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A time to be stressed? Time perspectives and cortisol dynamics among healthy adults

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Abstract

Perceptions of past, present, and future events may be related to stress pathophysiology. We assessed whether Time Perspective (TP) is associated with cortisol dynamics among healthy adults ($N = 61$, Ages = 18–35, $M = 22.9$, $SD = 4.1$) exposed to the Trier Social Stress Test (TSST). TP was measured according to two profiles: maladaptive Deviation from Balanced TP (DBTP) and adaptive Deviation from Negative TP (DNTP). Eight salivary cortisol samples were analyzed using area under the curve with respect to ground (AUC_g) and to increase (AUC_i). Statistic analyses involved partial correlations controlling for depressive symptoms. Results for both sexes showed that higher DBTP scores were associated with lower cortisol AUC_g scores, while higher DNTP scores were associated with higher cortisol AUC_g scores. These novel findings suggest that maladaptive TP profiles influence hypocortisolism, whereas adaptive TP profiles influence hypercortisolism. Thus, TP profiles may impact conditions characterized by altered cortisol concentrations.

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Declaration of interest

The authors have no conflicts of interest to report.

Keywords

Time Perspective (TP); Deviation from Balanced Time Perspective (DBTP); Deviation from Negative Time Perspective (DNTP); Stress physiology; Cortisol; Trier Social Stress Test (TSST); Area under the curve with respect to ground (AUCg); Area under the curve with respect to increase (AUCi)

1. Introduction

Throughout history, stress has evolved to help us thrive and survive (Nesse & Young, 2000; Parsons, 1991). The capacity to accurately contextualize and monitor time is similarly vital for our existence (Suddendorf & Corballis, 1997). As such, stress and time constantly interact, allowing organisms to appropriately address dangers arising from the natural environment and from complex social interactions. For example, the capacity to predict seasonal climate changes has promoted adaptation to temperate areas, while modern workplace stressors oblige individuals to fulfill demands within projected deadlines. Given the importance of stress and time, it is important to delineate their functions, mechanisms, and interactions.

The physiological response to perceived stress contributes to regulation of metabolism. When the brain detects a stressor in the environment, the hypothalamus–pituitary–adrenal (HPA) axis activation leads to the release of cortisol in humans to mobilize metabolic energy. Stress responsivity is expressed differently in men and women when tested in laboratory settings: men are generally more physiologically reactive (Kudielka & Kirschbaum, 2005), whereas women self-report more psychosocial distress (Taylor et al., 2000). Four psychological components evoke a physiological stress response in humans: novelty (Fishman, Hamburg, Handlon, Mason, & Sachar, 1962), unpredictability, low sense of control (Mason, 1968a,b), and threat to the ego/self (Dickerson & Kemeny, 2004). Novelty and unpredictability intrinsically implicate time. For example, distress is more pronounced among those who lack time management skills in academic settings (Macan, Shahani, Dipboye, & Phillips, 1990) and work environments (Jex & Elacqua, 1999).

From a transactional perspective, stress and time are also intricately intertwined to maintain social self-preservation (Dickerson & Kemeny, 2004). However, stress/time interactions can also lead individuals to become overly sensitized and negatively preoccupied. For instance, individuals characterized by Type A coronary-prone behaviour pattern estimate one-minute time periods as elapsing sooner than individuals characterized by Type B non-coronary-prone behaviour pattern (Burnam, Pennebaker, & Glass, 1975). Correspondingly, the same study also showed that compared to Type Bs, Type As work on tasks at maximum capacity, regardless of the presence or absence of time deadlines. In terms of sleep, anticipations of the “stress” related to the waking phase increase concentrations of the stress hormone adrenocorticotropin in the blood one hour before waking, indicative that the regulation of adrenocorticotropin release during nocturnal sleep reflects a preparatory process in anticipation of the end of sleep (Born, Hansen, Marshall, Mölle, & Fehm, 1999). Similarly, psychological distress has been associated with the cortisol awakening response (CAR) at lower levels of dispositional mindfulness towards the present moment, but not at higher

levels (Daubenmier, Hayden, Chang, & Epel, 2014). As such, stress/time interactions can be potentially adaptive or maladaptive, depending on the manner individuals conceptualize time and process stress responses. To address whether there is a “time” to be stressed, our study focused on the recent concept of Time Perspective.

Time perspective (TP) is operationally defined as the cognitive representation of time in which human beings perceive – in negative or positive fashion – their life experiences according to their temporal orientation towards the past, present or future (Holman & Zimbardo, 2009). Research has shown that TP is malleable in response to life changing situations that include stress, adversity, and traumas that in turn can significantly affect the notion of time that individuals have in their lives (Carstensen, Isaacowitz, & Charles, 1999; Holman & Silver, 1998, 2005; Lavi & Solomon, 2005). The Zimbardo Time Perspective Inventory (ZTPI) was developed to measure TP across five tendencies (Zimbardo & Boyd, 1999), some of which have been linked to personality traits (functional and dysfunctional) and/or psychiatric symptoms (Boniwell & Zimbardo, 2003).

