4. Cardiovascular and cortisol assessment

Saliva cortisol was assessed at four time points (T0—[up to 36 min prior to the first stressor, depending on time taken for equipment calibration and practice trials], T1—immediately after the second stressor, T2—14 min after the stressors, and T3—44 min after the stressors). At each timepoint, participants placed the cotton swab of the Salivette in their mouth and chewed it until saturated. Salivettes were stored in −80 F freezer. Cortisol is reported in nanomoles per liter (nmol/l) and was log-transformed for analyses (Weiss and Weiss, 2016). Heart rate and HRV were measured using a beat-to-beat electrocardiogram (ECG). Beat-to-beat analogue ECG signals were digitized at 500 Hz and collected by a microcomputer. ECG waveforms were submitted to proprietary event detection software to identify R waves. MIDUS research staff visually reviewed all ECG waveforms to correct software errors in identifying normal R waves. The resulting series of normal RR intervals was used to calculate HR and HRV (see Ryff et al., 2011). HF-HRV (0.15–0.50 Hz) was natural log-transformed to normalize the distributions.

Both SBP and DBP were recorded using a Finometer monitor (Finapres Medical Systems, Amsterdam, Netherlands). Derived from the volume-clamp method of Penãz (1973), the Finometer uses a finger cuff for continuous blood pressure measurement by photoplethysmography. To keep the arterial size constant, the air pressure in the cuff adjusts in response to any increases in the size of the finger arteries, reflective of blood pressure changes. The pressure wave form is indirectly measured using an electric gauge, and mean pressure is then calculated by integrating it over a single heart-beat (Langewouters et al., 1998).

2.5. Personality

Developed by Lachman and Weaver (1997), the MIDUS self-report personality measure contains 26 adjectives measuring neuroticism (4 items), extraversion (5 items), agreeableness (5 items), conscientiousness (5 items), and openness to experience (7 items). Participants are invited to 'Please indicate how well each of the following (adjectives) describe you'. There were four possible answers; 1 (*not at all*), 2 (*a little*), 3 (*some*), 4 (*a lot*). The adjectives associated with each trait were as follows; neuroticism (moody, worrying, nervous, and [not] calm; $\alpha = 0.76$), extraversion (outgoing, friendly, lively, active, and talkative; $\alpha = 0.77$), agreeableness (helpful, warm, caring, soft-hearted, and sympathetic; $\alpha = 0.82$), conscientiousness (organized, responsible, hardworking, thorough and [not] careless; $\alpha = 0.70$), openness to experience (creative, imaginative, intelligent, curious, broad-minded, sophisticated, and adventurous; $\alpha = 0.77$).

2.6. Control variables

We included, as far as possible, the same control variables as Bibbey et al. (2013). The height and weight of each participant was measured, and body mass index (BMI) computed by dividing weight by height squared ($M = 29.23$ kg/m^2, $SD = 5.75$). Socio-economic status ($M = 43.44$, $SD = 13.73$) was based on occupational categories, as derived from (Hauser and Warren, 1997). To address skew (Hostinar et al., 2015) alcohol consumption in the last month was estimated based on the average number of days per week participants drank alcohol and the average daily amount of alcohol consumed. Smoking status was categorised as current smoker, former smoker, or never smoked. Participants were coded as taking or not taking medication for high blood pressure/hypertension, and taking or not taking anti-depressant or anxiolytic medication. See Table 1 for descriptive statistics.

Table 1
Characteristics of final sample for analysis ($N = 817$).

Variable name (measurement scale/reference category)		M/N	*SD* (%)
Age (years)		56.33	10.87
Sex (women)		442	54.1%
SES (occupational class)		43.44	14.73
Body mass index (kg/m^2)		29.23	5.75
Alcohol consumption (*none*)	< 10 drinks/week	464	56.8%
	≥10 drinks/week	91	11.1%
Smoking (*never smoked*)	Current smoker	91	11.1%
	Former smoker	265	32.4%
Hypertension/high blood pressure medication (*missing*)	Yes	175	22.4%
	No	542	66.3%
Anti-depressant or anxiolytic (*missing*)	Yes	125	15.3%
	No	568	69.5%

Note: Reference categories for dummy variables are italicised (including missing indicators for medication use, to retain cases missing these data in the analyses). Where occupational class was missing, this was replaced with standardized education level.

