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Association of Type D personality with the autonomic and hemodynamic response to the cold pressor test

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Abstract

Mechanisms relating Type D personality to poor health are largely unknown, with autonomic nervous system function being a candidate. This study examined the physiologic response to cold stress. Undergraduates ($N = 101$, 84% female) underwent a cold pressor test. An electrocardiogram, impedance cardiogram, and blood pressure were recorded. Type D personality was assessed by self-report questionnaire. Type D was associated with increased systolic and diastolic blood pressure reactivity. Exploratory analyses showed Type D men to respond with increased respiratory sinus arrhythmia (i.e., higher parasympathetic activity), and decreased pre-ejection period (i.e., larger sympathetic activity), while Type D women showed a reciprocal response pattern. In conclusion, Type D personality was associated with an exaggerated hemodynamic response to cold stress, which may contribute to an increased risk of hypertension in Type D individuals.

Descriptors: Type D personality, Cold pressor task, Impedance cardiography, Blood pressure, Heart rate, Autonomic nervous system, Cardiovascular reactivity

The Distressed or Type D personality, characterized by the tendency to experience negative emotions (negative affectivity; NA) combined with the tendency to inhibit self-expression in social situations (social inhibition; SI, Denollet, 2005), has been shown to increase the risk of mortality by two- to three-fold in patients with coronary artery disease (Denollet, Schiffer, & Spek, 2010; Grande, Romppel, & Barth, 2012; O'Dell, Masters, Spielmans, & Maisto, 2011). Healthy individuals with Type D personality have demonstrated an increased estimated risk of developing coronary heart disease (Svansdottir et al., 2013). However, the mechanisms by which Type D personality exerts its effects on cardiovascular disease development and prognosis largely remain to be elucidated. The chronic experience of emotional distress may disrupt major biological regulatory systems, such as the autonomic nervous system in Type D individuals, potentially resulting in the reported increased incidence of coronary heart disease and the reported premature cardiovascular mortality. Previous studies on Type D personality and cardiovascular reactivity have shown an altered heart rate and blood pressure response to acute mental stress in healthy individuals (Habra, Linden, Anderson, & Weinberg, 2003; Howard, Hughes, & James, 2011; Williams, O'Carroll, & O'Connor, 2009) as well as in cardiac patients (Kupper, Denollet, Widdershoven, & Kop, 2013). Moreover, Type D personality has been associated with a higher likelihood of experiencing ventricular arrhythmias, a sign of a chronically more active sympathetic nervous system, during 24-hr electrocardiogram (ECG) monitoring in healthy individuals (Einvik et al., 2012). Also, ventricular arrhythmias were more frequent in anxious Type D patients implanted with an internal cardiac defibrillator (ICD; van den Broek et al., 2009), as well as lower overall autonomic control of 24-hr cardiac function in ICD patients (Hoogwegt, Pedersen, Theuns, & Kupper, submitted). Altered functioning of the autonomic regulation of the heart and vessels can be a risk factor for primary and secondary cardiac events, due to the increased probability of cardiac arrhythmias and altered endothelial function (Carney, Freedland, & Veith, 2005).

Two types of stressors may be identified that are typically characterized by a different adrenergic response profile (Schneiderman & McCabe, 1989). Active stressors such as mental arithmetic or public speaking tasks involve active participation that allows performance to affect stress reactivity. Passive stressors, such as the viewing of a stressful film, mirror tracing, or cold stress, require endurance and acceptance of an aversive situation. The cardiovascular response profile is different for these two types of stressors, and they may have differential effects on cardiovascular outcome variables (Schneiderman & McCabe, 1989). While active stressors generally are associated with an increased hemodynamic and myocardial response, indicating a beta-adrenergic response profile, passive stressors in general elicit an alpha-adrenergic response, induced both by the baroreceptor response as well as the cold-induced pain, and visible in an attenuated cardiac output response and a more pronounced effect on diastolic blood pressure. The blood pressure response to the cold pressor test has been shown to predict the development of hypertension (Kasagi, Akahoshi, & Shimaoka, 1995; Matthews et al., 2004), so a deviating response pattern might point towards a pathophysiological mechanism involved in the cardiovascular risk associated with Type D.

