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Endocrine response patterns after uncontrollable experimental stress: an application of CFA

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Abstract

According to biological stress theories cortisol increases (C+) and testosterone decreases (T-) characterize uncontrollable (UC) stress and the opposite pattern is observed in controllable (CON) stress. The influence of CON/UC on hormone responses to a mental (d2) and a physical (E) short-term stressor was tested by two-sample configural frequency analysis in a cross-over design on 74 healthy males assigned to either CON or UC conditions. Areas under the response curves of saliva C and T were computed and dichotomized (+/-). The evaluation of bivariate response patterns (C/T) revealed that the combination C+T- was significantly more prevalent after UC than after CON with both stressors. The pattern C-T+ constituted a significant discrimination type between CON and UC across both stressors.

Key words: configural frequency analysis; discrimination type; hormone response pattern; cortisol; testosterone

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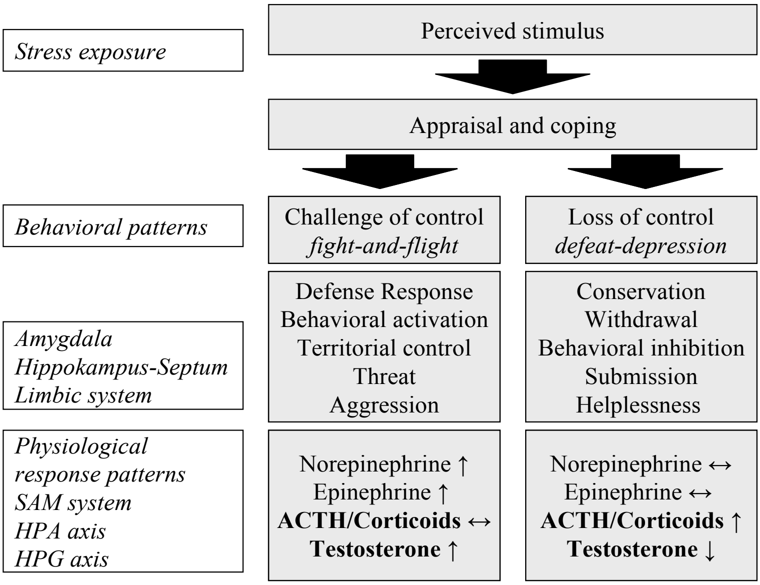
Background

This paper is designed to demonstrate that Configural Frequency Analysis (CFA) (Krauth & Lienert, 1973; Lautsch & von Weber, 1995; Lienert, 1969; von Eye, 1990, 2001, 2002) is a suitable device for the statistical identification of physiological response patterns elicited by different stress conditions, thus contributing to assessment as well as to stress research.

Uncontrollability and endocrine stress response

After the development of Learned Helplessness Theory by Seligman (1975) a number of experiments tried to identify aspects of stressors which contribute to behavioral and physiological stress reactions. Two of the salient components were unpredictability and uncontrollability (Dess, Limwick, Patterson, Overmier, & Levine, 1983). In particular the role of uncontrollability in psychological and endocrine stress responses attracted researchers from different fields of psychophysiology and neurochemistry (Christianson,



SAM, sympatho-adreno-medullary system; HPA, hypothalamo-pituitary-adrenal axis; HPG, hypothalomo-pituitary-gonadal axis; ACTH, adrenocorticotropic hormone; ↑, increase; ↓, decrease; ↔, no change

Figure 1:
Specific response patterns for controllable and uncontrollable stressors (Henry, 1982, 1986, 1997; Henry & Stephens, 1977)

Ragole, Amat, Greenwood, Strong, Paul, Fleshner, Watkins, Maier, 2010; Dickerson & Kemeny, 2004; Diener, Struve, Balz, Kuehner, & Flor, 2009; Foley & Kirschbaum, 2010; Rozeske, Evans, Frank, Watkins, Lowry, & Maier, 2011).