To measure the past, the ZTPI assesses two constructs: Past Negative and Past Positive TP. Past Negative TP refers to the propensity of looking upon the past in a negative way; such individuals experience undermining interactions, social conflict, less social support, and briefer relationships in the aftermath of stress (Holman, 2015; Holman & Zimbardo, 2009), as well as utilize non-adaptive coping strategies (Bolotova & Hachaturova, 2013). Past Positive TP refers to an opposite propensity of seeing the past from a pleasant, nostalgic point of view; such individuals report fewer social conflicts (Holman, 2015; Holman & Zimbardo, 2009), as well as adaptive behavioral and emotional coping strategies (Bolotova & Hachaturova, 2013).

To measure the present, the ZTPI assesses two constructs: Present Hedonistic and Present Fatalistic TP. Present Hedonistic TP reflects preferences for pleasurable activities and sensation-seeking behaviours; such individuals are prone to experience academic/professional difficulties, accidents, injuries, and addictions (Boniwell & Zimbardo, 2003), as well as utilize emotional coping behavior during conflicts (Bolotova & Hachaturova, 2013), and avoidance coping strategies (Bolotova & Hachaturova, 2013; Zimbardo & Boyd, 1999). Present Fatalistic TP denotes a catastrophic view of the present, without hope for the future; such individuals ultimately experience more stress-related problems, aggression, symptoms of depression, anxiety (Zimbardo & Boyd, 1999), post-traumatic stress disorder (PTSD) (Djarallah & Chorfi, 2012; Sword, Sword, Brunskill, & Zimbardo, 2014; Sword, Sword, & Brunskill, 2015; Zimbardo, Sword, & Sword, 2012), as well as utilize rigid, non-adaptive behavioral strategy choices to resolve conflicts (Bolotova & Hachaturova, 2013).

To measure the future, the ZTPI assesses one fifth construct: Future TP. Future TP denotes an orientation towards planning for the future, which has been correlated with positive outcomes, such as adaptive coping, happiness with weight, vitality, sleep sufficiency (Chua, Milfont, & Jose, 2014), use of active coping strategies in response to terrorist attacks like September 11 in New York (Holman & Silver, 2005), use of variable cognitive and behavioral coping strategies to resolve interpersonal conflicts (Bolotova & Hachaturova, 2013), and optimism that is protective against distress (Kimhi, Eshel, & Shahar, 2013;

Segerstrom, Taylor, Kemeny, & Fahey, 1998). On the other hand, Future TP has also been related to high degrees of stress, heightened pressures to use time efficiently (Zimbardo & Boyd, 1999), future anxiety (Zaleski, 1996), pupillary responses (Nowack, Milfont, & van der Meer, 2013), and brain functioning involved in impulsivity (Carelli & Olsson, 2015; Wittmann et al., 2011). Interestingly with regards to stress physiology, Schechter and Francis report that decreased Future TP scores combined with increased cortisol concentrations predict risky attitudes among Native American youngsters between ages 10 and 19 in the context of a stressful interview (Schechter & Francis, 2010). Similarly, Kozik, Hoppmann, and Gerstorf (2015) found that a low focus on limitations characterized by Future TP was associated with reduced hair cortisol, though this association was mediated by subjective well-being.

Although each of the five TP tendencies are believed to be independent of each other, distinct TP profiles have been identified (Boyd & Zimbardo, 2005). In terms of an adaptive TP profile, individuals who score moderately high on the Past Positive, Present Hedonistic and Future TPs, but low on Past Negative and Present Fatalistic TPs are characterized by the Balanced Time perspective (BTP) profile (Boniwell & Zimbardo, 2004). The BTP profile is associated to decreased negative affect, higher positive affect, life satisfaction, happiness, psychological need satisfaction, self-determination, vitality, gratitude (Zhang, Howell, & Stolarski, 2013), positive mood, (Stolarski, Matthews, Postek, Zimbardo, & Bitner, 2013), emotional intelligence (Stolarski, Bitner, & Zimbardo, 2011), mindfulness (Drake, Duncan, Sutherland, Abernethy, & Henry, 2008; Seema & Sircova, 2013), and psychological well-being (Sailer et al., 2014). In terms of a maladaptive TP profile, individuals who score high on the Past Negative and Present Fatalistic TPs but low on the Past Positive, Present Hedonistic and Future TPs tend to exhibit an emotionally stressful profile opposite to BTP, known as the Negative Time perspective (NTP) profile (Oyanadel & Buéla-Casal, 2014, 2015; Zimbardo et al., 2012). Despite the growing popularity of TP in psychology, we do not know of any investigations that have addressed whether TP profiles influence stress-related cortisol dynamics in relation to a laboratory-based psychosocial stressor.

1.1. Research goals and hypotheses

This study investigated whether TP profiles (BTP and NTP) in healthy men and women would be divergently associated with cortisol dynamics in relation to a well-validated psychosocial stressor. Using deviation coefficients, we hypothesized that increased BTP and NTP scores would be associated to changes in the magnitude of cortisol dynamics using area under the curve formulae representing systemic output throughout testing as well as stress reactive increases or decreases.

2. Methods

2.1. Participants

Sixty-seven healthy adults (men = 36, women = 31) ranging in age from 18 to 35 ($M = 22.8$, $SD = 3.9$ years) participated. Participants were recruited through advertisements posted on university and classified websites. A screening assessment was conducted via telephone to ensure that participants did not suffer from any physical or psychiatric conditions.

Participants were generally above high school education (years of education: $M = 15.3$, $SD = 2.2$ years). All participants were non-smokers, reported no illicit drug use during study participation, and were of normal weight (body mass index: $M = 22.38$, $SD = 2.3$). We excluded individuals who were taking medications that could alter cortisol concentrations, except for oral contraceptive use.