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PSYCHOPHYSIOLOGY

Only a small number of studies have examined the autonomic response to passive stressors, such as the cold pressor task in association with emotional distress. In college students, depressed mood was associated with smaller increases in parasympathetic activity (as assessed with high-frequency heart rate variability) in response to a cold pressor stimulus (Hughes & Stoney, 2000). High depression scores were also associated with attenuated blood pressure and electrodermal reactivity to the cold pressor test in female college students (Schwerdtfeger & Rosenkaimer, 2011). However, other studies found that the parasympathetic or sympathetic autonomic response patterns were not related to worry (Knepp & Friedman, 2008), or that anxiety was associated with an increased blood pressure and heart rate response to cold stress (Pointer et al., 2012).

Currently, there is no information on the autonomic response to passive stressors in individuals with Type D personality, while for active mental stressors, as described above, a role is suggested for dysregulation of autonomic cardiac control, due to reported differences in heart rate (Habra et al., 2003; Howard et al., 2011; Kupper et al., 2013).

In addition, there might be sex differences in the relation between Type D personality and the response to stress. Sex differences have been documented in previous studies employing active stressor paradigms (Habra et al., 2003; Howard et al., 2011; Williams et al., 2009), although comparisons across studies are complicated because of differences in sample characteristics such as age, physiological measurements, experimental design, and statistical approach. Sex differences have also been found for the physiologic response to the cold pressor task (Wu, Snieder, & de Geus, 2010), and may therefore be worth investigating in the context of potential risk mediators such as physiological stress reactivity.

Because deviations in the physiological response to cold stress have been shown to be predictive of future hypertension (Kasagi et al., 1995; Matthews et al., 2004), and therefore may be a potential explanatory mechanism in the observed relation between Type D and cardiovascular disease progression, we investigated the association of Type D personality with hemodynamic and autonomic responses to a cold pressor test in young, healthy individuals. Potential sex differences in the relation between Type D and stress reactivity were explored in secondary analyses.

Method

Participants

The sample included 101 undergraduate students (84% women) from Tilburg University, the Netherlands, with an average age of 19.8 (± 4.0) that volunteered to participate in the current experiment to earn course credits. None of the participants reported being in poor health at the time of the experiment (no diabetes, lung disease, heart disease, or hypertension).

Procedure

Participants were instructed to fast and to refrain from smoking and coffee consumption for at least 2 hr before testing as well as not to ingest more than three alcoholic beverages during the 24 hr before testing. Upon arrival, all participants were welcomed, placed in a quiet, dimly lit room, and asked to fill out a psychological survey, including dedicated questions on demographics (age, sex, partner status), health behaviors (exercise, smoking, weekly alcohol consumption, daily coffee consumption), body composition (length, weight), illnesses (cardiovascular disease, lung disease, hypertension, diabetes), medication use, personality (e.g., Type D personality), and mood disorders (anxiety, depression: Has a medical doctor or registered psychologist told you that you have depression/anxiety, or are you being treated for anxiety/depression?). Then, participants were fitted with the cardiovascular measurement equipment. Participants were examined in a sitting position. After a 20-min resting period, during which a physiological baseline was recorded, participants took part in a stress test battery, consisting of active and inactive stress tasks. The two active stress tests, a mental arithmetic and a public speech task (not reported here), were followed by a 10-min recovery period. Next, the inactive stress task took place, which consisted of a cold pressor task (Lovallo, 1975), that is, a 1-min immersion of the hand and wrist of the dominant arm (nondominant arm was used for blood pressure measurement) in cold water with cup-sized ice cubes (mix of water and ice, with a temperature of 3–4°C). The instruction was given to keep the open hand including the wrist under water for 1 min. The experimenter stayed in the room to observe the compliance, but made sure not to make eye contact by standing behind the participant, and observing the hand in the water. The stress test battery was followed by a 15-min recovery period.

The study protocol was approved by the Institutional Ethics Review Board (protocol #EC2006.1001). All participants gave informed consent before participating and were debriefed afterwards. The study was conducted according to the most recent version of the World Medical Association (2008).