Many of them tried to test the psychoneuroendocrinological model of controllable and uncontrollable stress developed by J.P. Henry (Henry, 1982, 1986, 1997; Henry & Stephens, 1977) depicted in Figure 1 which gave rise to the concept that sustained perceived uncontrollability and helplessness are risk factors for affective disorders and the accompanying physiological changes may cause cardiovascular and metabolic disorders (Björntop, 1997; Bose, Oliván, & Laferrère, 2009; Chrousos, 2000; Ruige, 2011).

The psychoendocrinological hypothesis derived from this model states that uncontrollable stress leads to activation of the hypothalamo-pituitary-adrenal (HPA) axis with the consequence of elevated cortisol levels (C↑) and inhibition of the gonadal axis leading to a decrease of testosterone (T↓) in men, a pattern which is the opposite in controllable stress conditions (C↓, T↑). So the endocrinological response pattern of this model hypothetically links controllable stress (CON) to a response of cortisol decrease (C↓) and of testosterone increase (T↑), and uncontrollable stress (UC) to a response of cortisol increase (C↑) and testosterone decrease (T↓) in men.

Objective

So far, no data are available as to the validity of this hypothesis for different types of short term laboratory stressors, e.g., physical and mental stressors, in humans. Accordingly, the following questions were investigated: (1) Do short term experimental laboratory stressors elicit cortisol increases and testosterone decreases in uncontrollable and cortisol decreases and testosterone increases in controllable conditions? (2) Do mental and physiological stressors elicit the same response patterns in healthy men?

Transformed into the hypothesis of bivariate response patterns, question (1) would read: CON leads to C↑T↓, and UC is followed by C↓T↑. This hypothesis requires adequate statistical analysis techniques. Configuration Frequency Analysis (CFA) developed by Lienert (Krauth & Lienert, 1973; Lienert, 1969; von Eye, 1990, 2002) seems highly appropriate for this purpose.

Method

Participants

Seventy-four healthy male students (age 18 - 40 years, M = 25, SD = 3) were included. Exclusion criteria were checked by a trained physician and comprised severe physical diseases, psychiatric disorders, continuous medication in particular with substances which could have an impact on cortisol and testosterone levels.

Stressors

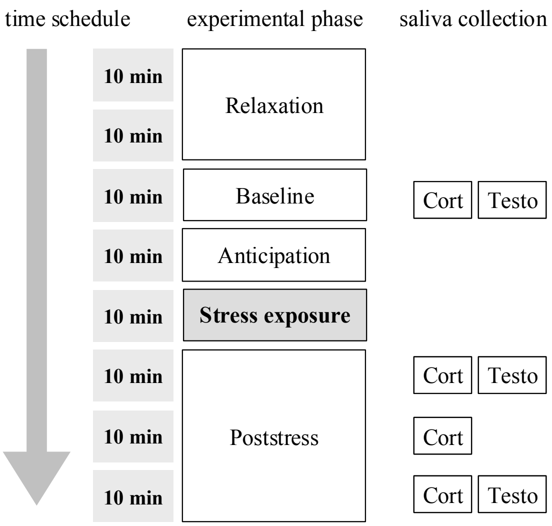
A modified version of the letter cancellation attention test d2 (Brickenkamp, 1994) was used as mental stressor and applied for 10 minutes according to the original instructions.

Electrical skin stimuli (E) were applied as physical stressor. The stimuli were tested for just painfully experienced individual thresholds in a preceding trial and all participants were exposed to 30 stimuli with a mean inter-stimulus-interval of about 20-sec (10 min duration of stress exposure; for details of the procedure c.f. Müller, 2011).

Controllability was achieved by contingent vs. non-contingent feedback in the d2 test and by self vs. experimenter administered electrical stimuli in the physical stress condition (E).