2.7. Statistical analyses

Data were analysed using SPSS (IBM, version 24, SPSS Inc., Chicago, IL, USA). Repeated-measures ANOVAs were used to determine if each of the stress reactivity measures had significantly changed from baseline. ANOVA was also used to determine if the Big Five personality scores differed between those who participated in the Biomarker Project and those who did not.

Following the approach employed by Bibbey et al. (2013), CVR was computed as the difference between average baseline measures and average stress measures (across the two stress tasks). Bibbey et al. (2013) calculated cortisol reactivity as the difference between baseline levels and the average of two measures taken at 10 and 20 min post-stressor (the peak measures). Based on the Dutch Famine Birth Cohort data, the T2 measure in MIDUS (14 min post-stressor) might be expected to constitute the peak measure. However, diurnal variation in cortisol is well-established (Weitzman et al., 1971). Given the MIDUS stress protocol took place in the morning rather than the afternoon; differences in reactivity profiles between the studies are not surprising. We calculated cortisol reactivity as the difference between (log-transformed) baseline levels and T1 cortisol (i.e., immediately after the second stressor; also the peak cortisol values in the present study). Linear regression analyses evaluated 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 stressfulness (as a proxy for stress task commitment) and baseline cardiovascular (or cortisol) levels. Degrees of freedom were constant across models for different outcomes: $F(1, 816)$ for simple models, $F(4, 812)$ for adjusted model 1, $F(15, 801)$ for adjusted model 2. Given the number of statistical tests conducted, and because we assessed five related dependent variables, the Bonferroni correction was applied to our final adjusted models. Thus, a conservative two-tailed p-value of $< .01$ ($=0.05/5$) was considered statistically significant.

3. Results

3.1. Stress reactivity

Summary baseline and stress task data are presented in Table 2. There was a significant elevation in self-reported stress from baseline to stressor $F(1, 816) = 1951.84$, $p < .001$, $\eta^2 = 0.70$. In addition, each cardiovascular parameter significantly changed from baseline to task, $F(1, 816) = 790.15$, $p < .001$, $\eta^2 = 0.49$ for HR; $F(1, 816) = 1378.77$,

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

	Cortisol (log(nmol/l))	HR (bpm)	HF-HRV (log)	SBP (mm Hg)	DBP (mm Hg)	Self-reported stress
Baseline	2.22 (0.61)	72.93 (10.89)	4.77 (1.22)	123.57 (17.47)	61.04 (11.33)	1.88 (1.34)
Stress	2.33 (0.64)	76.67 (11.40)	4.42 (1.18)	137.67 (20.96)	67.59 (11.77)	4.60 (1.84)

Note: All measures were significantly different from baseline for each variable (all $ps < .001$). Stressor measures for cardiovascular variables and psychological stress are averaged across the two stress tasks (Stroop and MATH).

Table 3
Correlations between the Big Five personality characteristics and stress reactivity ($N = 817$).