Measures

Hemodynamic and autonomic variables. Systolic (SBP) and diastolic (DBP) blood pressure was assessed using an ambulatory blood pressure monitor (ABP monitor type 90207; Spacelabs Healthcare Ltd., Issaquah, WA), which took blood pressure measurements every 6 min during rest, once halfway through the cold pressor task, and every 3 min during the recovery phase. Pulse pressure was calculated by subtracting the DBP value from the SBP value at all measurement occasions. Hypertension was defined as having an average resting blood pressure over 140/90 mmHg.

The Vrije Universiteit Ambulatory Monitoring System (VU-AMS 4.6; Vrije Universiteit Amsterdam, the Netherlands) was used to record a continuous ECG and impedance cardiogram (ICG; Willemsen, de Geus, Klaver, Van Doornen, & Carroll, 1996). The VU-AMS device records 3-lead ECG and 4-lead ICG using pregelled AgCl electrodes (Ultratrace; ConMed Corporation, Utica, NY). The event button on the device was used to indicate start and end times of the phases of the experimental protocol.

VU-AMS software automatically detected all R-peaks in the ECG, and all R-peak markers were visually checked and adjusted when necessary. The software automatically marked the starting points of inspiration and expiration derived from the ICG, which were automatically scored for each breath and checked manually for the presence of signal artifacts before analyses (Kupper et al., 2005). From the corrected signal, mean heart period (IBI), respiration rate (RR), and respiratory sinus arrhythmia (RSA) were computed. RSA is considered a direct noninvasive measure of parasympathetic cardiac drive and was determined using the peak-to-trough method (Fouad, Tarazi, Ferrario, Fighaly, & Alicandri, 1984).

Systolic time intervals (pre-ejection period, PEP; left ventricular ejection time, LVET) were manually scored from 60-s ensemble averages of the ICG by an experienced scorer of ICG signals (first author) using the VU-AMS interactive scoring software. Scoring procedures for impedance cardiography have been published previously (Kupper, Willemsen, Boomsma, & de Geus, 2006; Kupper et al., 2005). The PEP is defined as the time interval between the onset of electromechanical systole (ECG Q-wave onset) and the onset of left ventricular ejection at the opening of the aortic valves. LVET is defined as the time between the opening and closing of the aortic valves. Reduced values of PEP and increased values of PEP/LVET ratio both indicate increased inotropic control, that is, larger sympathetic cardiac control (Sherwood et al., 1990).

Type D personality. Type D personality was assessed with the 14-item Type D scale, the DS14 (Denollet, 2005), which measures the two stable personality traits, NA and SI. All items are answered on a 5-point Likert scale ranging from 0 = *false* to 4 = *true*. A standardized cut-off ≥ 10 on both subscales indicates Type D caseness (Denollet, 2005; Emons, Meijer, & Denollet, 2007). In addition to this previously validated dichotomized Type D personality classification, the interaction between continuous NA and SI scores was used to examine the prediction from the Type D model that it is the synergistic interaction of NA and SI that is associated with cardiovascular outcomes, and not the main effect of either trait alone (Ferguson et al., 2009; Howard & Hughes, 2012). The NA and SI subscales of the DS14 have good psychometric properties with Cronbach's α =.88/.86 and 3-month test-retest reliability r = .72/.82 (Reimann et al., 2012). In the current dataset, Cronbach's α was .86 (NA) and .88 (SI) for the two subscales.

Statistical Analysis

Baseline characteristics are presented as descriptive statistics (means (*SD*) and frequencies). Student *t* tests for independent samples (continuous variables) and chi-square tests (categorized variables) were used to assess associations of Type D personality with baseline characteristics. General linear models (GLM) repeated measures analysis in SPSS 19 (SPSS Statistics for Windows, v. 19.0; IBM, Armonk, NY) was used to assess the hemodynamic (SBP, DBP, PP) and autonomic (HR, RSA, PEP, PEP/LVET) response to the cold stressor and included a baseline, cold pressor, and recovery period. When Mauchly's test of sphericity of variances was violated ($p < .05$), ε was evaluated to choose the proper correction for the F ratio. When $\varepsilon < .75$, the Greenhouse-Geisser correction was used, and when $\varepsilon > .75$, the Huynh-Feldt correction was used. We were interested in the within-subject effect of Time × Type D. In addition, we explored the potential presence of a Time × Type D × Sex interaction.

