2016

Stress reactivity and personality in extreme sport athletes: The psychobiology of BASE jumpers

Erik Monasterio
University of Otago

Omer Mei-Dan
University of Colorado, Boulder

Anthony C. Hackney
University of North Carolina at Chapel Hill

Amy R. Lane
University of North Carolina at Chapel Hill

Igor Zwir
Washington University School of Medicine in St. Louis

See next page for additional authors

Authors
Erik Monasterio, Omer Mei-Dan, Anthony C. Hackney, Amy R. Lane, Igor Zwir, Sandor Rozsa, and C. Robert Cloninger

Physiology & Behavior 167 (2016) 289–297

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

Stress reactivity and personality in extreme sport athletes: The psychobiology of BASE jumpers

Erik Monasterio, MBChB, FRANZCP [a], Omer Mei-Dan, MD [b], Anthony C. Hackney, PhD, DSc [c], Amy R. Lane, MA [c], Igor Zwir, PhD [d], Sandor Rozsa, PhD [d], C. Robert Cloninger, MD, PhD [d,*]

[a] University of Otago, Hillmorton Hospital, Private Bag, 4733, Christchurch, New Zealand
[b] Department of Orthopedics, University of Colorado, CU Sports Medicine and Performance Center, Boulder, CO 80309, United States
[c] Department of Exercise & Sport Science, University of North Carolina, Chapel Hill, NC, United States
[d] Department of Psychiatry, Washington University School of Medicine, Campus Box 8134, 660 South Euclid Avenue, St. Louis, MO 63110, United States

HIGHLIGHTS

- BASE jumpers are usually resilient but vary widely in stress reactivity.
- Stress reactivity depended on profiles of personality and experience.
- Cortisol reactivity was dissociated from sympathetic arousal.
- Emotional style predicted cortisol reactivity, but not sympathetic arousal.
- Experience and tenacity predicted alpha-amylase, but not cortisol, reactivity.

ARTICLE INFO

Article history:
Received 11 July 2016
Received in revised form 13 September 2016
Accepted 27 September 2016
Available online 29 September 2016

Keywords:
Extreme sports
BASE jumping
Resilience
Stress reactivity
Temperament
Character

ABSTRACT

This is the first report of the psychobiology of stress in BASE jumpers, one of the most dangerous forms of extreme sport. We tested the hypotheses that indicators of emotional style (temperament) predict salivary cortisol reactivity, whereas indicators of intentional goal-setting (persistence and character) predict salivary alpha-amylase reactivity during BASE jumping. Ninety-eight subjects completed the Temperament and Character Inventory (TCI) the day before the jump, and 77 also gave salivary samples at baseline, pre-jump on the bridge over the New River Gorge, and post-jump upon landing. Overall BASE jumpers are highly resilient individuals who are highly self-directed, persistent, and risk-taking, but they are heterogeneous in their motives and stress reactivity in the Hypothalamic-Pituitary-Adrenal (HPA) stress system (cortisol reactivity) and the sympathetic arousal system (alpha-amylase reactivity). Three classes of jumpers were identified using latent class analysis based on their personality profiles, prior jumping experience, and levels of cortisol and alpha-amylase at all three time points. "Masterful" jumpers (class 1) had a strong sense of self-directedness and mastery, extensive prior experience, and had little alpha-amylase reactivity and average cortisol reactivity. "Trustful" jumpers (class 2) were highly cooperative and trustful individuals who had little cortisol reactivity coincident with the social support they experienced prior to jumping. "Courageous" jumpers (class 3) were determined despite anxiety and inexperience, and they had high sympathetic reactivity but average cortisol activation. We conclude that trusting social attachment (Reward Dependence) and not jumping experience predicted low cortisol reactivity, whereas persistence (determination) and not jumping experience predicted high alpha-amylase reactivity.

1. Introduction

Little is known about stress reactivity in athletes in extreme sports despite their increasing popularity [1]. "Extreme sports" include high-risk sports such as mountaineering, rock climbing, downhill mountain biking, and BASE jumping. BASE jumping developed out of skydiving and uses specially adapted parachutes to jump from fixed objects. "BASE" is an acronym for the four categories of fixed objects from which one can jump: a Building, Antenna, Span, and Earth. BASE jumpers rely on a single canopy with no reserve parachute. Estimates of injury rate are 0.2–0.4% per jump [2,3] and fatality rates of 0.04% per jump or 1.7% per participant per year [3,4], suggesting that this is one of the most dangerous sporting activities. BASE jumping is 20 to 40 times

* Corresponding author.
E-mail addresses: Erik.Monasterio@cdhb.health.edu (E. Monasterio), omer.meidan@ucdenver.edu (O. Mei-Dan), ach@email.unc.edu (A.C. Hackney), crcloninger44@gmail.com (C.R. Cloninger).

http://dx.doi.org/10.1016/j.physbeh.2016.09.025

more dangerous than skydiving, so it is legally prohibited in many areas. The New River Gorge Bridge Day in West Virginia, the site of the current study, is the main legal BASE jump meet in the USA.

Monasterio and colleagues examined high-performance mountaineers and BASE jumpers with the Temperament and Character Inventory (TCI) to assess their personalities [5,6]. The TCI provides a comprehensive account of personality traits, measuring seven dimensions of personality (see Table 1) that are moderately heritable and associated with distinct brain networks and psychological characteristics [7,8]. The model measures four dimensions of temperament, which involve basic emotional drives modulated by the hypothalamus and related limbic structures [9], and three character dimensions, which involve self-regulation of emotions in order to achieve intentional goals and values regulated mainly in the neocortex [6,8]. In temperament, BASE jumpers were often adventurous risk-takers, as measured in the TCI by lower Harm Avoidance (HA), higher Novelty Seeking (NS), and lower Reward Dependence (RD) compared to low-risk sports participants and people in the general population. In character, they were highly self-controlled and well-organized, as characterized in the TCI by higher Self-directedness, higher Cooperativeness, and lower Self-Transcendence [1,10].

There is no consistent temperament and character profile that characterizes all extreme sports athletes because the choice of such activities is influenced by diverse personal, social and geographic variables. As a result, extreme sports athletes provide an unusual opportunity to understand the effects of variable combinations of traits and situations that may influence their decision-making and stress reactivity.

Table 1
Descriptors of people with high or low scores on TCI personality scales and subscales.

TCI scales	TCI subscales	High scorers	Low scorers
Novelty seeking			
	NS1 excitability	Exploratory	Reserved
	NS2 impulsivity	Impulsive	Rigid
	NS2 extravagance	Extravagant	Thrifty
	NS4 disorderly	Rule-breaking	Orderly
Harm avoidance			
	HA1 pessimism	Pessimistic	Optimistic
	HA2 fearfulness	Fearful	Risk-taking
	HA3 shyness	Shy	Outgoing
	HA4 fatigability	Fatigable	Vigorous
Reward Dependence			
	RD1 sentimentality	Sentimental	Objective
	RD2 sociability	Open	Secretive
	RD3 attachment	Friendly	Detached
	RD4 dependence	Approval-seeking	Independent
Persistence			
	PS1 eagerness	Enthusiastic	Hesitant
	PS2 hard-working	Determined	Easily discouraged
	PS3 ambition	Ambitious	Lazy
	PS4 perfectionism	Perfectionistic	Underachieving
Self-directedness			
	SD1 responsibility	Responsible	Blaming
	SD2 purposefulness	Purposeful	Aimless
	SD3 resourcefulness	Resourceful	Helpless
	SD4 self-acceptance	Hopeful	Hopeless
	SD5 self-actualizing	Self-actualizing	Unfulfilled
Cooperativeness			
	CO1 social tolerance	Tolerant	Prejudiced
	CO2 empathy	Empathetic	Self-centered
	CO3 helpfulness	Considerate	Hostile
	CO4 compassion	Forgiving	Revengeful
	CO5 conscience	Principled	Opportunistic
Self-transcendence			
	ST1 self-forgetfulness	Acquiescent	Controlling
	ST2 transpersonal identification	Altruistic	Individualistic
	ST3 spiritual acceptance	Spiritual	Skeptical

Stress activates two major neurobiological systems: (i) the endocrine response involves activation of the HPA axis and results in increased cortisol levels, whereas (ii) the autonomic nervous system response involves activation of the sympathetic-adrenal medullary (SAM) axis and results in release of norepinephrine from sympathetic nerve terminals [11]. Salivary cortisol provides a non-intrusive index of activation of the HPA axis, whereas salivary alpha-amylase provides an index of arousal of the SAM axis [12].