	M (*SD*)	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. N	3.42 (0.50)	−0.21*	−0.14*	−0.15*	−0.24*	0.04	0.03	0.03	−0.07	0.03	−0.10*	−0.06	0.01	−0.12*	−0.10*
2. E	3.13 (0.57)	–	0.49*	0.22*	0.48*	0.05	0.01	−0.03	0.03	−0.02	0.01	0.05	−0.04	0.05	0.06
3. A	2.03 (0.63)	–	–	0.27*	0.28*	−0.02	0.07	−0.04	0.04	−0.001	0.003	0.07	−0.03	0.01	0.05
4. C	3.40 (0.45)	–	–	–	0.28*	−0.04	0.02	−0.02	0.002	−0.003	−0.02	0.03	0.02	0.08	0.09
5. O	2.96 (0.52)	–	–	–	–	0.06	−0.01	−0.01	0.05	0.02	−0.04	0.03	0.003	0.05	0.04
6. Cort.	2.22 (0.61)	–	–	–	–	–	0.08	−0.07	−0.02	−0.08	−0.41*	0.03	0.03	0.10*	0.04
7. HR	72.93 (10.88)	–	–	–	–	–	–	−0.50	0.01	0.19*	−0.02	−0.04	−0.04	0.03	−0.01
8. HF HRV	4.77 (1.22)	–	–	–	–	–	–	–	−0.04	−0.02	−0.10*	0.12*	−0.33*	−0.15*	−0.08
9. SBP	123.57 (17.47)	–	–	–	–	–	–	–	–	0.67*	0.10*	0.14*	−0.02	0.04	0.02
10. DBP	61.04 (11.33)	–	–	–	–	–	–	–	–	–	0.09	0.08	−0.03	−0.03	−0.07
11. Cort.	0.10 (0.56)	–	–	–	–	–	–	–	–	–	–	0.10*	0.04	0.13*	0.12*
12. HR	3.76 (3.82)	–	–	–	–	–	–	–	–	–	–	–	−0.34*	0.27*	0.38*
13. HF HRV	−0.35 (0.62)	–	–	–	–	–	–	–	–	–	–	–	–	0.09	−0.03
14. SBP	14.10 (10.85)	–	–	–	–	–	–	–	–	–	–	–	–	–	0.80*
15. DBP	6.55 (4.08)	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Notes. "Cort." indicates cortisol. Only correlations significant at $p < .01$ are highlighted (*).
Baseline levels for physiological variables are in bold; change scores are italicised.

$p < .001$, $\eta^2 = 0.63$ for SBP, $F(1, 816) = 2108.53$, $p < .001$, $\eta^2 = 0.72$ for DBP, and $F(1, 816) = 260.47$, $p < .001$, $\eta^2 = 0.24$ for HF-HRV. Cortisol also demonstrated a significant increase from T0 to T1; $F(1, 817) = 26.67$, $p < .001$, $\eta^2 = 0.03$.

3.2. Big Five personality traits

Independent *t*-tests revealed that in comparison to MIDUS 2 participants who did *not* participate in the Biomarker Project, those who did participate had significantly lower levels of neuroticism ($M = 2.03$, $SD = 0.63$ vs. $M = 2.08$, $SD = 0.62$; $t(4007) = -2.47$, $p = .01$, $d = 0.09$), and significantly higher levels of openness ($M = 2.96$, $SD = 0.51$ vs. $M = 2.88$, $SD = 0.54$ vs. $t(1920.96) = 4.25$, $p < .001$, $d = 0.15$). No significant differences were observed for extraversion, agreeableness, or conscientiousness (all $p \geq .08$).

As expected, neuroticism was negatively associated with each of the other four traits (see Table 3). Baseline self-reported stress was positively associated with neuroticism ($r = +0.13$, $p < .001$); no traits were significantly correlated with change in self-reported stress. Neuroticism was inversely correlated with cortisol, SBP and DBP reactivity.

3.3. Personality and cortisol reactivity

In the unadjusted models, as observed in Bibbey et al. (2013), neuroticism was negatively associated with cortisol reactivity; no other significant associations were observed (see Table 4). This association did not withstand adjustment for age, sex, and SES, or for the full range of control variables (i.e., age, sex, SES, alcohol consumption, smoking, BMI, use of anti-hypertensive medication, use of anti-depressant or anxiolytic medication, perceived stressfulness, and baseline measures).

3.4. Personality and HR reactivity

In the unadjusted models, only agreeableness was (positively) associated with HR reactivity at the conventional alpha level. This association was robust to adjustment for age, sex, and SES, and for the full range of control variables; however, no significant associations were observed following adjustment for multiple tests. The adjusted model 1 for neuroticism revealed a significant association between neuroticism and blunted HR reactivity, which was no longer significant in the fully adjusted model (see Table 5).