Experimental design

A two-group balanced cross-over design was used, i.e., two experiments, applied one week apart, comprising one day with the physical stressor (E) and one day with the mental stressor (d2) presented in randomized order and lasting 80 minutes each. Groups were defined as “uncontrollable” (UC) with both stressors presented in the uncontrollable condition (n = 37) and “controllable” (CON) with both stressors presented in the controllable condition (n = 37).



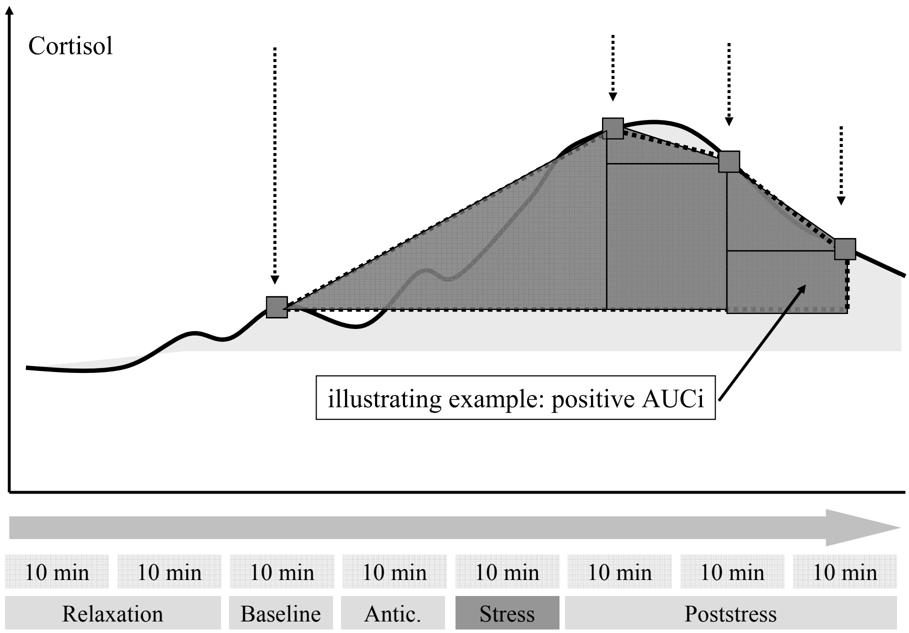
Cort, Cortisol; Testo, Testosterone; Cort and Testo indicate the time of saliva sampling for obtaining levels of the two hormones in question

Figure 2:
Procedure of testing on experimental days

Testing was started at 2 p.m. in order to hit the phase of a fairly balanced steady state of both hormones since they show circadian rhythmicity with a decelerating decline in the afternoon. The procedure on each day of testing is depicted in Figure 2.