2.2. Sex/gender considerations

Because men tend to react more strongly in terms of physiological responses than women to laboratory-based psychosocial stress induction paradigms (Kudielka & Kirschbaum, 2005), and women tend to score higher than men on the Past Positive and Future TP tendencies (Ely & Mercurio, 2011; Zimbardo & Boyd, 1999), sex differences were assessed in preliminary analyses. Furthermore, menstrual cycle and oral contraceptive use were analyzed across women, since menstrual cycle and oral contraceptive use can confound cortisol (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Wolfram, Bellingrath, & Kudielka, 2011). To calculate menstrual cycle, the participants' date of testing was subtracted by the date of last menstruation. Using an example of a 28-day cycle, women for whom their last menstruation began 14 days or less than the date of testing were considered to be undergoing the follicular menstrual cycle phase (days 1–14; $n = 5$), whereas women for whom their last menstruation onset was 15 days or more prior to the test day were considered to be undergoing the luteal menstrual cycle phase (days 15–28; $n = 17$). In addition to these women, nine reported utilization of oral contraceptives that we confirm did not meaningfully alter cortisol results.

2.3. General protocol

Selected participants were requested to visit the laboratory during afternoon hours to avoid heightened levels of cortisol associated with elevated circadian output in the morning (de Weerth, Zijl, & Buitelaar, 2003; Liddle, 1966; Van Cauter & Turek, 1995). Upon arrival to the laboratory, participants were provided information and asked to sign a consent form. We then administered the ZTPI to obtain a profile of each participant's TPs before exposing them to the psychosocial stressor. Following study completion, participants were debriefed and compensated with 50\$ CAD.

The Ethics committee of the Montreal Mental Health University Institute approved the study protocol. All procedures followed Canada's Tri-Council's Policies for experiments conducted on human populations, whose guidelines are based upon the World Medical Association's Declaration of Helsinki.

2.4. Depressive symptoms

The 21-item Beck Depression Inventory II (Beck, Steer, & Brown, 1996) was administered to assess depressive symptoms with a 4-point Likert scale, ranging from 0 to 3 in accord to statements pertaining to the last two weeks. Our goal for using this well-validated instrument is threefold: (1) to exclude participants with scores above 14 for whom depressive symptoms might confound cortisol concentrations (Burke, Davis, Otte, & Mohr, 2005); (2) to provide convergent and divergent validity in relation to our TP deviation calculations; and finally (3) to use sub-clinical depressive symptoms as a covariate in our

main analysis. This latter goal is based on the notion that TP overlaps considerably with established psychological constructs like neuroticism (Kairys, 2010; Kairys & Liniauskaite, 2015) and psychological functioning (van Beek, Berghuis, Kerkhof, & Beekman, 2010). Any detected associations between TP and cortisol dynamics therefore represent those over and above effects explained by depressive symptoms.

2.5. Positive and negative affect

The 20-item Positive and Negative Affect Schedule (PANAS) was administered to assess state affect (Watson, Clark, & Tellegen, 1988). The PANAS is in a 5-point Likert scale format, ranging from 1 to 5. It measures how individuals feel at the present moment, as well as over the previous week through words that describe different feelings and emotions. This scale was administered in this study before and after exposure to the psychosocial stressor to assess changes in affect that could influence the results of the study.

2.6. Time perspectives

The 56-item ZTPI (Zimbardo & Boyd, 1999) was used to measure TP as our main independent variable. The ZTPI assess different aspects of all five TP categories; namely, Past Positive, Past Negative, Present Hedonistic, Present Fatalistic, and Future. Each questionnaire item follows a 5-point Likert scale format, ranging from very characteristic (5) to very uncharacteristic (1). For this study, the English version of the ZTPI (Zimbardo & Boyd, 1999) was administered to Anglophone participants ($n = 42$), whereas the validated French-language version of the ZTPI (Apostolidis & Fieulaine, 2004) was administered to Francophone participants ($n = 19$). There were no differences between Anglophones and Francophones on Past Negative ($t(59) = .945, p = .349$), Present Hedonistic ($t(59) = 1.531, p = .131$) and Future ($t(59) = -.119, p = .906$). However, Anglophone participants scored higher than the Francophone participants on Past Positive ($t(59) = 2.434, p = .018$) and Present Fatalistic ($t(59) = 2.118, p = .038$). Subsequent analyses detailed in Section 3 showed that this difference between Anglophone and Francophone groups had no effect on cortisol measures either.

This study assessed BTP and NTP profiles by calculating coefficients that examine how individuals deviate from each of these profiles. These coefficients are known as the Deviation from the Balanced Time perspective (DBTP) and the Deviation from the Negative Time perspective (DNTP). The DBTP coefficient measures the distance where an individual is along a dimension towards an optimal TP profile. As such, the further a DBTP value is from zero, the more misbalanced an individual's TP profile is considered to be, resulting in the NTP profile. By contrast, the DNTP coefficient measures the distance each individual is from a maladaptive TP profile. As such, the farther a DNTP value is from zero, the more balanced that individual's TP profile is considered to be, resulting in the BTP profile.