Table 4
Regression models for neuroticism, extraversion, agreeableness, conscientiousness, openness to experience, and cortisol reactivity ($N = 817$).

	F	B	β	*t*	*p*	$R^2/\Delta R^2$
Neuroticism						
Unadjusted model	7.57**	−0.08	−0.10	−2.75	0.006*	0.009
Adjusted model 1	6.90*	−0.08	−0.09	−2.44	0.02*	0.007
Adjusted model 2	16.98***	−0.03	−0.03	−0.10	0.32	0.001
Extraversion						
Unadjusted model	0.07	0.01	0.01	0.27	0.79	< 0.001
Adjusted model 1	5.44***	0.02	0.02	0.46	0.64	< 0.001
Adjusted model 2	16.99***	0.03	0.03	1.05	0.29	0.001
Agreeableness						
Unadjusted model	0.009	0.004	0.003	0.10	0.92	< 0.001
Adjusted model 1	5.77***	0.05	0.04	1.22	0.22	0.002
Adjusted model 2	17.08***	0.05	0.05	1.43	0.15	0.002
Conscientiousness						
Unadjusted model	0.38	−0.03	−0.02	−0.61	0.54	< 0.001
Adjusted model 1	5.38***	−0.001	0.00	−0.01	0.99	< 0.001
Adjusted model 2	16.97***	−0.04	−0.03	−0.89	0.38	0.001
Openness						
Unadjusted model	1.33	−0.04	−0.04	−1.16	0.25	0.002
Adjusted model 1	5.78*	−0.05	−0.04	−1.25	0.21	0.002
Adjusted model 2	16.94***	−0.02	−0.02	−0.71	0.48	< 0.001

Note. Adjusted model 1 – adjusted for age, sex, and SES. Adjusted model 2 – additional adjustment for alcohol consumption, smoking, BMI, use of medication for hypertension/high blood pressure, use of anti-depressant or anxiolytic medication, perceived stressfulness, and baseline measures. *F* values for overall models are presented; ***$p < .001$; **$p < .01$, *$p < .05$. R^2 for all adjusted model 1s = 0.03. R^2 for all adjusted model 2s = 0.24. R^2 for unadjusted models is reported; otherwise ΔR^2 is reported.

Table 5
Regression models for neuroticism, extraversion, agreeableness, conscientiousness, openness to experience, and HR reactivity ($N = 817$).

	F	B	β	t	p	$R^2/\Delta R^2$
Neuroticism						
Unadjusted	3.03	−0.36	−0.06	−1.74	0.08	0.002
Adj. model 1	3.06*	−0.52	−0.09	−2.40	0.02*	0.01
Adj. model 2	3.05***	−0.27	−0.05	−1.22	0.23	0.002
Extraversion						
Unadjusted	1.66	0.31	0.05	1.29	0.20	0.001
Adj. model 1	2.18	0.36	0.05	1.51	0.13	0.006
Adj/d model 2	3.12***	0.38	0.06	1.58	0.11	0.003
Agreeableness						
Unadjusted	4.29	0.54	0.07	2.07	0.04*	0.004
Adj. model 1	2.77*	0.59	0.08	2.15	0.03*	0.009
Adj. model 2	3.35***	0.64	0.09	2.38	0.02*	0.007
Conscientiousness						
Unadjusted	0.84	0.27	0.03	0.92	0.36	< 0.001
Adj. model 1	1.81	0.27	0.03	0.89	0.37	0.004
Adj. model 2	2.95***	0.002	0.00	0.01	0.947	< 0.001
Openness						
Unadjusted	0.72	0.22	0.03	0.85	0.40	< 0.001
Adj. model 1	1.85	0.26	0.04	0.99	0.33	0.004
Adj. model 2	3.07***	0.34	0.05	1.32	0.19	< 0.001

Note. Adj. model 1 – adjustment for age, sex, and SES. Adj. model 2 – additional adjustment for alcohol consumption, smoking, BMI, use of medication for hypertension/high blood pressure, use of anti-depressant or anxiolytic medication, perceived stressfulness, and baseline measures. F values for overall models are presented; ***$p < .001$; **$p < .01$, *$p < .05$. R^2 for all adjusted model 1s = 0.01–0.02. R^2 for all adjusted model 2s = 0.05–0.06. R^2 for unadjusted models is reported; otherwise ΔR^2 is reported.