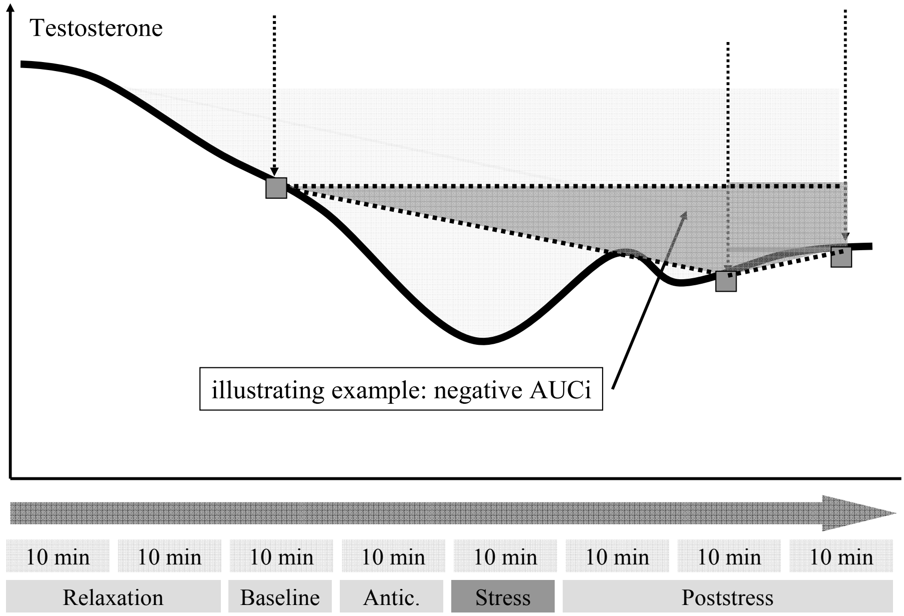
Measures

Endocrine parameters: Free saliva *cortisol (C)* and free saliva *testosterone (T)* concentrations were taken at baseline and after stress exposure (c.f. Fig. 2). Hormone concentration analysis was achieved by ELISA technique resulting in coefficients of variation of *CV* < 11% each. Areas under the hormone response curve *(AUCs)* of endocrine parameters were calculated with reference to baseline measures according to the literature (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). AUCs were dichotomized (+/-) with "AUC-" = decrease or no change and "AUC+"= increase compared to baseline. Figures 3 and 4 demonstrate how dichotomized scores for positive and negative AUC results were obtained.



AUCi, area under the response curve with respect to increase compared to baseline; illustrating example of a positive cortisol response ("+")

Figure 3:
Definition of a positive AUC in the case of a fictive cortisol response curve



AUCi, area under the response curve with respect to increase compared to baseline; illustrating example of a negative testosterone response (“-“)

Figure 4:
Definition of a negative AUC in a case of a fictive testosterone response curve

Statistical analysis

Descriptive statistics (means, standard deviations, proportions) were calculated for hormone data at baseline and for possible confounders (age, body mass index [BMI], and smoking status [yes/no]). Differences between groups were analyzed by means of Mann-Whitney *U*-tests for ordinal data and by χ^2 test in case of categorical data. Areas under the response curves (AUCs) were descriptively shown as cumulative frequency distributions, Mann-Whitney *U*-tests were used to explore group differences in AUC values.

Differences between corresponding dichotomized AUC values (“+” and “-“) of the experimental groups (CON and UC) were tested by conventional χ^2 tests. Conventional χ^2 tests yielded single χ^2 values ($df = 1$) for the probability of frequencies of “+” and “–“ values in groups CON and UC separately for cortisol (C) and testosterone (T) in each of the two stressors. Additionally, χ^2 tests were computed for the global comparison of the distribution of bivariate response patterns (C+/- and T+/-) in both groups (CON and UC) ($df = 3$) in each of the two stressors. Results of conventional χ^2 tests were reported as frequencies of endocrine responses, χ^2, *df*, and corresponding two-tailed *p*-values.

Two-sample configuration frequency analysis (CFA)

As outlined above, the questions raised required a procedure allowing to test for the validation of a combined hypothesis concerning the pattern of two variables (C/T) in two independent samples (CON/UC). Two-sample CFA is suitable to compare two samples with respect to a series of configurations of states of random variables (Krauth & Lienert, 1973; Stemmler & Bingham, 2003; von Eye, 1990, 2002).

Basically, two-sample CFA is used to explore whether the frequency distributions of the studied configurations are homogenous when compared across two samples. Therefore, the null hypothesis of no differences is locally tested for each configuration under a base model with the following features (von Eye, 2002, p. 174):

a) the model is saturated in the variables used to compared two groups, and
b) the model assumes independence between the grouping variable(s) and the comparison ("discriminant") variables.

In two-sample CFA, significant "types" can emerge only if a relationship between the "discriminant" variables and the "grouping" variable exists. A "type" suggests that in one of the two samples a particular configuration was observed more often than expected based on the above mentioned model. Such configurations are called "discrimination types". If in one group a particular configuration was observed more often than in the other group, this "discrimination type" always constitutes both a "type" (observed more often than expected in one group) and an "antitype" (observed less often than expected in the other group).