Prior literature led us to hypothesize that temperament profiles of Novelty Seeking, Harm Avoidance, and Reward Dependence predict stress reactivity of the HPA axis whereas the effortful struggle to control events measured by persistence and character profiles predict reactivity in the SAM axis. Specifically, lower cortisol reactivity has been observed in healthy individuals who are high in Novelty Seeking and/or low in Harm Avoidance compared to others [13,14]. In addition, individuals who are high in Reward Dependence (i.e., warmly sociable and trusting) have larger oxytocinergic regions in their hypothalamus and higher circulating levels of oxytocin [15,16], which reduces activation of the amygdala, insular salience network, and cortisol release in dangerous situations [17–19]. Accordingly, individuals who are highly sociable have reduced cortisol responses to stress in socially supportive situations [18,20]. In contrast, cortisol release by activation of the HPA axis is usually blunted in individuals who are high in neuroticism (i.e., high Harm Avoidance and/or low self-directedness) [21–23] or who experience chronic adversity or repeated stress beyond their control and/or without adequate social support [20,24].

Little objective information about alpha-amylase or cortisol reactivity is available in extreme sports enthusiasts. Heterogeneity in cortisol reactivity has been documented in parachute jumpers [25]. Skydiving has been shown to stimulate a rise in salivary cortisol compared to the level before the jump and at recovery in both novice and experienced skydivers [26]. Novices reported greater anxiety than did experienced skydivers, but there were no significant differences in their salivary cortisol levels.

We hypothesized that personality measures of emotional style (temperament) predict salivary cortisol reactivity, whereas personality measures of intentional goal-seeking (persistence and character) predict salivary alpha-amylase reactivity during BASE jumping. We also hypothesized that resilient individuals (measured by high Persistence combined with low Harm Avoidance and high Self-directedness) would show “The Right Stuff” [27], accomplishing their dangerous mission without substantial arousal of either stress system.

2. Methods

2.1. Study site

Data for the study was collected from the 2014 New River Gorge Bridge Day BASE Jumping event. This is an annual event in October in Fayetteville, West Virginia USA where participants jump from a bridge 876 ft above the New River. Participants freefall for 2 to 6 s and then release a parachute prior to landing at a site adjacent to the New River that flows through the gorge, as shown in videos posted (https://www.youtube.com) about the event (New River Gorge Bridge Day 2014). The videos show the cheerful camaraderie among participants and spectators at the event. Although injuries and fatalities have occurred at this event, the supervision of jump conditions was collegial but well-disciplined.

2.2. Literature review

In order to generate testable hypotheses, a systematic literature review was conducted in PubMed using all possible combinations of three groups of search terms: (1) extreme sports, BASE jumping, (2) personality, temperament, character, motivation, and (3) stress reactivity, cortisol, alpha-amylase, norepinephrine. References were included or excluded on the basis of their providing information useful in informing testable hypotheses about how temperament and character mediate stress reactivity in the HPA and SAM axes.

2.3. Demographics and BASE jumping characteristics

100 subjects (81 men, 19 women) out of about 400 participants in Bridge Day volunteered to complete several paper questionnaires providing demographic information and BASE jump information the day before the jump without remuneration. They reported their number of BASE jumps per year, how long they had been involved in the sport, whether they had had "near misses", and whether they had suffered base jumping accidents.

2.4. Temperament and character inventory (TCI)

Subjects completed the TCI, a 240 item true-false questionnaire designed to assess differences between people in seven basic dimensions of personality [6,28]. Extensive data on the reliability and validity of the TCI have been reported, showing sound psychometric characteristics with strong internal consistency and test-retest reliability of its scales ($r = 0.8$ to 0.9) [28,29]. The TCI of two subjects were incomplete and were excluded, leaving 98 valid self-reports.

2.5. Physiological stress measures

Twenty-four hours before they jumped, participants provided a baseline (basal) saliva sample. On the day of the event, saliva was collected 3–10 min prior to jumping (pre-jump) and another time within 1–5 min following the jump (post-jump). 79 participants (11 first-time jumpers (novices), and 68 more experienced jumpers) provided saliva samples at all three time-points, and all but two of these completed the TCI.

Prior to all sample collection, participants were required to rinse their mouths with water to eliminate large particulate matter based on recommendations of the manufacturer of the ELISA assays used in the salivary analyses (Salmetrics Incorporated) and the research literature [30]. Samples were collected via an oral absorbent device placed in the mouth for 1–2 min then sealed in a secure cylinder, as described elsewhere [31]. All saliva samples were obtained between 11 am and 4 pm, and were stored on ice following collection. Once returned to the laboratory, saliva was expressed from the saturated collection device, centrifuged at 4 °C × 3000*g*, and stored at —80 °C until analysis. Samples were later evaluated in duplicate for cortisol and alpha-amylase via high-sensitivity ELISA procedures using a standard assay protocol [30]. In the ELISA assays, the mean within-assay coefficient of variation was 7.2% while the mean between-assay coefficient of variation was 9.2%.

Although both cortisol and alpha-amylase have well-established circadian rhythms [32,33], the period of saliva collection between 11 am and 4 pm minimized the need for controlling for circadian variability in salivary cortisol and alpha-amylase, thereby facilitating participation by minimizing our demands on volunteers for their time and information. In healthy adults, there is a peak of cortisol release within 30 min of awakening in the morning (7 am to 9 am) and a nadir at night (9 pm to 2 am) with a mid-day plateau at an intermediate level with little or no variability between 11 am and 4 pm [32,34,35]. In contrast, in healthy adults, there is a pronounced decrease in salivary alpha-amylase within an hour of awakening and then a general increase to a nighttime peak, with a mid-day plateau at an intermediate level with little or no variability between 11 am and 4 pm [32]. Although age, gender, contraceptive use, body mass index, and smoking status may or may not [32,36] have significant impact on the extremes of variability in salivary cortisol and/or alpha-amylase in the morning and at night, they have negligible impact on mid-day levels of salivary cortisol [37,38] or salivary alpha-amylase [32,39] because of the minimal variation in levels during the mid-day plateau of healthy adults in the absence of acute stress.

2.6. Ethics

IRB approval was obtained prior to commencement of the study from the University of North Carolina at Chapel Hill (IRB# 14-1942; approved 9/4/2014). Written consent was obtained from those who agreed to participate in the survey and salivary measurements in accordance with the stipulated IRB procedure.