3.5. Personality and HF-HRV reactivity

No significant associations between personality and HF-HRV reactivity were observed in either simple or adjusted models (see Table 6).

Table 6
Regression models for neuroticism, extraversion, agreeableness, conscientiousness, openness to experience, and HF-HRV reactivity ($N = 817$).

	F	B	β	t	p	$R^2/\Delta R^2$
Neuroticism						
Unadjusted model	0.13	0.01	0.01	0.36	0.72	< 0.001
Adjusted model 1	3.03*	0.04	0.04	1.17	0.24	0.002
Adjusted model 2	7.84***	0.04	0.04	1.17	0.24	0.002
Extraversion						
Unadjusted model	1.45	−0.05	−0.04	−1.20	0.23	0.002
Adjusted model 1	3.20*	−0.06	−0.05	−1.43	0.15	0.002
Adjusted model 2	8.03***	−0.07	−0.07	−1.96	0.05	0.004
Agreeableness						
Unadjusted model	0.89	−0.04	−0.03	−0.94	0.35	0.001
Adjusted model 1	2.85*	−0.04	−0.03	−0.81	0.42	0.001
Adjusted model 2	7.81***	−0.04	−0.04	−101	0.31	0.001
Conscientiousness						
Unadjusted model	0.36	0.03	0.02	0.60	0.55	< 0.001
Adjusted model 1	2.81*	0.03	0.02	0.69	0.49	0.001
Adjusted model 2	7.75***	0.02	0.01	0.34	0.69	< 0.001
Openness						
Unadjusted model	0.01	0.004	0.003	0.10	0.92	< 0.001
Adjusted model 1	2.69*	−0.01	−0.01	−0.16	0.89	< 0.001
Adjusted model 2	7.74***	−0.01	−0.01	−0.32	0.75	< 0.001

Note. Adjusted model 1 – adjustment for age, sex, and SES. Adjusted model 2 – additional adjustment for alcohol consumption, smoking, BMI, use of medication for hypertension/high blood pressure, use of anti-depressant or anxiolytic medication, perceived stressfulness, and baseline measures. F values for overall models are presented; ***$p < .001$; **$p < .01$, *$p < .05$. R^2 for all adjusted model 1s = 0.01–0.02. R^2 for all adjusted model 2s = 0.13. R^2 for unadjusted models is reported; otherwise ΔR^2 is reported.

3.6. Personality and SBP reactivity

In the unadjusted model, SBP reactivity was negatively predicted by neuroticism, and positively predicted by conscientiousness. In the first adjusted model, conscientiousness remained the only significant predictor of SBP reactivity. However, in the final adjusted model, none of the variables significantly predicted SBP reactivity, as outlined in Table 7.

3.7. Personality and DBP reactivity

In the unadjusted regression models, DBP reactivity was negatively predicted by neuroticism and positively predicted by conscientiousness. In the first adjusted model, conscientiousness was the only variable which significantly predicted DBP reactivity; however, this did not withstand adjustment for the full range of control variables (see Table 7).

3.8. Analyses using the separate tasks

All adjusted regression models were repeated with reactivity in response to each task separately (i.e., MATH or Stroop) used as the outcome variable. Results are reported in the supplementary analyses. Findings remained as when examining the averaged task values.

4. Discussion

This study was a conceptual replication of the Bibbey et al. (2013) analyses using data from MIDUS 2 and the Biomarker Project. Our findings contrast with earlier reported associations between neuroticism and openness, and blunted reactivity. Associations between neuroticism and blunted reactivity did not withstand adjustment for confounding variables, and no significant associations with openness were observed. Although a similar positive association between agreeableness and HR reactivity was observed, this did not withstand correction for multiple analyses. Further, in contrast to research with younger samples (e.g., Oveis et al., 2009), no significant associations for HF-HRV reactivity were observed. This aligns with previous research evaluating resting HF-HRV in MIDUS. Sloan et al. (2017) found no significant associations with indices of psychological well-being or affect, with the exception of an inverse association with negative affect, raising questions regarding the generalizability of findings based on young adults to midlife groups.