To compare the $2^2 = 4$ bivariate patterns of C+/- and T+/- (i.e., C+T+, C+T-, C-T+, and C-T-) between CON and UC and to detect potential discrimination types, the data were subjected to two-sample CFAs, separately for the mental and physical stress condition. Finally, a two-sample CFA comparing the frequency of $2^4 = 16$ patterns (4 endocrine response patterns, 2 stressor types) between CON and UC was computed to explore a hypothetical endocrine discrimination type (CON vs. UC) for both stressor types. CFA results are shown as frequencies of endocrine response patterns, χ^2 statistics ($df = 1$), and two-tailed p-values. For an estimation of the strength of association and effect sizes, the correlation coefficient φ, the squared coefficient $\varphi^2 * 100$ for the percentage of variability accountable by the relationship, the odds ratio θ, and the binomial effect size (*BES*) are reported. Odds-ratio (Bland & Altman, 2000) and correlation coefficients are standard indicators of the degree of non-independence in two-sample CFA (von Eye, 2002). The binomial effect size (*BES*; Rosenthal & Rubin, 1982) is a measure of effect size in 2×2 tables and is defined as $BES = N_{11} / (N_{11} + N_{12}) - N_{21} / (N_{21} + N_{22})$ for $N_{i.}$ and $N_{.j} > 0$, with a range of $-1 \leq BES \leq +1$. In two-sample CFA, the *BES* is an estimation of the discrimination effect and indicates "the proportionate surplus of cases in one group over the other" (von Eye, 2002, p. 187).

The level of statistical significance was set at $\alpha = .05$; in case of multiple tests (two-sample CFA) alpha levels were Bonferroni-adjusted. Conventional χ^2 tests and Mann-

Whitney *U*-tests were calculated with SPSS 15.0 (2006), two-sample CFAs were computed by the CFA program by von Eye (2001).

Results

To prove that randomization between the "controllable" and "uncontrollable" groups was successful, Table 1 gives means and standard deviations of baseline values of the two hormones in each stress condition as well as means and standard deviations of possible confounders (age, body mass index and smoking) in the two groups. Significance tests yielded no significant group difference in any of the variables indicating that randomization was successful.

Distribution of endocrine AUCs

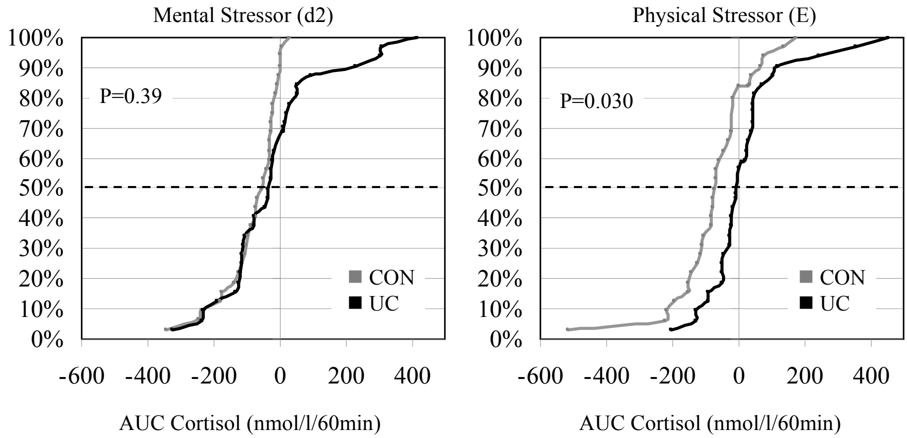
The cumulative AUC distribution curves for cortisol values obtained with the mental and physical stressor in the "controllable" and "uncontrollable" group are depicted in Figure 5; the respective testosterone AUC distribution curves are shown in Figure 6.