For this study, DBTP was calculated to measure the distance of each individual from the optimal TP profile as previously developed (Stolarski et al., 2011; Stolarski, Wiberg, & Osin, 2015; Zhang et al., 2013). To reiterate, the farther a DBTP value is from zero, the more misbalanced an individual's TP profile is, resulting in NTP. The formula to calculate DBTP is as follows:

$$DBTP = \sqrt{(oPN - ePN)^2 + (oPP - ePP)^2 + (oPF - ePF)^2 + (oPH - ePH)^2 + (oF - eF)^2}$$

where o equals the observed optimal value obtained for each TP tendency measured in this study, and e equals the expected optimal value for each TP tendency, as indicated by Zimbardo and Boyd (2008) [1.95 for Past Negative (PN), 4.6 for Past Positive (PP), 1.5 for Present Fatalistic (PF), 3.9 for Present Hedonistic (PH), and 4.0 for Future (F)].

In addition to DBTP, DNTP was calculated to measure the distance of each individual from the negative TP profile (Oyanadel & Buéla-Casal, 2014). To reiterate, the farther a DNTP value is from zero, the more balanced an individual's TP profile is, resulting in BTP. The formula to calculate DNTP is as follows:

$$DNTP = \sqrt{(nPN - ePN)^2 + (nPP - ePP)^2 + (nPF - ePF)^2 + (nPH - ePH)^2 + (nF - eF)^2}$$

where n equals the observed negative value obtained for each TP tendency measured on this study, and e equals the expected negative value for each TP tendency, as indicated by Zimbardo et al. (2012) [4.35 for Past Negative (PN), 2.80 for Past Positive (PP), 3.30 for Present Fatalistic (PF), 2.65 for Present Hedonistic (PH), and 2.75 for Future (F)].

Convergent and divergent validity was assessed in relation to depressive symptoms. For the maladaptive DBTP, in which increased scores represent increased TP misbalance, a positive association was detected with depressive symptoms ($r = .393, p = .002$). In reverse for the adaptive DNTP, whereby increased scores represent increased TP balance, a negative association was detected with depressive symptoms ($r = -.346, p = .006$). Based on the directionality of these complementary associations, we confirm that the construct validity of DBTP and DNTP calculations is acceptable in our study in relation to the construct of depression.

2.7. Psychosocial stress induction

Stress was induced using the Trier Social Stress Test (TSST) that effectively activates the HPA axis (Kirschbaum, Pirke, & Hellhammer, 1993). The TSST is composed of an anticipation phase lasting 10 min, and a test phase of 10 min divided across two 5-min sub-tasks: a mock job interview and mental arithmetic calculation. Each sub-task involves social-evaluative threat, elicited from a performance evaluation by a committee of supposed experts behind a one-way mirror (Dickerson & Kemeny, 2004). During the anticipation phase, participants were briefly introduced to the committee members and told that their performance would be videotaped, even though this was not the case. All communication took place through an intercommunication device. This “panel-out” approach maximizes sex differences in cortisol stress reactivity among heterosexual women that respond even less than men (Andrews et al., 2007; Diener, Emmons, Larsen, & Griffin, 1985; Juster et al., 2014; Juster et al., 2011b; Soler et al., 2012).

2.8. Cortisol measurements

To measure stress objectively, eight saliva samples of cortisol were taken at the following 10-min intervals upon the participant's arrival (timeframes): (1) –30 min (habituation); (2) –20 min (habituation); (3) –10 min (anticipation); (4) 0 min (anticipation); (5) +10 min (reactivity); (6) +20 min (reactivity); (7) +30 min (recovery); and (8) +40 min (recovery).

Saliva was analyzed at the Centre for Studies on Human Stress (www.humanstress.ca) with a high sensitivity enzyme immunoassay kit (Salimetrics® State College, PA, Catalogue No. 1-3102). Frozen samples were brought to room temperature to be centrifuged at $15,000 \times g$ for 15 min. The standards, controls and unknowns were placed into a micro-plate pre-coated with monoclonal antibodies to cortisol. The antibodies compete with cortisol bound to horseradish peroxidase for the binding sites on the plate. After an incubation period the unbound portion was washed away. Tetramethylbenzadine was added to stain the bound portion blue, and then this reaction was stopped with a 3-molar solution of sulphuric acid making a yellow color. Within five min. the optical density of the yellow reaction was measured on a plate reader at 450 nm with a correction at 490 nm. The intensity of color measured is an indication of the level of horseradish peroxidase bound to the plate and is therefore inversely proportional to the concentration of cortisol present. The range of detection for this assay was between .012 and 3 µg/dL.

2.9. Treatment of cortisol data

Outliers were first carefully scrutinized according to sub-clinical psychiatric criteria and extreme cortisol values. In this manner, three participants (two men and one women) with scores of 14 for depressive symptoms were excluded. The research team subsequently called these participants, informed them of their depressive symptoms, and provided them the contact information of various psychological resources in the Montreal area. In addition, extreme cortisol values were inspected to identify potential cortisol outliers. The criteria for exclusion was defined as two or more standard deviations above or below the mean cortisol value obtained for all participants during each saliva sample: outlier cortisol values were identified for three men that were excluded from the analyses. The final sample size was therefore $N = 61$, ranging in age from 18 to 35 years ($M = 22.9$, $SD = 4.1$ years). Of this final sample thirty-two were men ($n = 32$) ranging in age from 18 to 35 years ($M = 23.8$, $SD = 4.9$ years), and twenty-nine were women ($n = 29$) ranging in age from 18 to 29 years ($M = 21.8$, $SD = 2.7$ years).