For clarity, we also summarized the effects of the active stressor that preceded the cold pressor task on SBP, DBP, HR, RSA, and PEP, and we have checked whether there were differences in active stressor recovery levels in association with Type D, as this may affect subsequent cold pressor response.

A priori covariates. Covariates were included based on their a priori association with predictor and/or outcome variables. Smoking was included as a covariate, because of previously established associations with Type D personality (Gilmour & Williams, 2012), blood pressure (Al-Safi, 2005; Flouris, Faught, & Klentrou, 2008), and heart rate (Al-Safi, 2005). Sex was included as a covariate and interaction factor, due to known differences in the physiological response to cold stress (Hogarth, Mackintosh, & Mary, 2007), as well as known sex differences in the physiological response of Type D individuals to active stressors (Habra, et al., 2003; Howard et al., 2011; Williams et al., 2009).

Analyses were repeated using the scores of the two continuous Type D components (NA and SI) as well as their interaction. For this purpose, a new interaction variable was created by taking the product of the two continuous variables, representing the interaction effect of the continuous NA and SI trait scores. This variable was used as a continuous predictor in the analyses. Smoking was dropped in these analyses as a covariate to maintain sufficient statistical power.

Results

Descriptives

Table 1 displays the descriptive statistics of the sample. The prevalence of Type D personality in this healthy student sample was 30%. There were no significant differences associated with Type D classification, except that Type D students were significantly more often smokers ($p = .03$). A statistical trend was observed for Type D students to have a higher body mass index (BMI) than non-Type D students ($p = .09$).

Efficacy of the Stress Protocol

All participants kept their hand and wrist immersed in the water for the full minute. The cold pressor test successfully elicited a significant physiological response and appropriate recovery (SBP: $F(2,174) = 150.5$, $p < .001$; DBP: $F(1.6,140.8) = 170.4$, $p < .001$; IBI: $F(1.6,157.6) = 57.1$, $p < .001$; RSA: $F(1.5,142.4) = 4.5$, $p = .01$; PEP: $F(1.7,166.0) = 55.7$, $p < .001$). The mental stress task (arithmetic and speech challenge) that preceded the cold pressor test also elicited a significant response (SBP: $F(3.5,303.7) = 157.4$, $p < .001$; DBP: $F(3.4,296.3) = 147.9$, $p < .001$; IBI: $F(2.4,35.1) = 140.2$, $p < .001$; RSA: $F(2.7,265.6) = 13.2$, $p < .001$; PEP: $F(2.9,282.2) = 76.2$, $p < .001$). There were no differences between Type D and non-Type D individuals and between men and women in the recovery period levels following the mental stress task. Also, there were no differences between baseline and mental stress task recovery levels of SBP, DBP, IBI, and PEP between Type D and non-Type D individuals and between men and women. Mental stress recovery levels were therefore not included as a confounding variable in further analyses for these variables. With respect to RSA, there were differences in RSA recovery, with Type D showing stronger recovery from the mental stress task ($t = -2.2$, $p = .03$). RSA mental stress recovery levels were therefore included in the repeated measures GLM.

In response to the cold stress, SBP and DBP increased with a respective 10% and 17% increase from baseline resting levels. The autonomic response was smaller, with an increase in sympathetic activity of 5%, and a decrease in parasympathetic activity of 2%, resulting in a 4% decrease in heart period (Table 2).

Hemodynamic Response in Relation to Type D Personality

Sphericity assumptions were met for SBP reactivity ($p > .05$) but not for DBP reactivity ($\chi^2 = 20.68$, $p < .001$; $\varepsilon = .86$), therefore, no correction was applied for SBP, and Huynh-Feldt correction was applied for DBP. Type D personality was associated with slightly increased reactivity of SBP, $F(2,166) = 2.68$, $p = .07$, and significantly increased reactivity of DBP, $F(1.72,143.10) = 4.64$,