2.7. Statistical analysis

TCI raw scores were converted to T-scores (mean 50, SD 10) taking into account age and gender using US norms [28]. Multidimensional profiles of high and low scorers were computed using median splits as described elsewhere [40]. Quantitative measures of these profiles were computed as the product of possible combinations of high and low T-scores for particular traits. Scores higher than the median were designated by capital letters: Novelty Seeking (N), Harm Avoidance (H), Reward Dependence (R), Persistence (P), Self-directedness (S), Cooperativeness (C), and Self-Transcendence (T). Low scores on the same traits were designated by the corresponding lower case letters: n, h, r, p, s, c, and t. Salivary cortisol and alpha-amylase values were log-transformed to reduce skewness. A stress index was computed as the ratio of salivary alpha-amylase to salivary cortisol, and also log-transformed [12]. The pattern of change in salivary hormone values was quantified as the differences from baseline of the later two values. Salivary values at different times of the same jumper were compared by paired sample t-tests, and differences between groups of novice and experienced jumpers were compared using simple t-tests. Results were similar for log-transformed and raw values, but statistical tests were based on log-transformed values and raw values were plotted in all figures for ease of interpretation.

Latent class analysis (LCA) was used as a "person-centered" method designed to identify latent classes within a group of individuals based on two or more indicator measures [41]. LCA is an analytic strategy that can be used, similar to a cluster analysis, to group individuals into classes. Classifying individuals into these classes was done based on the analysis of patterns of scores on the personality dimensions, jumping characteristics, and biological markers. Unlike the classical cluster analysis approach, LCA gives fit statistics and significance tests to assess what number of classes best fit the data and is model based [42].

LCA was carried out using the Latent GOLD 5.0 statistical package (Vermunt & Magidson, 2013). Final optimal class solutions were based on several fit indices including maximum likelihood estimation using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log-likelihood were examined [43]. Lower AIC, BIC, and log-likelihood values indicate better fit to the data or increased probability of replication. Additional fit indices, such as class error, number of parameters, and entropy were also examined to minimize the risk of overfitting the data. Entropy values range from 0 to 1 with values closer to 1.00 indicating greater class separations and homogeneity [44]. Because some evidence suggests that the BIC performs best of the information criterion indices [42], BIC was prioritized in interpreting the current data. BIC increases the log likelihood by a function of the number of parameters in the model and the sample size in order to minimize the risk of overfitting small data sets with a falsely large number of classes [42]. We used the Bootstrap Likelihood Ratio Test procedure to estimate the log likelihood (LL) distribution and the significance of the difference between classes [42].

Mediation analysis was used to estimate the relative roles of a direct effect of individual TCI personality traits on stress reactivity and the indirect effect of personality mediated by prior jumping history. Bootstrapping was used to estimate the bias-corrected non-normal sampling distribution of the direct and indirect paths using the PROCESS macro in SPSS [45].

Variability in stress reactivity was examined in relation to individual TCI traits and multidimensional profiles by Pearson correlations and multiple linear regression using standard methods (Statistical Toolbox, Matlab 2007b). The differences among the classes in indices of stress reactivity at each time point (baseline, pre-jump, and post-jump) were evaluated using standard Analysis of Variance (ANOVA) (Statistical Toolbox, Matlab 2007b). After ANOVA, we performed multiple pairwise t-test comparisons with a significance level cutoff value of 0.05 (Multcompare, Statistical Toolbox, Matlab 2007b).

3. Results

3.1. Subjects and demographics

The 100 subjects included 81 men and 19 women. Their age was 37.3 on average (SD = 13.7), and ranged from 17 to 79 years of age. Most subjects were from 26 to 49 years of age (n = 59), 22 were 17 to 25 years old, and 19 were from 50 to 79 years old. Male jumpers reported 5.9 ± 6.6 years of experience with 39 ± 48 jumps per year. Female jumpers reported 7.0 ± 8.0 years of experience with 21 ± 27 jumps per year.

3.2. Temperament and character inventory

3.2.1. Mean values

The T-scores (mean 50, SD 10) for TCI traits were computed for the 98 jumpers who completed the TCI (Supplementary Table 1). Compared to average scores in the general population ($T = 50$), the participants were higher than average in NS and lower in HA and RD, which is the pattern seen in the "adventurous" temperament profile, as observed in prior work without collection of salivary hormone samples. Likewise they were also higher in SD and CO and lower in ST, which is the pattern seen in highly self-controlled individuals with an "organized" character profile. They were also higher on average in PS, which combined with low HA and high SD is the pattern seen in "resilient" personalities.

3.2.2. Multidimensional profiles

The distribution of multidimensional temperament configurations was examined using a person-centered approach using median splits of the temperaments (Table 2). Most participants had either adventurous (Nhr, 36.7%) or passionate (NhR, 18.4%) temperament profiles, which are both high in Novelty Seeking (N) and low in Harm Avoidance (h) but vary in Reward Dependence (R or r). The third most frequent group of participants had independent profiles (nhr, 14.3%), typical of individuals who are detached and resistant to outside control and stress. These three profile types are all below average in Harm Avoidance, and accounted for 69.4% of participants.

Most participants had either organized (SCt, 43.9%) or creative (SCT, 18.4%) character profiles, which are high in both Self-directedness (S) and Cooperativeness (C) (Table 3). In terms of plasticity configurations (see Supplementary Table 2), most participants had either resilient profiles (hPS, 49.0%) or self-reliant profiles (hpS, 19.4%). Three of the four prevalent plasticity profiles (i.e. resilient, conscientious, and happy-go-lucky) were high in Persistence and accounted for 67% of participants.

3.3. Cortisol and alpha-amylase

All three saliva samples were collected for 79 participants (62 men, 17 women). The average values of salivary cortisol and alpha-amylase at the three time points are depicted in Supplementary Figs. 1 and 2 respectively. Average salivary cortisol increased from baseline to pre-jump ($t = 10.70$, $p < 0.001$) and then fell slightly post-jump but remained above baseline (Fig. 1). In contrast, average levels of salivary alpha-amylase increased from baseline to pre-jump ($t = 26.87$, $p < 0.001$) and increased again from pre-jump to post-jump ($t = 5.23$, $p < 0.01$) (Fig. 2).

There were 11 first-time jumpers and 68 more experienced jumpers who gave all three saliva samples. There was no significant difference in salivary cortisol levels between the novice and experienced jumpers at any time point (Fig. 1). For alpha-amylase (Fig. 2), there was no difference between groups at baseline but the novices had higher alpha-amylase than the others both pre-jump ($t = 3.39$, $p < 0.001$) and post-jump ($t = 2.94$, $p < 0.01$).

3.4. Latent class analysis

77 subjects completed the TCI, jumping questionnaire, and provided salivary samples at all three occasions. In these 77 subjects we carried out a latent class analysis using 14 indicator variables to distinguish possible subgroups in a strictly data-driven manner. The variables included 7 TCI personality dimensions, 6 biological markers of stress reactivity (baseline, pre-jump, and post-jump levels of salivary cortisol and alpha-amylase), and the number of past jumps. A total of five LCA models were tested, ranging from one to six classes.

The empirical fit of the models is summarized in Table 4. The one-class solution exhibited a poor fit with the data relative to the other models. The two- and three-class solutions had highly significant improvements in fit measured by all indices compared to the one class solution. The three-profile model exhibited the lowest BIC and was also a highly significant improvement by the bootstrap likelihood ratio test over the two-class solution (−2LL difference = 133.82, $p < 0.0001$). The entropy value for the three-class solution was >0.90, indicating that our indicator variables were strong predictors of class membership. Overall, the three-class solution exhibited the best empirical fit with the data based on the BIC.