Cortisol dynamics throughout the TSST paradigm were calculated using the area under the curve with respect to ground (AUC_G) and area under the curve with respect to increase (AUC_I) based on the trapezoid formula (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). The AUC_G represents total systemic “output” throughout all salivary cortisol measures, whereas the AUC_I represents presumed “reactive” increases (or decreases) in cortisol levels in relation to the TSST without regard for zero (Pruessner et al., 2003). Collectively, AUC_G and AUC_I capture individual differences in cortisol dynamics used in TP main analyses. As will become evident from Fig. 1, the cyclical distribution of cortisol over time was vast and potentially negating. To assess periods representing discrete variation that might not otherwise be detected by a global AUC_I score, we additionally

calculated three sub-type AUCi scores for habituation (cortisol samples 1–4), reactivity (cortisol samples 4–6), and recovery (cortisol samples 6–8), used in a sensitivity analysis.

Supplemental analyses also re-assessed TP associations according to “responders” and “non-responders” to the TSST. This assessment is based on a suggested threshold in which an increase of at least .09 µg/dl (equivalent to 2.5 nmol/l) above the individual baseline concentration reflects an HPA-axis secretory episode (Schommer, Hellhammer, & Kirschbaum, 2003; Van Cauter & Refetoff, 1985). We differentiated “responders” from “non-responders” by identifying non-responders as “0” if their cortisol increase was less than .09 µg/dl from time 4 to 6. Note that samples 4 (pre-TSST) and 6 (+20 min post-TSST) respectively represented the minimum and maximum cortisol concentrations for our sample that is consistent with existing studies (Dickerson & Kemeny, 2004).

2.10. Statistical analysis

Preliminary analyses were conducted to identify potential variables influencing cortisol concentrations. Any sex differences in cortisol responsiveness to the TSST were assessed using a mixed- design analysis of variance (ANOVA). Likewise, menstrual cycle (follicular vs. luteal) and oral contraceptive use (yes vs. no) were assessed among the women using mixed design ANOVAs. PANAS associations to TP and cortisol dynamics were assessed using bivariate correlations.

Our main analyses employed partial-correlations with DBTP and DNTP in association with cortisol dynamics while controlling for depressive symptoms. Cortisol dynamics represented systemic output (AUCg) and time-dependent reactivity (AUCi). Given wide cortisol variation, uncertainty analysis also assessed AUCi sub-scores re-calculated to capture individual differences in habituation, reactivity, and recovery. Finally, supplemental analyses using bivariate correlations were split according to TSST cortisol “responders” and “non-responders” to assess main associations based on differential sensitivities.

3. Results

3.1. Preliminary analysis

As illustrated in Fig. 1, a “double V” distribution for cortisol over time was observed. A repeated-measures (RM) ANOVA was first conducted using all eight salivary cortisol levels with Greenhouse–Geisser correction: results indicated a statistically significant main effect of time ($F_{(2.12,124.97)} = 4.534; p = .011$). To confirm time effects attributable to the TSST, a second RM-ANOVA was limited to five samples beginning immediately before TSST: time was again significant ($F_{(1.84,108.38)} = 8.1; p = .001$), confirming strong HPA-axis reactivity following the TSST. No sex differences ($F_{(158)} = .669, p = .417$) or sex by time interactions ($F_{(2.129,123.456)} = 1.007, p = .372$) were detected for cortisol in this study.

For women, the use of oral contraceptives was not significant ($F_{(1,27)} = .872, p = .359$) nor did it interact with time ($F_{(1.927,52.02)} = .691, p = .500$). Negative results were also found when assessing menstrual cycle phase among naturally cycling women, all $ps > .662$. In summary, time effects in cortisol was observed and not confounded by sex differences of reproductive considerations among women.

For psychometrics, the PANAS sub-scales for Positive Affect and Negative Affect failed to yield any statistically significant associations to any TP tendency or cortisol measurement. We therefore do not include PANAS sub-scales as covariates in main analyses.

3.2. Main analysis

Table 1 reports descriptive statistics and correlations for all TP sub-scales and cortisol dynamics. As illustrated in Fig. 2A and while controlling for depressive symptoms, higher DBTP scores were associated with lower cortisol AUCg scores ($r = -.272, p = .035$) but not with cortisol AUCi scores ($r = -.124, p = .344$). This finding suggests that men and women who score high on DBTP (indicative of a maladaptive NTP profile) exhibited decreased HPA-axis systemic output (AUCg) throughout testing, but not with regards to stress reactivity (AUCi). In contrast to DBTP and as illustrated in Fig. 2B while controlling for depressive symptoms, higher DNTP scores were associated with higher cortisol AUCg scores ($r = .258, p = .046$) but not with cortisol AUCi scores ($r = .210, p = .108$). This pattern is the reverse of those for DBTP, suggesting that men and women who score high on DNTP (indicative of an adaptive BTP profile) exhibited increased HPA-axis systemic output (AUCg) throughout testing, but not with regards to stress reactivity (AUCi). Given the “double V” distribution of cortisol (Fig. 1) that may have negated time-dependent dynamics using a summary AUCi score, uncertainty analysis compelled us to recalculate AUCi sub-scores for habituation (cortisol sampled at $-30, -20, -10$, and 0), reactivity (cortisol sampled at $0, +10$, and $+20$), and recovery (cortisol sampled at $+20, +30$, and $+40$) time-frames. No significant findings were detected with TP.