Table 1. *Sample Characteristics*

	Total group (N = 101)*	Type D (N = 30)	Non-Type D (N = 71)	Test statistic	P value
Demographics					
Women	84% (85)	83% (25)	85% (60)	0.02	.88
Age, mean (*SD*) yrs	19.8 (4.0)	19.5 (1.7)	20.0 (4.6)	-0.5	.62
Partner status (single)	46% (46)	43% (13)	47% (33)	2.41	.49
Health behaviors					
Smoking (yes)	15% (15)	**27% (8)**	**10% (7)**	**4.58**	**.03**
Regular exercise (yes)	70% (70)	60% (18)	74% (52)	2.04	.15
Coffee consumption	43% (43)	37% (11)	46% (32)	0.70	.40
More than moderate alcohol consumption**	20% (20)	27% (8)	17% (12)	1.67	.43
Body composition					
BMI, mean (*SD*)	22.2 (3.3)	23.1 (3.9)	21.8 (2.9)	−1.7	.09
Overweight (BMI > 25 kg/m^2)	14% (14)	17% (5)	13% (9)	0.25	.62
Medication					
Psychotropic medication***	2% (2)	7% (2)	0% (0)	4.83	.09
Hormonal contraceptives§	32% (27/85)	27% (10/25)	28% (17/60)	1.11	.29
Mood disorders****					
Depression	4% (4)	7% (2)	3% (2)	0.79	.37
Anxiety***	2% (2)	7% (2)	0% (0)	4.70	.09

Note. Bold-faced typing indicates significant ($p < .05$) differences between Type D and non-Type D participants.
**N* varies between 101 and 100 for individual variables due to missing items. **On average more than 1 glass a day (7/week). ***Fisher exact test. ****Self-report.
§Women only (N = 27 out of 85).

$p = .015$, $\eta^2 = .05$, to the cold pressor test, independent of sex and smoking status (Figure 1). Contrasts of Time × Type D showed a significant quadratic effect for SBP, $F(1,83) = 4.80$, $p = .03$, and DBP, $F(1,83) = 6.25$, $p = .01$, indicating unaltered baseline and recovery levels and an elevated blood pressure level during the cold pressor test (Figure 1). There were no significant effects for pulse pressure, indicating that SBP and DBP responded in similar amounts. Using the continuous scales, no significant associations were found for the interaction variable NA × SI (SBP: $F(2,164) = 0.26$, $p = .77$; DBP: $F(1.7,141.2) = 0.25$, $p = .74$). Exploratory analysis further showed that there were no differences between men and women in the relation between Type D and SBP and DBP reactivity.

Hemodynamic Response in Relation to Type D Personality

Heart period. The sphericity assumption was not met ($\chi^2 = 27.02$, $p < .001$; $\varepsilon = .84$), and therefore Huynh-Feldt correction was applied. Type D personality was unrelated to the heart period response to and recovery from the cold stressor, $F(1.7,157.2) = 0.45$, $p = .60$. Analysis using the continuous NA and SI scales were nonsignificant as well, $F(1.7,158.2) = 0.08$, $p = .89$ for the NA × SI interaction. In exploratory analysis, we examined whether there were sex differences in the effect of Type D on heart period. Results showed a significant Time × Type D × Sex effect, $F(1.7,158.1) = 3.42$, $p = .04$, $\eta^2 = .04$, with heart period increasing slightly for Type D men, while decreasing for the other three groups.

RSA. The sphericity assumption was not met ($\chi^2 = 42.0$, $p < .001$; $\varepsilon = .78$), and therefore Huynh-Feldt correction was applied. There were no differences in RSA response between Type D and non-Type D participants, $F(1.5,144.0 = 0.45$, $p = .58$, $\eta^2 = .005$;

Table 2. *Means* (±SD) *of Hemodynamic and Autonomic Measures During Rest, Cold Stress, and Recovery*

	Rest	Cold stress	Recovery
DBP (mmHg)	70.7 ± 7.7	83.9 ± 11.1	72.1 ± 7.5
SBP (mmHg)	116.1 ± 9.0	127.4 ± 9.9	117.9 ± 8.1
Heart period (ms)	825.9 ± 123.7	793.9 ± 108.7	854.2 ± 118.6
RSA (ms)	70.6 ± 37.7	68.9 ± 37.1	76.6 ± 40.1
PEP (ms)	111.5 ± 19.4	105.5 ± 18.6	110.9 ± 18.7

Note. Data are represented as mean ± *SD*. DBP = diastolic blood pressure; SBP = systolic blood pressure; RSA = respiratory sinus arrhythmia; PEP = pre-ejection period.