Descriptive statistics for personality, biological characteristics and number of jumps for the three-class solution are shown in Fig. 3. Class 1 was the largest subgroup identified (N = 28, 36.4%). People in class 1 were labeled as "*masterful*" jumpers because of their fearless self-confidence, extensive experience, and low level of sympathetic arousal. Specifically, they were highly self-directed, adventure-seeking (i.e., high Novelty Seeking with low Harm Avoidance), had the greatest number of prior jumps, and the lowest levels of alpha-amylase throughout the jump (baseline, pre-jump, post-jump), indicating their feeling of being in control with a sense of mastery.

Table 2
Distribution of temperament profile types (n = 98).

Profile type	Configuration	Number	Cumulative %
Adventurous	Nhr	36	36.7
Passionate	NhR	18	55.1
Independent	nhr	14	69.4
Explosive	NHr	8	77.6
Methodical	nHr	8	85.7
Reliable	nhR	8	93.9
Cautious	nHR	4	98.0
Sensitive	NHR	2	100.0

Table 3
Distribution of character configurations in Base jumpers (n = 98).

Profile type	Configuration	Number	Cumulative %
Organized	SCt	43	43.9
Creative	SCT	18	62.2
Bossy	Sct	12	74.5
Apathetic	sct	10	84.7
Disorganized	scT	7	91.8
Dependent	sCt	4	95.9
Moody	sCT	3	99.0
Absolutist	ScT	1	100.0

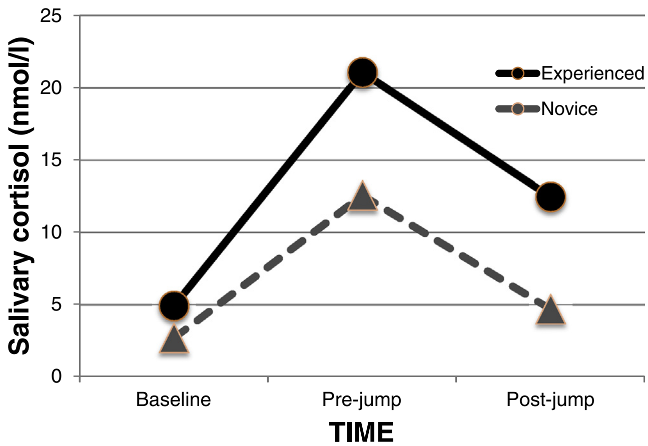

Fig. 1. Mean salivary cortisol levels (11 novices, 68 experienced jumpers; no difference significant at any time point).

Like those in class 1, jumpers in class 2 (n = 26, 33.7%) were low in Harm Avoidance and high in Self-directedness, but they were intermediate in their number of prior jumps. People in class 2 were labeled as "trustful" because they were relaxed, collegial, and trusting based on both their personality and low HPA stress reactivity. They were distinguished from jumpers in other classes by being highest in Cooperativeness (i.e., socially tolerant, helpful, and considerate of others). They were also distinguished by not showing a pre-jump rise in cortisol (i.e., cortisol level was stable across all three time-points), suggesting that they felt well-supported by responsible and trustworthy colleagues. Their alpha-amylase levels were intermediate to those in classes 1 and 3 at each of the three measurement points.

People in class 3 (n = 23, 29.9%) were described as "*courageous*" because they were anxious but overcame their fear with firm determination despite little experience. Specifically, they were distinguished by higher Harm Avoidance (i.e., more anxiety prone), lower Self-directedness (i.e., less intentional self-control), and slightly lower Self-transcendence (i.e., less able to let go of struggling), and the least jumping experience. Their strength was their high Persistence (i.e., being determined and less easily discouraged). Their cortisol level and reactivity was about the same as the "masterful" jumpers in Class 1 who had more jumping experience and greater character development (i.e., higher Self-directedness and Self-transcendence) but lower

Table 4
Fit statistics of latent class analysis solutions according to various criteria[a].

No. of classes	AIC	BIC	LL	Num Par	Class error	Entropy
1	4980.50	5076.59	−2449.25	41	0.0000	N/A
2	4875.55	5037.27	−2368.77	69	0.0263	0.8998
3	4791.39	5018.73	−2298.69	97	0.0181	0.9464
4	4744.05	5037.02	−2247.02	125	0.0193	0.9561
5	4704.28	5062.88	−2199.14	153	0.0113	0.9771
6	4648.81	5073.04	−2143.40	181	0.0130	0.9792

[a] Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), log-likelihood (LL), number of parameters (Num Par), classification error, and entropy.

Persistence. In addition, they had the highest levels of alpha-amylase at each of the three measurement points (baseline, pre-jump, post-jump).

3.5. The relative roles of personality and jumping history on stress reactivity

We evaluated the relative roles of personality and jumping history on stress reactivity in three ways that clarify the complex relationships involved. First, we tested which individual variables significantly distinguished the three classes of jumpers in the latent class analysis. Alpha-amylase levels at all three time points distinguished the three classes most strongly at all three time points (p value of Wald statistic < 7 E - 24), but cortisol did not distinguish the classes (p = 1.0 at baseline, 0.5 pre-jump, and 0.21 post-jump). Number of jumps was also strongly significant (p = 3.7 E - 7). Among the personality variables, the significant variables were Cooperativeness (p = 0.000029), Persistence (p = 0.005), and Self-directedness (p = 0.022), and not Novelty Seeking (p = 0.83), Reward Dependence (p = 0.61), Harm Avoidance (p = 0.59), or Self-Transcendence (p = 0.28).

Second, we checked how well alpha-amylase activity was predicted in multivariate regression on personality and jumping history. At all three time points 17 to 19% of variance in alpha-amylase activity was explained by jumping history (standardized regression coefficients - 0.32 to - 0.38, p ≤ 0.001 to 0.004) and by the personality trait of Persistence (standardized regression coefficients 0.22 to 0.26, p = 0.02 to 0.04).

However, jumping history was also predicted by personality traits. First-jumpers were much more risk-taking (i.e., lower in Harm Avoidance) than others (38.8 vs 44.7, p ≤ 0.001), more determined to succeed (i.e., higher in Persistence) than others (57.4 vs 52.9, p ≤ 0.001), and more self-directed and self-confident (i.e., higher in Self-directedness)

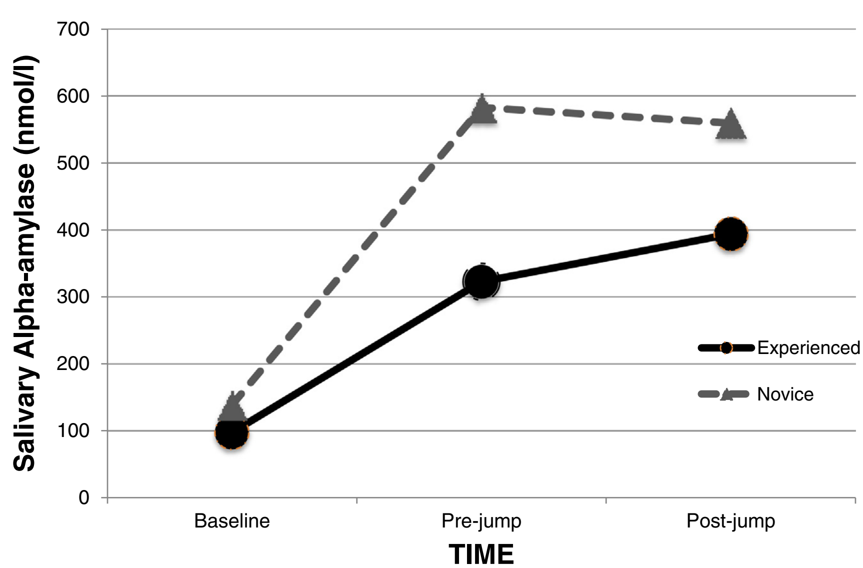

Fig. 2. Mean salivary Alpha-amylase levels (11 novices, 68 experienced jumpers, differences significant at each time point).