In particular, the lack of a robust association between neuroticism and reactivity merits consideration. Several studies have established associations between neuroticism (and related constructs such as negative affect), and blunted cardiovascular and cortisol reactivity (Bibbey et al., 2013; Phillips et al., 2005). There are several potential reasons why our findings diverge from previous results, including differences between the overall MIDUS cohort and other studies, personality differences in the MIDUS Biomarker Project subsample (relative to the larger MIDUS cohort), and methodological and measurement issues.

Differences between samples may have impacted our ability to detect the same relationship with neuroticism and openness that Bibbey et al. (2013) observed. We found that participants who volunteered to take part in the Biomarker Project had significantly lower neuroticism and significantly higher openness than those who did not, which is unsurprising. Those who have greater openness are, by definition, more likely to be receptive to requests to take part in research. Similarly, those with high neuroticism are unlikely to be as willing to volunteer for a research protocol that explicitly involves stressful contexts. Therefore, while research participants may be characterized as having particular personality profiles, this is likely to be common across research studies and not an explanation for discrepant findings.

Methodological differences between the two studies may also have contributed to the disparate findings; including different sample

Table 7
Regression models for neuroticism, extraversion, agreeableness, conscientiousness, openness to experience, and SBP and DBP reactivity ($N = 817$).

	F	B	β	t	p	$R^2/\Delta R^2$
Neuroticism and SBP reactivity						
Unadjusted model	11.69**	−2.02	−0.12	−3.42	0.001*	0.014
Adjusted model 1	15.96***	−0.99	−0.06	−1.67	0.10	0.003
Adjusted model 2	7.32***	−0.29	−0.02	−0.47	0.64	< 0.001
Neuroticism and DBP reactivity						
Unadjusted model	7.89**	−0.62	−0.10	−2.81	0.005**	0.01
Adjusted model 1	6.86***	−0.39	−0.06	−1.71	0.09	0.003
Adjusted model 2	3.75***	−0.02	−0.03	−0.73	0.47	0.001
Extraversion and SBP reactivity						
Unadjusted model	2.24	1.00	0.05	1.50	0.14	0.003
Adjusted model 1	15.49***	0.67	0.04	1.03	0.31	0.001
Adjusted model 2	7.31***	0.63	0.03	0.98	0.33	0.001
Extraversion and DBP reactivity						
Unadjusted model	2.65	0.41	0.06	1.63	0.10	0.003
Adjusted model 1	6.44***	0.29	0.04	1.15	0.25	0.002
Adjusted model 2	3.77***	0.23	0.03	0.93	0.35	0.001
Agreeableness and SBP reactivity						
Unadjusted model	0.02	0.10	0.01	0.14	0.89	< 0.001
Adjusted model 1	15.25***	0.31	0.02	0.41	0.68	< 0.001
Adjusted model 2	7.33***	0.45	0.02	0.60	0.55	< 0.001
Agreeableness and DBP reactivity						
Unadjusted model	1.74	0.37	0.05	1.32	0.19	0.002
Adjusted model 1	6.38***	0.30	0.04	1.04	0.30	0.001
Adjusted model 2	3.82***	0.36	0.05	1.25	0.21	0.002
Conscientiousness and SBP reactivity						
Unadjusted model	5.12*	1.91	0.08	2.26	0.02*	0.006
Adjusted model 1	16.79***	2.00	0.08	2.43	0.02*	0.007
Adjusted model 2	7.50***	1.34	0.06	1.63	0.10	0.003
Conscientiousness and DBP reactivity						
Unadjusted model	6.33*	0.80	0.09	2.52	0.01*	0.008
Adjusted model 1	7.45***	0.75	0.08	2.37	0.02*	0.007
Adjusted model 2	3.93***	0.60	0.06	1.76	0.08	0.004
Openness and SBP reactivity						
Unadjusted model	2.11	1.06	0.05	1.45	0.15	0.003
Adjusted model 1	15.38***	0.58	0.03	0.81	0.42	0.001
Adjusted model 2	7.39***	0.80	0.04	1.12	0.26	0.001
Openness and DBP reactivity						
Unadjusted model	1.60	0.34	0.04	1.27	0.21	0.002
Adjusted model 1	6.32***	0.25	0.03	0.92	0.36	0.001
Adjusted model 2	3.80***	0.31	0.04	1.13	0.26	0.001