According to Figures 5 and 6 the group with uncontrollable conditions exhibited larger positive cortisol AUC responses and lower negative AUC responses than the group with controllable conditions. The non-parametric group differences (CON vs. UC) in AUC

Table 1:
Means, standard deviations, and statistical tests for group differences between the "controllable" and "uncontrollable" stress group for possible confounders and baseline hormone levels

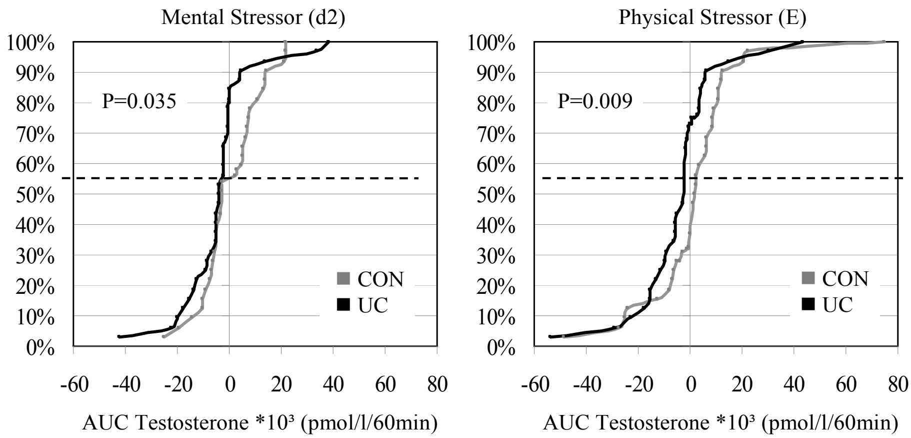
	Total	CON	UC	group difference[a,b]		*p*-value
N	74	37	37	-		-
Age (years)	24.8 ± 2.9	23.6 ± 2.2	25.8 ± 3.1	z = 1.23		.20[a]
BMI (kg/m²)	22.2 ± 1.8	22.4 ± 1.7	22.1 ± 1.9	z = .59		.55[a]
Smoking (% yes)	47 %	53 %	43 %	χ^2 = 1.004	*df* = 1	.32[b]
Baseline salivary hormone levels						
Cortisol (d2)[c]	5.4 ± 3.3	5.4 ± 3.1	5.3 ± 3.5	z = .26		.80[a]
Cortisol (E)[c]	4.7 ± 2.9	5.1 ± 3.2	4.3 ± 2.6	z = 1.20		.23[a]
Testosterone (d2)[d]	961 ± 542	913 ± 392	1009 ± 661	z = .18		.86[a]
Testosterone (E)[d]	1009 ± 732	1030 ± 718	989 ± 757	z = .53		.60[a]

BMI, body mass index; d2, mental stressor; E, physical stressor; CON, controllable condition, UC, uncontrollable condition; [a], Mann-Whitney *U*-test; [b], χ^2 test; [c], nmol/l; [d], pmol/l



Mann-Whitney *U*-test for differences between the “controllable” (CON) and “uncontrollable” (UC) group, *n* = 37 each

Figure 5:
Cumulative presentation of areas under the curve (AUC < 0: decrease, AUC > 0: increase) in the mental (left) and physical stress condition (right) for cortisol responses



Mann-Whitney *U*-test for differences between the “controllable” (CON) and “uncontrollable” (UC) group, *n* = 37 each

Figure 6:
Cumulative presentation of areas under the curve (AUC < 0: decrease, AUC > 0: increase) in the mental (left) and physical stress condition (right) for testosterone responses

values was more pronounced for testosterone but was only significant on the 5 % level for cortisol in the physical condition, whereas it did not reach significance for cortisol responses to the mental stressor. It must be emphasized that the considerable number of negative AUC values is due to the circadian decline of both hormones.

Group comparisons by conventional χ^2 tests

The results of comparisons between the experimental groups (CON vs. UC) with respect to endocrine responses by using conventional cross-classification and χ^2 tests are presented in Table 2.