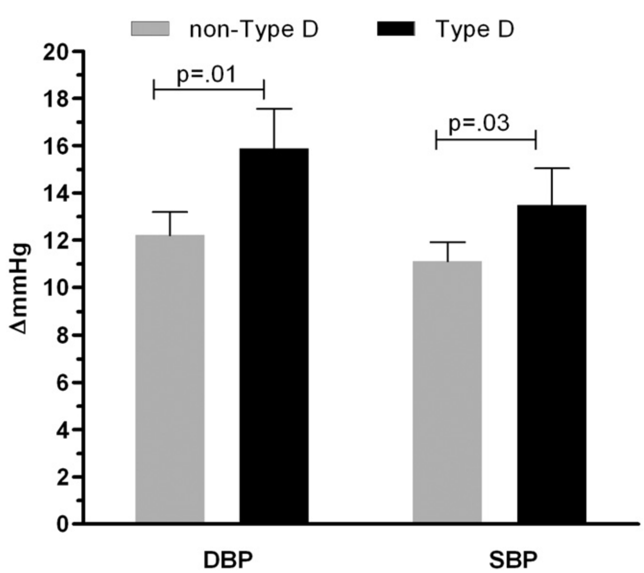

Figure 1. Hemodynamic responses to cold stress, stratified by Type D personality. DBP = diastolic blood pressure; SBP = systolic blood pressure. P values are from the Time × Type D contrast analysis.

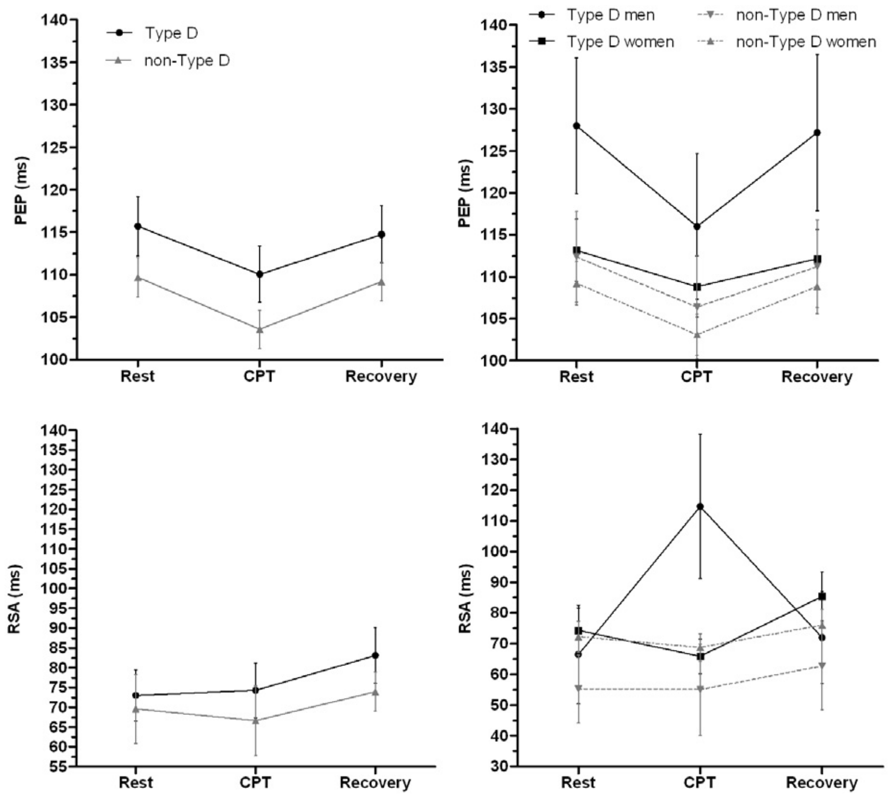

Figure 2. Autonomic responses to cold stress, stratified by Type D personality and sex. Left: Main effect of Type D personality on PEP (pre-ejection period) and RSA (respiratory sinus arrhythmia). Right: Effect of Type D personality separately for men and women. PEP response: a lower value indicates sympathetic activation; RSA response: a higher value indicates parasympathetic activation. PEP and RSA are visualized in mean levels during rest, cold pressor test (CPT), and recovery. Error bars represent one standard error of the mean.