3.3. Supplemental analysis

Because some individuals respond minimally to the TSST in terms of cortisol reactivity, supplemental re-analyses differentiated “responders” from “non-responders”. Using the afore-mentioned criteria (see Methods), 28 participants (men = 13, women = 15) were considered “non-responders”, whereas 33 participants (men = 19, women = 14) were considered “responders”. AUCi scores were expectedly higher among “responders” than “non-responders” ($F_{(1,59)} = 2.93, p = .006$). Groups did not otherwise differ according to AUCg scores ($p = .84$), depressive symptoms ($p = .99$), or any other study variables ($ps > .18$).

Splitting analyses according to “responders” and “non-responders”, bivariate correlations were executed to scrutinize our main findings linking TP scores to cortisol dynamics. No statistically significant findings were observed for AUCi scores ($ps > .15$). Among “non-responders”, higher DNTP scores were associated with higher AUCg scores ($r = .386, p = .043$). Among “responders”, higher DBTP scores were associated with lower AUCg scores ($r = -.373, p = .032$).

4. Discussion

This study assessed associations between TP profiles and HPA-axis dynamics throughout the popular TSST paradigm in healthy adults of both sexes. Using AUC scores that summarized cortisol dynamics based on eight samples, we found that both DBTP and DNTP

were associated with divergent cortisol dynamics. Specifically, higher DBTP scores were associated with lower cortisol AUCg scores, meaning that the closer an individual was to a maladaptive TP profile (i.e. NTP), the lower their overall cortisol was during the stress task. In contrast, higher DNTP scores were associated with higher cortisol AUCg scores, meaning that the closer an individual was to an adaptive TP profile (i.e. BTP), the higher their overall cortisol was during the stress task. We interpret these patterns as evidence that TP predispositions are associated with reverse patterns, but only as they pertain to cortisol systemic output (AUCg). By contrast, no TP associations were detected for stress reactivity (AUCi), even when further scrutinized in relation to increases or decreases during habituation, reactivity, and recovery. While preliminary in nature, our findings have implications for further understanding psychophysiological vulnerabilities and the expanding TP literature. Although we must be cautious in our interpretations based on healthy adults, future studies could explore psychiatric populations where NTP may influence hypocortisolemic profiles, whereas BTP could influence hypercortisolemic profiles.

With regards to maladaptive NTP, we speculate that the observed reverse associations among elevated DBTP and lower cortisol dynamics might point to an inhibitory drive on the HPA-axis. It is particularly noteworthy that this association was of strongest magnitude among “responders” that did not differ according to study variables. While our study cannot address hypocortisolemic conditions due to our cross-sectional design, this dampened responsivity may be related to chronic stress (Fries, Hesse, Hellhammer, & Hellhammer, 2005; Hellhammer & Wade, 1993). For example, low HPA-axis functioning could reflect an increased vulnerability to stress-related disorders implicating hypocortisolism, such as PTSD (Heim, Ehler, Hanker, & Hellhammer, 1998; Heim, Ehler, & Hellhammer, 2000; Rohleder, Joksimovic, Wolf, & Kirschbaum, 2004), atypical depression (Brantley, 2005; Burke et al, 2005), chronic fatigue syndrome (Gur, Cevik, Nas, Colpan, & Sarac, 2004; Roberts, Wessely, Chalder, Papadopoulos, & Cleare, 2004; Tak et al., 2011), fibromyalgia (Griep et al., 1998; Gur et al., 2004), chronic pelvic pain (Heim et al., 1998; Heim et al., 2000), low back pain (Griep et al., 1998), and burnout (Pruessner, Hellhammer, & Kirschbaum, 1999a). Future research will need to delineate the functional significance of maladaptive TP profiles and hypocortisolism in these diverse populations, as compared to healthy controls using prospective designs that go beyond our correlational study.

With regards to adaptive BTP, the opposite hypercortisolemic tendency was found. Specifically, higher DNTP scores were associated with higher cortisol dynamics detected through AUCg. Does this represent a deleterious cortisol profile? We believe that individuals with increased BTP might manifest amplification of HPA-axis output that might actually be considered healthy, since they are appropriately activating stress responses (Nesse & Young, 2000) in the context of a novel and potentially stressful environment (Sindi, Fiocco, Juster, Pruessner, & Lupien, 2013). This association was especially pronounced among “non-responders” but not among “responders”, as evidenced by our supplemental analysis. As such, individuals characterized by the BTP profile might have a psychoneuroendocrinological predisposition to respond more moderately to TSST-like psychosocial stressors.

Increased cortisol concentrations in the context of laboratory-based stress paradigms can be considered adaptive. For example, our group previously showed that increased anticipatory stress before TSST exposure was positively associated with cortisol reactivity (AUCi), but also a rapid and adaptive decrease during recovery (Juster, Perna, Marin, Sindi, & Lupien, 2012). As such, BTP appears to be functioning in a similar manner by modulating cognitive states of vigilance and physiological readiness to respond that must be elucidated further in multi-dimensional studies. Our psychometric associations among TP deviation scores and depressive symptoms reported in our Methods strengthen this interpretation. The reader will recall that depressive symptoms were positively correlated with maladaptive DBTP scores and negatively correlated with adaptive DNTP scores. Higher scores on DNTP may thus be associated with higher AUCg scores, but also with lower depressive symptoms that were adjusted for in our main analysis.