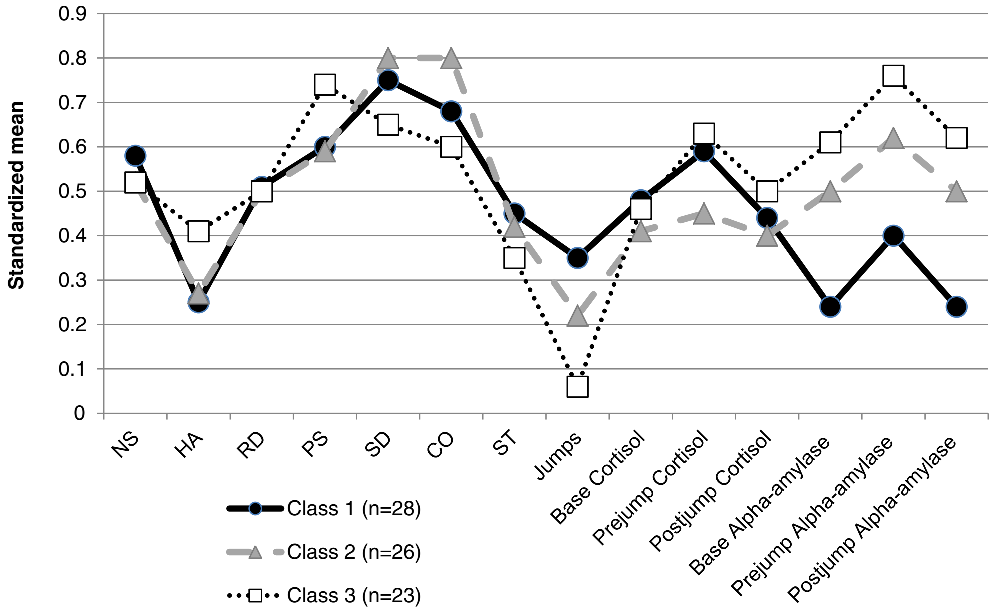

Fig. 3. Profiles of latent classes of base jumpers (n = 77).

than others (57.9 vs 53.3, $p < 0.001$). Therefore, we carried out a mediation analysis to take into account both the direct effects of personality on stress responses and the possible indirect effect of personality on stress response mediated by jumping experience. Two personality variables, Novelty Seeking and Persistence, were associated with fewer jumps (standardized regression coefficients on jumps = −0.19 to −0.21). However, jumping history did not have any significant effects on either alpha-amylase or cortisol levels at any time point when associated personality traits were taken into account. Therefore we examined the associations of personality and stress response in more detail.

3.6. Correlation between TCI traits and cortisol and alpha-amylase

The three classes of jumpers differed in multiple ways so we further evaluated the associations with stress reactivity with individual personality traits. At baseline, cortisol was negatively correlated with Harm Avoidance ($r = -0.21$, $p < 0.05$) and showed a positive trend with Novelty Seeking ($r = +0.19$). The pre-jump increase in cortisol from baseline was negatively correlated with Reward Dependence ($r = -0.25$, $p < 0.05$), as was the peak increase in cortisol from its baseline value ($r = -0.25$, $p < 0.05$). The corresponding association with higher Cooperativeness observed in "trustful" Class 2 was not individually significant ($r = -0.13$). In contrast, the peak increases in cortisol were lower in those who were more responsive to social approval as measured by higher Reward Dependence, but not with higher Cooperativeness alone.

The correlations between personality and salivary alpha-amylase suggested by the latent class analysis were also examined. Individuals who were high in TCI Persistence (as in "courageous" Class 3) had higher alpha-amylase levels pre-jump ($r = +0.26$, $p < 0.05$) with trends at baseline and post-jump ($r = +0.22$). The peak alpha-amylase levels attained were positively correlated with Persistence ($r = +0.26$, $p < 0.05$), and also tended to be higher in those who were lower in Self-transcendence ($r = -0.20$), as observed in "trustful" Class 2 jumpers. The stress index at baseline also tended to be lower in those who were high in Self-transcendence ($r = -0.20$) and in those who were high in Novelty Seeking ($r = -0.25$, $p < 0.05$) and post-jump ($r = -0.21$), as in "masterful" Class 1 jumpers.

In addition, we tested whether the stress index distinguished the 3 latent classes of jumpers using ANOVA. We found the differences in stress index among the 3 classes overall were not significant at baseline ($F = 2.879$, $p = 0.075$) at baseline, but were significant both 0.014 pre-jump ($F = 4.536$, $p = 0.014$) and post-jump ($F = 3.697$, $p = 0.029$). Post-hoc comparisons by t-tests showed two significant pairwise differences between classes: "masterful" jumpers (class 1) were lower on the stress index than "trustful" jumpers (class 2) both pre-jump ($p = 0.011$) and post-jump ($p = 0.024$), but not at baseline ($p = 0.070$). The stress index of "courageous" jumpers (class 3) did not differ significantly from that of the other two classes at any time point ($p > 0.294$).

3.7. Correlation between TCI multidimensional profiles and stress indices

Stronger relations with stress reactivity were observed with multidimensional TCI profiles than with individual traits. Emotional style was quantified in terms of interactions among Novelty Seeking, Harm Avoidance, and Reward Dependence (see Supplementary Table 5). Being passionate in temperament (NhR) was correlated with higher baseline cortisol ($r = +0.30$, $p < 0.01$) and a lower stress index ($r = -0.31$, $p < 0.01$). On the other hand, being adventurous (Nhr) was not significantly correlated with either cortisol ($r = +0.13$) or the stress index at baseline ($r = -0.16$). Adventurous (Nhr) jumpers had the lowest stress index of all jumpers upon landing ($r = -0.24$, $p < 0.05$). Independent (nhr) jumpers showed no significant stress reactivity at any point, whereas those with a reliable emotional style (nhR, differing only in greater sociability) had a trend toward greater sympathetic arousal (alpha-amylase) at baseline and on landing ($r = 0.21$).

The style of intentional self-governance was quantified in terms of interactions among character dimensions (Supplementary Table 6). Being independent of social supports (Sct or ScT), as in "masterful" Class 1 (Sct), was correlated with lower alpha-amylase pre-jump ($r = -0.25$, $p < 0.05$), as well as trends for greater cortisol and alpha-amylase levels post-jump ($r = -0.20$) (Supplementary Table 6). On the other hand, being self-organized in character (as in "trustful" class 2 with high self-directedness and Cooperativeness but low self-transcendence, SCt) was not associated with cortisol reactivity. The organized characters showed a trend toward higher alpha-amylase at baseline ($r = +0.21$) and post-jump ($r = +0.21$), but not pre-jump. Character styles associated with high Self-transcendence (SCT or sCT), a measure of positive affect and letting go of struggling, did not show significant cortisol or alpha-amylase reactivity (Supplementary Table 6).