Note. Adjusted model 1 – adjustment for age, sex, and SES. Adjusted model 2 – additional adjustment for alcohol consumption, smoking, BMI, use of medication for hypertension/high blood pressure, use of anti-depressant or anxiolytic medication, perceived stressfulness, and baseline measures. F values for overall models are presented; ***$p < .001$; **$p < .01$, *$p < .05$. R^2 for all adjusted model 1s = 0.07–0.08 for SBP; 0.03–0.04 for DBP. R^2 for all adjusted model 2s = 0.12 for SBP; 0.07 for DBP. R^2 for unadjusted models is reported; otherwise ΔR^2 is reported.

characteristics, stressors, personality measures, psychophysiological data acquisition methods, and experimental settings. Importantly, the majority of participants here reported at least one chronic health condition; however, given that health conditions could be viewed as normative for this group, our study adds to the literature focusing on healthy samples. The two cohorts were similar in terms of mean age (58.23 years in the Dutch Famine Birth Cohort Study). Notably, in relation to stressors, the Dutch Famine Birth Cohort study included a speech stressor; and greater overall stress reactivity was elicited in this group in comparison to the MIDUS cohort. Previous research has identified different responses to social and asocial stress tasks, dependent on personality type (e.g., Type D personality; Bibbey et al., 2015), the negative affectivity component of which is strongly related to neuroticism (Howard and Hughes, 2012). Therefore, the inclusion of only asocial stressors (albeit, reliable and valid stressors) in the MIDUS protocol may mask the effects of personality on social stressors, observed elsewhere. Another consideration is the interaction of participant motivation with task demand. While the adaptation of difficulty level as a function of participant performance in the MATH task allows some flexible standardisation of maths difficulty, it may be the case that a very motivated individual would perceive the task as more demanding due to their attempts to perform well on the task. However, the flexible standardisation of the MATH task in the current study most likely reflects the optimal way to produce a flexible and generalizable maths-based stressor. Differences in task instructions are also pertinent; for example, while participants were informed that speed and accuracy on computerised tasks would be assessed in both studies, the Dutch Famine Birth Cohort participants were also informed that their speech performance would be evaluated by a team of communication experts and psychologists. Thus, the degree of social evaluation in the MIDUS stress protocol could be considered to be relatively low in comparison to the Dutch Famine Birth Cohort protocol. Further, different equipment was used to collect HR data in the two studies, which may have some bearing on our findings. However, both studies used validated measurement techniques.

We also note that the time of day differed between studies; this is particularly relevant given diurnal variation in cortisol, which peaks shortly after awakening and diminishes steadily over the early morning (Weitzman et al., 1971). Cortisol reactivity protocols typically take place in the afternoon, on the premise that large responses should occur more readily against low afternoon baselines compared to high morning baselines. However, using a protocol that included both mental arithmetic and public speaking, Lovallo et al. (2010) demonstrated that despite a higher baseline, the magnitude of cortisol reactivity is larger in the morning and smaller in the afternoon when compared to a resting control day, but identical when compared to resting baseline on a stress day. Given the MIDUS protocol took place in the morning, and the stressors used were asocial in nature, we acknowledge that diurnal variation may have masked the acute cortisol stress response. Indeed, the final cortisol measure (44 min after the start of the protocol) was lower than the first measure.