4.1. Limitations

Because the present study is the first to assess TP profiles and cortisol dynamics in relation to a psychosocial stressor, various limitations must be discussed in order to help guide future research. We concluded that TP is associated to global HPA-axis systemic output rather than time-dependent stress cortisol reactivity specific to the TSST because all findings observed in this study were detected through AUCg and not AUCi (Pruessner et al., 2003). This highlights AUC's continued dual incorporation, as originally proposed (Pruessner et al., 2003), as well as alternative associations to assess time windows like recovery (Juster, Perna, Marin, Sindi, & Lupien, 2012) that may be modulated by unmeasured phenomena (e.g., rumination). Even though many reports reflect findings with one AUC but not the other, we must be cautious in our interpretations of findings detected with cortisol AUC, since AUCg and AUCi are intrinsically different.

In terms of sample size, the present study was conducted using a relatively small, albeit well-controlled, sample. Moreover, participants were all from Montreal, highlighting that they might not generalize to other populations. Relatedly, cross-cultural differences exist in TP (Sircova et al., 2014, 2015), as well as in cortisol (Souza-Talarico, Plusquellec, Lupien, Fiocco, & Suchecki, 2014), that must be assessed in future international studies. Furthermore, the DBTP and DNTP formulation does not take into account different socio-cultural, environmental, and life history factors that could affect the "optimal/suboptimal" time-orientation (Oyanadel & Buéla-Casal, 2014; Stolarski et al., 2015). As such, the "optimal/suboptimal" point of BTP/NTP for any given individual (i.e., mathematically the centrum by which all distances assessed through the DBTP/DNTP coefficients are determined) should not be assumed but rather be empirically quantified, perhaps through person-oriented cluster-analyses (Magnusson, 1999, 2003). Such approaches might demonstrate that promoting temporal shifts on an individual toward a balance point could lead to certain benefits. Thus, our study warrants follow-ups that replicate findings among diverse samples.

Future studies could empirically address what combination of TP scales composing DBTP and DNTP exert the maximum or minimum influence in cortisol AUCg concentrations, in relation to psychosocial stressors. Additionally, future studies with more power could also

assess moderation effects with other psychological constructs previously shown to exert influence on cortisol secretion: for example, coping strategies (Bohnen, Nicolson, Sulon, & Jolles, 1991), optimism/pessimism (Lai et al., 2005), state anxiety (Noto, Sato, Kudo, Kurata, & Hirota, 2005), emotional affect (Buchanan, al'Absi, & Lovallo, 1999), self-esteem (Pruessner, Hellhammer, & Kirschbaum, 1999b), locus of control (Pruessner et al., 1997), and psychiatric symptoms like those of PTSD (Meewisse, Reitsma, de Vries, Gersons, & Olff, 2007). In particular, the role of personality constructs that strongly overlap with TP tendencies (Kairys, 2010; Kairys & Liniauskaitė, 2015) and influence cortisol secretion in relation to the TSST (Oswald et al., 2006) should ideally be addressed on future studies using sophisticated statistics across larger samples. Follow-up studies could moreover contrast healthy participants from individuals afflicted with psychiatric disorders. If TP is indeed related to physical and/or mental well-being (Oyanadel & Buéla-Casal, 2010), it will be important to differentiate balanced/adaptive profiles from misbalanced/maladaptive profiles (Stolarski et al., 2015; Webster, 2011), and how this differs from existing constructs in psychobiological research.

This study only accounted for neuroendocrine measures of stress. Given that we found associations with cortisol systemic output, we recommend that future studies assess stress biomarkers and algorithms subsuming cumulative processes rather than those with short-lives (e.g., reactive). An excellent example would be to use the allostatic load model representing multi-systemic physiological dysregulation (Juster et al., 2011a; McEwen & Stellar, 1993; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997) in relation to TP tendencies in future inquiry. Additional measures of biopsychosocial stress could also be implemented and triangulated, such as other physiological measures of stress, like cardiovascular functioning or skin conductance (Westenberg et al., 2009). In addition, the modulatory effects of sex hormones like testosterone, estrogen, and progesterone on stress dynamics (Newhouse et al., 2010; van Wingen et al., 2008) could allow further insights into sex-based interactions that would be refined by also assessing socio-cultural gender.

Furthermore, the interplay of TP and stress could also be tested across various cognitive functions relevant to the personal identity of individuals. For instance, autobiographical memory is an explicit form of memory previously shown to be influenced by TP (Ely & Mercurio, 2011) and cortisol levels (Schwabe & Wolf, 2010), respectively. As such, future studies could address the role of TP on the known interrelationships between memory, stress and emotion (Olivera-Figueroa, Marin, & Lupien, 2012). Moreover, associations between TP profiles and cortisol dynamics could be further moderated by cognitive appraisals shaped by pondering upon past, present, and/or future experiences that are outside conscious awareness. This predisposition could in turn prompt changes in cortisol secretion during stress anticipation, reactivity, and/or recovery that must be demarcated further using more multi-level analyses among diverse populations. Finally, TP's relationship with cortisol could also be assessed in relation to well-being, life satisfaction and mindfulness across cultures (Olivera-Figueroa et al., 2016).