Resilience was quantified in terms of interactions among high or low Persistence (P or p), Harm Avoidance (H or h), and Self-directedness (S or s). Being conscientious (HPS) was correlated with greater sympathetic arousal (alpha-amylase levels) at all time points, including at baseline ($r = +0.24$, $p < 0.05$), pre-jump ($r = 0.22$), and post-jump ($r = +0.24$, $p < 0.05$). Being perfectionistic (HPs) was associated with trends toward increased sympathetic reactivity pre-jump ($r = 0.20$) followed by a decrease post-jump upon landing ($r = -0.20$). In contrast, being resilient (hPS) or happy-go-lucky (hPs) was not associated with stress reactivity in BASE jumpers at any point (Supplementary Table 7). In other words, being low in Harm Avoidance and high in Persistence protected against stress reactivity regardless of the level of Self-directedness.

4. Discussion

4.1. Novel findings

This is the first report describing the psychobiology of stress reactivity in BASE jumpers. We identified distinct personality profiles that predicted distinct patterns of stress reactivity among people who parachuted from the 876-foot bridge above the New River Gorge in 2014. We found that the regulation of cortisol and alpha-amylase reactivity is dissociated in people with particular profiles of personality and experience.

4.2. Heterogeneity in BASE jumpers and their stress reactivity

The HPA and SAM stress systems had different reactivity trajectories across time. Compared to baseline measures taken the day before the jump, average salivary cortisol levels of jumpers initially increased on the bridge just prior to jumping and then decreased upon landing. In contrast, average salivary alpha-amylase, an indicator of sympathetic arousal, increased from baseline to pre-jump and again after the effort of guiding the parachute to land.

The BASE jumpers had a similar profile of average values compared to those previously reported [5,10]. On average they are certainly described as adventurers with the "Right Stuff" [27] – that is, on average they are adventurous in temperament (i.e., Nhr referring to high Novelty Seeking and low in Harm Avoidance and Reward Dependence), self-controlled in character (i.e., SCt referring to being high in Self-directedness and Cooperativeness, and low in Self-transcendence), and resilient (i.e., hPS referring to low Harm Avoidance, high Persistence, high Self-directedness) [46]. Nevertheless, in this study we demonstrated substantial heterogeneity among BASE jumpers in their individual personality profiles, and the multidimensional profiles of individuals had stronger relations with stress reactivity than the average effects of individual traits.

4.3. Relations among components of personality and stress reactivity

We identified three classes of BASE jumpers with distinct personality traits and distinct patterns of stress reactivity in the HPA and SAM systems. People in class 1 were described as "masterful" because they were highly self-directed, fearless (i.e., very low in Harm Avoidance), and experienced jumpers. They had very low sympathetic arousal from jumping and average HPA reactivity. In contrast, people in class 2 were described as "trustful" because they were highly cooperative (socially tolerant, appreciative, and considerate of colleagues) and seemed to approach the jumping as a festive social occasion among mutually supportive and trustworthy friends. They had little or no pre-jump rise in cortisol and average levels of alpha-amylase reactivity. Finally, people in class 3 were described as "courageous" because they were anxious, less self-directed and less cooperative than the others, but faced the challenge of the jump with firm determination despite being the least experienced. Their cortisol reactivity was similar to "masterful" class one despite their being much less experienced and confident, but their alpha-amylase levels were the highest of the three groups.

Both personality and prior jumping history distinguished these three classes of jumpers, so part of the differences between the classes may be attributed to the differences in their experience level rather than their personality. In particular, we found that first-time jumpers had higher levels of sympathetic arousal than more experienced jumpers (Fig. 2). Without prospective follow-up of subjects as they continue to participate in BASE jumping, we cannot say with certainty whether the less experienced "courageous" class 3 participants become "trustful" and eventually "masterful" as they increase in experience and self-confidence. However, we found personality was associated directly with stress reactivity and with jumping history, but jumping history did not influence stress reactivity once personality was taken into account. Nevertheless, the power to detect the effect of jumping history may be weak in a mediation analysis of a small sample like ours, even though we used bootstrapping methods to estimate the sampling distribution of the variables [45]. Therefore it would be useful to further test the possible influence of increasing jumping experience on stress reactivity by following a cohort of first-time BASE jumpers over time in future work.

Simple bivariate analyses confirmed that high Persistence (i.e. being determined, courageous, high-achieving) was positively correlated with alpha-amylase levels overall, a finding that had never been tested prior to this study to our knowledge. Also Reward Dependence (i.e., being friendly, sympathetic, and approval-seeking) was associated with a lower pre-jump increase in cortisol. People with high Reward Dependence have previously been found to have larger oxytocinergic regions in their hypothalamus [15] and higher levels of circulating oxytocin [16], which reduces cortisol reactivity by the HPA axis [17,18]. The association of a lower peak cortisol in jumpers who were sociable (i.e., high in Reward Dependence) is consistent with the expected buffering effect of oxytocin [18,20]. However, the strongest predictors of stress reactivity were multidimensional personality profiles, not the average effects of individual traits.

4.4. Relations of stress reactivity to multidimensional personality profiles

Multidimensional personality profiles were more strongly related to stress reactivity than were the average effects of individual personality traits. This was true of temperament profiles (i.e., combinations of Novelty Seeking, Harm Avoidance, and Reward Dependence) (Table 2 and Supplementary Table 5). It was also true of character profiles (i.e., combinations of Self-directedness, Cooperativeness, and Self-transcendence) (Table 3 and Supplementary Table 6), and profiles related to plasticity and resilience (i.e. combinations of Persistence, Harm Avoidance, and Self-directedness) (Supplementary Tables 2 and 7). The observed bivariate relationships of stress measures to individual personality traits were weak, as is typical of large-scale studies of stress indicators, but the multivariate profiles of personality and biomarkers were strongly distinguished ($p < 0.0001$). For example, being resilient (hPS) or happy-go-lucky (hPs) was not associated with stress reactivity in BASE jumpers at any point. In other words, being both low in Harm Avoidance and high in Persistence protected against stress reactivity regardless of the level of Self-directedness. Our findings encourage greater consideration of multidimensional personality profiles rather than individual traits in studying stress reactivity.

4.5. Stress regulation and brain circuitry

High Persistence was correlated with a tendency toward greater sympathetic arousal at all time points unless combined with low Harm Avoidance (Supplementary Table 7). The interaction of Persistence and Harm Avoidance in regulating stress reactivity can be understood by reference to their underlying brain circuitry. Individual differences in Persistence are mediated by activation of a brain circuit involving connections between the anterior cingulate cortex (ACC), the ventral striatum, and the inferior frontal gyrus in the orbital prefrontal cortex (BA 47) [47]. The ventral striatum is activated by the anticipation of pleasure and other rewards [46], whereas orbital PFC (BA 47) is involved in decision making that weighs the relative incentive values of small likely rewards and punishments versus large unlikely rewards and punishments [48]. Patients with lesions in BA 47 exhibit marked impairments in decision-making about risk-taking. In turn, pre-processed information about risk-taking is relayed by the ACC to other parts of the PFC for possible action, particularly to the medial PFC when people are high in Self-directedness [8,48]. However, high Harm Avoidance is strongly related to the functional connectivity of the ACC and the amygdala, so sympathetic hyperarousal blocks further rational processing and inhibits reward-seeking and risk-taking in people who are high in Harm Avoidance, even if they are high in Persistence [46,49,50]. What distinguishes nearly all BASE jumpers is their combination of low Harm Avoidance with high Persistence and/or high Self-directedness. This combination of traits of resilience occurs in 87% of BASE jumpers, which motivates their pursuit of a likely reward despite substantial risk of injury.