In relation to personality measurement, MIDUS 2 used single-word adjective measures. In contrast, the Dutch Famine Birth Cohort employed a translated version of the Big Five Inventory (BFI), which uses phrases to measure the five constructs. Although the MIDUS measure has good construct validity (Mroczek and Kolarz, 1998), the BFI also included more items than the scale used in MIDUS 2; as such, it is possible that the BFI scale better captured variability in trait personality. There has been disagreement on how to precisely quantify the Big Five personality traits (Miller et al., 2011). Furthermore, even subtle changes, like the addition of an extra facet, can alter a trait's conceptualisation (Miller et al., 2011). Therefore, what each personality construct in MIDUS encapsulates is likely to differ, even slightly, from a more extensive single-adjective scale (Goldberg, 1992), and from phrase-based scales such as the NEO-FFI (Costa and McCrae, 1992) or the adapted BFI scale that was used in Bibbey et al. (2013). Discrepancies between scales are likely to be compounded across different samples and even more so across different populations. This may in part, explain discrepancies between our findings and those of Bibbey et al. (2013) for the Dutch Famine Birth Cohort. In particular, the MIDUS agreeableness scale, focusing on trust and altruism, has only moderate convergent validity (0.42) with the NEO measure (Lachman, 2005).

It is also likely that complexity and interactions of the traits themselves - not just methodological differences - may lead to differences in findings. For example, research indicates that those who have higher levels of extraversion are likely to exhibit cardiovascular responses which are more flexible, more attentive to changing environments, and therefore more adaptive (Lü et al., 2018). Although those with higher extraversion initially show lower responses to minor stressors, a reverse effect is observed when the magnitude of the stressor is increased significantly. When the intensity of a stressor is of sufficient magnitude, those higher in extraversion actually show more reactivity than average. This suggests that personality traits may relate to physiological stress responses in a complex manner that varies depending on the type and perceived stressfulness of a given stressor. However, given that the difficulty of the math task varied depending on participant performance, participants should have experienced relatively similar levels of difficulty (and arguably, intensity) for this element of the stress protocol (though not for the Stroop task). Furthermore, although individual traits are thought to contribute in particular ways to stress reactivity; these relationships may also be influenced by levels of other traits, a contention supported by research evaluating personality trait clusters. Dermody et al. (2016) reported that agreeableness, conscientiousness, and neuroticism may explain the relationship between personality traits and cardio-metabolic risk when combined and conceptualized as the latent factor of “stability”. Therefore, the conceptual (and practical) complexity of quantifying multiple personality traits and their relationships with stress reactivity also warrants attention in future research.

Several limitations of this study, as a standalone study and as a conceptual, rather than direct, replication, are noted. First, the personality measures were completed several months prior to the stress-testing session; however, this was also the case in the study we aimed to replicate, with personality traits demonstrating high temporal stability across time (Soldz and Vaillant, 1999). Second, our study also relies on self-report measures of personality (as many studies of personality, including Bibbey et al., 2013, do); thus, the limitations associated with such measures (including socially desirable responding) apply. Third, the majority of the sample reported at least one chronic health condition. However, given chronic health conditions are, in effect, normative for this sample, it was not feasible to evaluate only healthy participants, and a range of possible confounding variables were included in the adjusted models. In terms of replication, several differences between the studies have already been noted. Importantly, the MIDUS sample demonstrated lower levels of reactivity in comparison to the Dutch Famine Birth Cohort.

5. Conclusions

In conclusion, in contrast to the findings of Bibbey et al. (2013), no robust associations were observed between any of the Big Five traits and stress reactivity, when adjusted for multiple analyses. The discrepancies between our findings and previous large-scale research demonstrate that (a) further large-scale replication efforts are needed to clarify the importance of personality for acute stress responding across the lifespan and (b) methodological differences between studies may be important in explaining discrepant findings. In particular, consensus around optimal measurement of the Big Five personality traits, at least within the field of psychophysiology, could advance our understanding of links between personality and stress reactivity.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2019.11.014.

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