4.2. Clinical implications

Our findings among healthy adults could eventually have clinical implications. For instance, indexing TP profiles could allow clinicians to more accurately identify individuals who might benefit from reframing and shifting their NTP profile to a BTP profile. In terms of cortisol, we propose that profiling TP and baseline cortisol could provide scientist-practitioners with a method of assessing the efficacy of TP-based treatment approaches (Boniwell, 2005; Boniwell & Osin, 2015; Boniwell, Osin, & Sircova, 2014; Kazakina, 2015; Melges, 1982; Rappaport, 1990; Sword et al., 2014, 2015; van Beek, Kerkhof, & Beekman, 2009; Vilhauer et al., 2012; Zimbardo et al., 2012). Indeed, analogous treatment modalities, like Mindfulness-Based Interventions (MBIs), help normalize cortisol concentrations across veterans and nurses affected by PTSD symptoms (Bergen-Cico, Possemato, & Pigeon, 2014; Kim et al., 2013). Sampling stress biomarkers might show particular promise in clinical application to MBIs (Carlson, Specia, Faris, & Patel, 2007; Carlson, Specia, Patel, & Goodey, 2004; Marcus et al., 2003; Witek-Janusek et al., 2008) in which focusing on the present moment is key (Kabat-Zinn, 1994, 2003; Seema & Sircova, 2013). TP-based treatment approaches and MBIs are of potential clinical interest for understanding various conditions characterized by both altered cortisol functioning and TP, like PTSD (Djarallah & Chorfi, 2012; Heim et al., 1998, 2000; Rohleder et al., 2004), depression (Burke et al., 2005; van Beek et al., 2010), suicidal behaviours (Lindqvist, Isaksson, Traskman-Bendz, & Brundin, 2008; van Beek et al., 2009), substance abuse (Apostolidis, Fieulaine, Simonin, & Rolland, 2006; Apostolidis, Fieulaine, & Soule, 2006; Fieulaine & Martinez, 2010; Lovallo, 2006), and pathological gambling (Hodgins & Engel, 2002; Paris, Franco, Sodano, Frye, & Wulfert, 2010).

Based on our preliminary associations among healthy adults, we propose that combined TP profiling and cortisol sampling could potentially facilitate: (1) the shifting from NTP profiles to BTP profiles; (2) any measurable changes in cortisol concentrations; and (3) the overall health improvement of individuals treated with TP-based treatment approaches and MBIs for mental health conditions where cortisol levels tend to be altered. Finally, diverse psychiatric conditions likely differ in terms of TP, stress reactivity, and potentially even treatment responsivity in the context of distressing techniques (e.g. systematic desensitization, “flooding”, debriefing, and biofeedback) that would provide clinical information and a means to objectively assess the efficacy of novel therapeutic approaches. Future biopsychosocial research that combines empirical and clinical approaches would ultimately help further delineate the psychobiology of TP. Nonetheless, we acknowledge that the proposed health index approaches involving TP profiling and cortisol sampling also bear some intrinsic limitations, as cortisol is not the best predictor of health.

5. Conclusions

To the best of our knowledge, this is the first study to demonstrate associations among TP profiles and cortisol dynamics in the context of a psychosocial stressor. While results are modest, correlational, and require replication among diverse populations, our results nevertheless show for the first time that cortisol systemic output (AUCg) is negatively associated with maladaptive DBTP scores and positively associated with adaptive DNTP

scores. This association is exclusive to overall HPA-axis systemic output and not to stress reactive increases or decreases (AUCi). These findings may point to pervasive psychobiological modulation that must be explored further cross-culturally, as well as in clinical research. In summary, the observed cortisol dynamics are interpreted as having been influenced by each participant's respective TP profile. Importantly for this young field, our findings preliminarily confirm that TP profiles are associated with stress physiology (Zimbardo & Boyd, 1999; Zimbardo et al., 2012).

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Fig. 1.
Mean ($\pm$ standard error) salivary cortisol dynamics throughout testing for men and women.

Fig. 2. Scatterplots for cortisol systemic output (area under the curve with respect to ground; AUC) in association with Deviation from the Balanced Time Perspective (A) and Deviation from the Negative Time Perspective (B).

Table 1

Descriptive statistics and correlation coefficients of study variables for both men and women.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Past negative	-								
2. Past positive	-.107	-							
3. Present hedonistic	-.117	-.094	-						
4. Present fatalistic	**	.028	.257*	-					
5. Future	.085	.057	-.228	-.347**	-				
6. DBTP	.593**	-.421**	-.0142	.613**	-.303*	-			
7. DNTP	-.824**	.371**	0.09	-.642**	.264*	-.701**	-		
8. AUCg	-.262*	.229	.126	-.173	-.088	-.3*	.286*	-	
9. AUCi	-.154	.017	.107	-.112	.161	-.133	.213	-.088	-
<i>M</i>	2.525	3.896	3.467	2.207	3.605	1.679	2.862	1.088	-.164
<i>SD</i>	.634	.513	.475	.607	.475	.562	.634	.423	.638

Note: DBTP = Deviation from Balanced Time Perspective coefficient; DNTP = Deviation from Negative Time Perspective coefficient; AUCg = area under the curve with respect to ground; AUCi = area under the curve with respect to increase. *M* = mean; *SD* = standard deviation.

* $p < .05$.

** $p < .01$.