4.6. Study strengths and limitations

The study was a prospective investigation to predict salivary measures of stress at three time points from baseline personality traits. The timing of the jumping corresponded to the period of the mid-day plateau in levels of salivary cortisol [37,38] or salivary alpha-amylase [32,39], which provided an excellent opportunity to study the effects of the acute stress of BASE jumping without confounding variability attributable to circadian rhythms. We studied 100 subjects, which is about 25% of those present at Bridge Day and 3% of the approximately 3000 BASE jumpers in the world [2]. Many very experienced jumpers do not participate in Bridge Day because they prefer to pursue their sport in the high mountains where the jumps are more dangerous and less controlled. A limitation of the study is that we have no quantitative data about those who attended Bridge Day and did not agree to participate in our research. As a result of these selection effects the generalizability of our findings to all BASE jumpers may be limited, even though participants in Bridge Day did have a wide range of experience and personality profiles.

Another possible limitation of the study was that baseline salivary measures were taken at a gathering to orient participants for the jump the next day. The social setting is likely to have influenced the baseline stress measures, at least in sociable people, but the validity of the procedure is supported by the relationships observed between personality and stress indicators.

We did not include a measure of state anxiety in our study in order to increase cooperation by reducing subject burden. TCI Harm Avoidance is a well-validated measure of anxiety-proneness and is strongly correlated with both state and trait anxiety. Nevertheless it would be interesting to measure state and trait anxiety in future work in order to help unravel the relative roles of personality, jumping experience, and acute emotional state on stress reactivity.

Not all BASE jumpers agreed to complete the personality inventory and to give saliva samples at all three time points, but those who did are strongly representative of those who have been surveyed in other studies in which saliva was not collected. Furthermore, evidence-based coaching methods that improve mind-body awareness also reduce stress reactivity coincident with modifying these same personality traits [51–55], which supports the practical clinical importance of the relationship of multidimensional personality profiles to resilience and stress reactivity.

4.7. Conclusions

In summary, the emotional drives measured by the TCI temperaments of Harm Avoidance, Novelty Seeking, and Reward Dependence are predictive of individual differences in the emotional regulation of cortisol release by the HPA axis, but not sympathetic arousal. In contrast, personality measures of tenacity in self-governance (persistence and character) are predictive of differences in sympathetic reactivity, but not cortisol reactivity. In other words, the reactivity of the HPA and SAM stress systems can be dissociated in people with particular personality profiles. A personality profile of psychological resilience (i.e., low Harm Avoidance combined with high Persistence and/or high Self-directedness) mediates decision making to pursue likely rewards despite substantial risk of injury. Such resilience has been called "The Right Stuff" and is characteristic of nearly all BASE jumpers.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.physbeh.2016.09.025.

Funding source

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We thank the BASE jumpers who participated for making this work possible. We thank Ada Zohar, PhD for her comments on an earlier draft of the manuscript.

References

[1] E. Monasterio, Y.A. Alamri, O. Mei-Dan, Personality characteristics in a population of mountain climbers, Wilderness Environ. Med. 25 (2) (2014) 214–219.
[2] O. Mei-Dan, M.R. Carmont, E. Monasterio, The epidemiology of severe and catastrophic injuries in BASE jumping, Clin. J. Sport Med. 22 (3) (2012) 262–267.
[3] E. Monasterio, O. Mei-Dan, Risk and severity of injury in a population of BASE jumpers, N. Z. Med. J. 121 (2008) 70–75.
[4] K. Soreide, C.L. Ellingsen, V. Knutson, How dangerous is BASE jumping? An analysis of adverse events in 20,850 jumps from the Kjerag Massif, Norway, J. Trauma 62 (5) (2007) 1113–1117.
[5] E. Monasterio, Personality characteristics in extreme sports athletes: morbidity and mortality in mountaineering and BASE jumping, in: O. Mei-Dan, M.R. Carmont (Eds.), Adventure and Extreme Sports Injuries: Epidemiology, Treatment, Rehabilitation and Prevention, Springer, London 2013, pp. 303–314.
[6] C.R. Cloninger, D.M. Svrakic, T.R. Przybeck, A psychobiological model of temperament and character, Arch. Gen. Psychiatry 50 (12) (1993) 975–990.
[7] N.A. Gillespie, C.R. Cloninger, A.C. Heath, N.G. Martin, The genetic and environmental relationship between Cloninger's dimensions of temperament and character, Personal. Individ. Differ. 35 (2003) 1931–1946.
[8] P. Van Schuerbeek, C. Baeken, R. De Raedt, J. De Mey, R. Luypaert, Individual differences in local gray and white matter volumes reflect differences in temperament and character: a voxel-based morphometry study in healthy young females, Brain Res. 1371 (2011) 32–42.
[9] C.R. Cloninger, A systematic method for clinical description and classification of personality variants. A proposal, Arch. Gen. Psychiatry 44 (6) (1987) 573–588.
[10] E. Monasterio, R.T. Mulder, C. Frampton, O. Mei-Dan, Personality characteristics of BASE jumpers, J. Appl. Sport Psychol. 24 (4) (2012) 391–400.
[11] J.M. Wolf, E. Nicholls, E. Chen, Chronic stress, salivary cortisol, and alpha-amylase in children with asthma and healthy children, Biol. Psychol. 78 (1) (2008) 20–28.
[12] N. Ali, J.C. Pruessner, The salivary alpha amylase over cortisol ratio as a marker to assess dysregulations of the stress systems, Physiol. Behav. 106 (1) (2012) 65–72.
[13] A.R. Tyrka, L.M. Wier, L.H. Price, K. Rikhye, N.S. Ross, G.M. Anderson, et al., Cortisol and ACTH responses to the Dex/CRH test: influence of temperament, Horm. Behav. 53 (4) (2008) 518–525.
[14] A.R. Tyrka, L.M. Wier, G.M. Anderson, C.W. Wilkinson, L.H. Price, L.L. Carpenter, Temperament and response to the trier social stress test, Acta Psychiatr. Scand. 115 (5) (2007) 395–402.
[15] H. Tost, B. Kolachana, S. Hakimi, H. Lemaitre, B.A. Verchinski, V.S. Mattay, et al., A common allele in the oxytocin receptor gene (OXTR) impacts prosocial temperament and human hypothalamic-limbic structure and function, Proc. Natl. Acad. Sci. U. S. A. 107 (31) (2010) 13936–13941.
[16] C.J. Bell, H. Nicholson, R.T. Mulder, S.E. Luty, P.R. Joyce, Plasma oxytocin levels in depression and their correlation with the temperament dimension of reward dependence, J. Psychopharmacol. 20 (5) (2006) 656–660.
[17] M. Tops, F.T. Buisman-Pijlman, M.A. Boksem, A.A. Wijers, J. Korf, Cortisol-induced increases of plasma oxytocin levels predict decreased immediate free recall of unpleasant words, Front. Psych. 3 (2012) 43.
[18] M. Tops, J.M. van Peer, J. Korf, A.A. Wijers, D.M. Tucker, Anxiety, cortisol, and attachment predict plasma oxytocin, Psychophysiology 44 (3) (2007) 444–449.
[19] M.P. Paulus, C. Rogalsky, A. Simmons, J.S. Feinstein, M.B. Stein, Increased activation in the right insula during risk-taking decision making is related to harm avoidance and neuroticism, NeuroImage 19 (4) (2003) 1439–1448.
[20] D.J. Lee, S.J. Niemcryk, C.D. Jenkins, R.M. Rose, Type A, amicability and injury: a prospective study of air traffic controllers, J. Psychosom. Res. 33 (2) (1989) 177–186.
[21] A.C. Phillips, D. Carroll, V.E. Burns, M. Drayson, Neuroticism, cortisol reactivity, and antibody response to vaccination, Psychophysiology 42 (2) (2005) 232–238.