Figure 2, left panel. There were significant sex differences, though, $F(1.5,144.0) = 4.48$, $p = .02$, $\eta^2 = .05$, with contrasts showing these sex differences occurred during the recovery phase, $F(1,94) = 5.08$, $p = .03$, $\eta^2 = .05$. In exploratory analysis, we examined whether there were sex differences in the effect of Type D on RSA. Results showed a significant Time × Type D × Sex effect, $F(1.6,148.4) = 12.1$, $p < .001$, $\eta^2 = .13$, with male Type Ds responding with vagal activation and female Type Ds responding with vagal withdrawal (Figure 2, right panel). Analysis using the continuous NA and SI scales and their interaction showed similar findings, $F(1.6,49.5) = 3.1$, $p = .06$ for the NA × SI interaction and $F(1.6,149.5) = 12.4$, $p < .001$ for the NA × SI × Sex interaction.

PEP. The sphericity assumption was not met ($\chi^2 = 16.4$, $p < .001$; $\varepsilon = .90$), and therefore Huynh-Feldt correction was applied. There were no differences in PEP response to or recovery from cold stress in Type D and non-Type D participants, $F(1.8,165.9) = 0.54$, $p = .56$, $\eta^2 = .006$; Figure 2, left panel. In exploratory analysis, we examined whether there were sex differences in the effect of Type D on PEP. Results showed a significant Time × Type D × Sex effect, $F(1.9,168.3) = 3.88$, $p = .025$, $\eta^2 = .04$, with male Type Ds showing a stronger PEP response than the other three groups (Figure 2, right panel).

Correcting PEP for after load effects (i.e., taking the PEP:LVET ratio) did not alter the results. Analysis using the continuous NA and SI scales and their interaction showed similar findings, $F(1.9,169.6) = 3.1$, $p = .051$ for the NA × SI × Sex interaction.

Discussion

The current study examined the association of Type D personality with the hemodynamic and autonomic response to the cold pressor test. Results showed that cold stress elicited an exaggerated α-adrenergic vasoconstriction and pressor response in participants with Type D personality. Interestingly, preliminary exploratory analyses revealed potential sex differences in the autonomic response to cold stress; that is, Type D men showed parasympathetic and sympathetic coactivation, while Type D women were characterized by a reciprocal response pattern, with a more modest sympathetic response combined with vagal withdrawal.

Early identification of the risk of hypertension is important to the prevention of hypertension and potential reduction of its associated cardiovascular morbidity and mortality (Egan, Zhao, & Axon, 2010). Hypertension is more prevalent in individuals with Type D personality in the general population (Svansdottir et al., 2013), as well as in cardiac patients (Kupper et al., 2011). It has been shown that normotensive adults with an exaggerated blood pressure response to cold stress, particularly the systolic blood pressure response, were at increased risk of developing hypertension over a follow-up period of 28 years (Kasagi et al., 1995). Moreover, patients with hypertension display an increased blood pressure response to cold stress as compared to normotensive individuals (Farah, Keshav, & Pawan, 2011). The current results show that young adults with Type D personality have an exaggerated blood response to cold stress, which may increase their risk of hypertension later on in life. Future studies should examine whether the cold pressor response predicts hypertension incidence in at-risk populations with Type D personality. Cardiorespiratory fitness has been related to reduced systolic blood pressure response in women, but not in men, and may be an important covariate in using the cold pressor test as a predictor of hypertension risk in women (Dishman, Jackson, & Nakamura, 2002). In our study, adding regular or weekly exercise to the GLM model did not affect hemodynamic or autonomic results.