[22] L.M. Oswald, P. Zandi, G. Nestadt, J.B. Potash, A.E. Kalaydjian, G.S. Wand, Relationship between cortisol responses to stress and personality, Neuropsychopharmacology 31 (7) (2006) 1583–1591.
[23] J.M. McCleery, G.M. Goodwin, High and low neuroticism predict different cortisol responses to the combined dexamethasone—CRH test, Biol. Psychiatry 49 (5) (2001) 410–415.
[24] R.M. Rose, C.D. Jenkins, M. Hurst, J.A. Herd, R.P. Hall, Endocrine activity in air traffic controllers at work. II. Biological, psychological and work correlates, Psychoneuroendocrinology 7 (2–3) (1982) 113–123.
[25] R. Deinzer, C. Kirschbaum, C. Gresele, D.H. Hellhammer, Adrenocortical responses to repeated parachute jumping and subsequent h-CRH challenge in inexperienced healthy subjects, Physiol. Behav. 61 (4) (1997) 507–511.
[26] O.A. Hare, M.A. Wetherell, M.A. Smith, State anxiety and cortisol reactivity to skydiving in novice versus experienced skydivers, Physiol. Behav. 118 (2013) 40–44.
[27] T. Wolfe, The Right Stuff, Farrar, Straus and Giroux, New York, 1979.
[28] C.R. Cloninger, T.R. Przybeck, D.M. Svrakic, R.D. Wetzel, The Temperament and Character Inventory (TCI): A Guide to its Development and Use, Washington University Center for Psychobiology of Personality, St. Louis, 1994 1994.
[29] R.A. Grucza, L.R. Goldberg, The comparative validity of 11 modern personality inventories: predictions of behavioral acts, informant reports, and clinical indicators, J. Pers. Assess. 89 (2) (2007) 167–187.
[30] A.C. Hackney, A. Viru, Research methodology: endocrinologic measurements in exercise science and sports medicine, J. Athl. Train. 43 (6) (2008) 631–639.
[31] J.M. Dabbs Jr., Salivary testosterone measurements: collecting, storing, and mailing saliva samples, Physiol. Behav. 49 (4) (1991) 815–817.
[32] U.M. Nater, N. Rohleder, W. Schlotz, U. Ehlert, C. Kirschbaum, Determinants of the diurnal course of salivary alpha-amylase, Psychoneuroendocrinology 32 (4) (2007) 392–401.
[33] M. Deuschle, U. Schweiger, B. Weber, U. Gotthardt, A. Korner, J. Schmider, et al., Diurnal activity and pulsatility of the hypothalamus-pituitary-adrenal system in male depressed patients and healthy controls, J. Clin. Endocrinol. Metab. 82 (1) (1997) 234–238.
[34] H. Raff, H. Trivedi, Circadian rhythm of salivary cortisol, plasma cortisol, and plasma ACTH in end-stage renal disease, Endocr. Connect. 2 (1) (2013) 23–31.
[35] L.D. Dorn, J.F. Lucke, T.L. Loucks, S.L. Berga, Salivary cortisol reflects serum cortisol: analysis of circadian profiles, Ann. Clin. Biochem. 44 (Pt 3) (2007) 281–284.
[36] S. Wust, J. Wolf, D.H. Hellhammer, I. Federenko, N. Schommer, C. Kirschbaum, The cortisol awakening response - normal values and confounds, Noise Health 2 (7) (2000) 79–88.
[37] M. Deuschle, U. Gotthardt, U. Schweiger, B. Weber, A. Korner, J. Schmider, et al., With aging in humans the activity of the hypothalamus-pituitary-adrenal system increases and its diurnal amplitude flattens, Life Sci. 61 (22) (1997) 2239–2246.
[38] D.E. Polk, S. Cohen, W.J. Doyle, D.P. Skoner, C. Kirschbaum, State and trait affect as predictors of salivary cortisol in healthy adults, Psychoneuroendocrinology 30 (3) (2005) 261–272.
[39] U.M. Nater, C.A. Hoppmann, S.B. Scott, Diurnal profiles of salivary cortisol and alpha-amylase change across the adult lifespan: evidence from repeated daily life assessments, Psychoneuroendocrinology 38 (12) (2013) 3167–3171.
[40] C.R. Cloninger, A.H. Zohar, Personality and the perception of health and happiness, J. Affect. Disord. 128 (1–2) (2011) 24–32.
[41] B. Francis, R. Bowater, K. Soothill, Using homicide data to assist murder investigations, in: H. Office (Ed.), London, Home Office, UK, 2004.
[42] K.L. Nylund, T. Asparouhov, B. Muthen, Deciding on the number of classes in latent class analysis and growth mixture modeling: a Monte Carlo simulation study, Struct. Equ. Model. 14 (2007) 535–569.
[43] J. Uebersax, Latent Class Analysis: Frequently Asked Questions. Latent Structure Analysis, 2009 (Available from) http://www.john-uebersax.com/stat/index.htm.
[44] R.B. Kline, Principles and Practice of Structural Equation Modeling, 2nd ed Guilford Press, New York, 2005.
[45] A.F. Hayes, M. Scharkow, The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: does method really matter? Psychol. Sci. 24 (10) (2013) 1918–1927.
[46] C.R. Cloninger, A.H. Zohar, S. Hirschmann, D. Dahan, The psychological costs and benefits of being highly persistent: personality profiles distinguish mood disorders from anxiety disorders, J. Affect. Disord. 136 (3) (2012) 758–766.
[47] D.A. Gusnard, J.M. Ollinger, G.L. Shulman, C.R. Cloninger, J.L. Price, D.C. Van Essen, et al., Persistence and brain circuitry, Proc. Natl. Acad. Sci. U. S. A. 100 (6) (2003) 3479–3484.
[48] R.D. Rogers, A.M. Owen, H.C. Middleton, E.J. Williams, J.D. Pickard, B.J. Sahakian, et al., Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex, J. Neurosci. 19 (20) (1999) 9029–9038.
[49] P. Van Schuerbeek, C. Baeken, R. Luypaert, R. De Raedt, J. De Mey, Does the amygdala response correlate with the personality trait 'harm avoidance' while evaluating emotional stimuli explicitly? Behav. Brain Funct. 10 (2014) 18.
[50] L. Pezawas, A. Meyer-Lindenberg, E.M. Drabant, B.A. Verchinski, K.E. Munoz, B.S. Kolachana, et al., 5-HTTLPR polymorphism impacts human cingulate-amygdala interactions: a genetic susceptibility mechanism for depression, Nat. Neurosci. 8 (6) (2005) 828–834.
[51] A.H. Zohar, C.R. Cloninger, R. McCraty, Personality and heart rate variability: exploring pathways from personality to cardiac coherence and health, J. Soc. Sci. 1 (6) (2013) 32–39.
[52] R. McCraty, M. Atkinson, D. Tomasino, Impact of a workplace stress reduction program on blood pressure and emotional health in hypertensive employees, J. Altern. Complement. Med. 9 (3) (2003) 355–369.
[53] C.R. Cloninger, K.M. Cloninger, Person-centered therapeutics, Int. J. Person-centered Med. 1 (1) (2011) 43–52.
[54] F. Campanella, C. Crescentini, C. Urgesi, F. Fabbro, Mindfulness-oriented meditation improves self-related character scales in healthy individuals, Compr. Psychiatry 55 (5) (2014) 1269–1278.
[55] C.J. Haimerl, E.R. Valentine, The effect of contemplative practice on intrapersonal, interpersonal, and transpersonal dimensions of the self-concept, J. Transpers. Psychol. 33 (1) (2001) 37–52.