The current results add to mixed findings on personality, mood, and cold pressor responses. Previous studies have reported unaltered physiological responses to cold stress in relation to irritable personality and somatic anxiety (Flaa, Ekeberg, Kjeldsen, & Rostrup, 2007), trait anxiety (Pointer et al., 2012), and depression (Schwerdtfeger & Rosenkaimer, 2011). Exaggerated blood pressure responses have been associated with higher state anxiety (Pointer et al., 2012) and psychasthenia (Flaa et al., 2007). With respect to heart rate variability responsiveness to cold stress, prior work has shown that depression was associated with smaller increases in parasympathetic cardiac control (Hughes & Stoney, 2000), while no differences were found for parasympathetic or sympathetic autonomic response patterns in relation to worry (Knepp & Friedman, 2008). It is of note that there are also inconsistencies in heart rate variability reaction to cold stress per se, as studies have reported vagal withdrawal (Wirch, Wolfe, Weissgerber, & Davies, 2006), as well as small vagal activation responses (Huang et al., 2011). In addition, several studies have reported null findings with respect to the parasympathetic response (e.g., Hallman, Lindberg, Arnetz, & Lyskov, 2011; Moses, Luecken, & Eason, 2007). In the current study, Type D personality was only related to autonomic response patterns when looking at men and women separately. While Type D women showed increased vagal withdrawal and an unaltered sympathetic response, Type D men displayed sympathetic and parasympathetic coactivation, and non-Type D men only responded with increased sympathetic activity. Because of the small subsample size, these results should be considered preliminary. Previous studies have indicated that sex differences may be expected in the cardiovascular response to cold stress, with larger sympathetic and vasoconstrictor effects (Hogarth et al., 2007), as well as heart rate responses in men (Ruiz et al., 2006), potentially due to differences in genetic influences (Wu et al., 2010). The current results corroborate these previously reported sex differences, and recommend future studies examining sex differences in the effects of Type D on autonomic responses to cold stress in larger, more equally sex-distributed samples. With respect to these explored sex differences, we found coactivation of the parasympathetic and sympathetic nervous system in men, while women displayed a reciprocal activation pattern. It is not uncommon for psychological processes and higher neurobehavioral substrates to evoke a coactivation pattern (Berntson, Cacioppo, & Quigley, 1991, 1993). This has also been observed in response to nociceptive somatic stimuli, such as cold-induced pain, or when a "defense" response is mounted (Paton, Boscan, Pickering, & Nalivaiko, 2005). Prior studies have shown limited evidence for an association between negative affectivity/neuroticism and pain perception, or a sex difference therein (e.g., Garofalo, Lawler, Robinson, Morgan, & Kenworthy-Heinige, 2006; Lee, Watson, & Frey Law, 2010), although sex differences were found in physiological responsiveness of men and women (Garofalo et al., 2006). This therefore suggests that the Type D men may have been more alarmed by the nociceptive stimulus (i.e., cold stress) than the women or non-Type D men. Notably, coactivation of sympathetic and parasympathetic branches of the autonomic nervous system may be adaptive when high cardiac output is needed, but may also induce cardiac arrhythmia (Paton et al., 2005).

The current results should be viewed in light of several limitations. First, the magnitude of the blood pressure response to cold stress is related to pain intensity, perception, and appraisal (Peckerman et al., 1994; Reimann et al., 2012). The current study has collected no information on pain. It may be that Type D individuals are more sensitive to pain and therefore show exaggerated blood pressure responses and autonomic coactivity responses to cold stress. This should be examined in future research. Moreover, blood pressure was assessed only once during the cold pressor test, instead of using continuous blood pressure measurement. Further, there were some differences in the results from the dichotomous analyses as compared to the continuous analyses of Type D personality with respect to blood pressure and heart period, but not with respect to autonomic cardiac control. One explanation for the observed discrepancies may be statistical power, as in the continuous analyses Type D personality is represented by three variables (i.e., NA, SI, and NA $\times$ SI interaction) instead of one dichotomized score. It is recommended that attempts be made to replicate these results in a larger population, with a more equal representation of men and women.

In conclusion, young, healthy adults with Type D personality demonstrated an exaggerated hemodynamic and altered autonomic response to a passive, physiologic, cold challenge task, which may contribute to an increased risk of hypertension in Type D individuals.

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