Single χ^2 tests for endocrine responses obtained with both types of stressors yielded significantly higher proportions of increases (+) in cortisol in the UC group (d2: 30 %; E: 43%) than in the CON group (d2: 5 %, E: 16 %) (see also Figure 5). On the other hand, significantly more subjects in the UC group showed a decrease (-) in testosterone AUC (d2: 78 %; E: 73 %) compared to the CON group (d2: 54 %; E: 32 %) (c.f. Figure 6).

Table 2:
Dichotomized cortisol (C) and testosterone (T) AUC responses in the "controllable" and " uncontrollable" group: results of χ^2 tests

Stressor type	C	T	Controllable *n*	Controllable %	Uncontrollable *n*	Uncontrollable %	χ^2	*df*	*p*-value (2-tailed)
Mental (d2)	-		35	94.6	26	70.3	7.559	1	.012
	+		2	5.4	11	29.7			
		-	20	54.1	29	78.4	4.893	1	.048
		+	17	45.9	8	21.6			
Physical (E)	-		31	83.8	21	56.8	6.469	1	.021
	+		6	16.2	16	43.2			
		-	12	32.4	27	73.0	12.198	1	.001
		+	25	67.6	10	27.0			
Mental (d2)	-	-	19	51.4	19	51.4	10.885	3	.012
	-	+	16	43.2	7	18.9			
	+	-	1	2.7	10	27.0			
	+	+	1	2.7	1	2.7			
Physical (E)	-	-	10	27.0	16	43.2	17.573	3	.001
	-	+	21	56.8	5	13.5			
	+	-	2	5.4	11	29.7			
	+	+	4	10.8	5	13.5			

+/-, positive or negative area under the response curve (AUCs) after stress exposure with respect to baseline; C, cortisol; T, testosterone

The numerical group differences between controllable and uncontrollable conditions was slightly more pronounced for cortisol than for testosterone in the mental stress condition and clearly more pronounced for testosterone than for cortisol in the physical stress condition.

Global χ^2 tests to compare the distribution of combined cortisol/testosterone (C/T) response patterns revealed significant effects in favor of group discriminating patterns with both stressor types. After mental stress, in the UC group $n = 10$ (27 %) showed the response pattern C+T- whereas only $n = 1$ subject (3 %) in the CON group showed this pattern. Following physical stress (E) the endocrine response pattern C+T- was detected in $n = 11$ (30 %) subjects of the UC group and in $n = 2$ (5 %) of the CON group. Inverse response patterns (C+T-) occurred in $n = 16$ (43 %) of CON, vs. $n = 7$ (19 %) of UC after mental stress (d2) whereas after physical stress (E) this response pattern was revealed in $n = 21$ (57 %) subjects of the CON and in $n = 5$ (14 %) of the UC group.

Group comparisons by two-sample Configuration Frequency Analysis (CFA)

To test for discrimination types which represent our hypothesis of high cortisol and low testosterone in uncontrollable and the reverse pattern in controllable stress, two-sample CFAs were computed separately for the two stressors. Table 3 shows the results of both analyses.

Table 3:
Patterns of combined dichotomized cortisol (C) and testosterone (T) AUC responses in the "controllable" and " uncontrollable" group: results of two-sample CFAs

Stressor type	C	T	CON		UC		χ^2	Statistics					
			n	%	*n*	%	($df = 1$)	*p*-value[a]	*OR* θ	*BES*	φ	φ^2 %	*DT*
Mental (d2)	-	-	19	51.4	19	51.4	0	1	1	0	0	0	no
	-	+	16	43.2	7	18.9	5.110	.0238	3.27	.24	.26	6.9	no
	+	-	1	2.7	10	27.0	8.649	.00327[a]	13.33	-.24	-.34	11.7	yes
	+	+	1	2.7	1	2.7	0	1	1	0	0	0	no
Physical (E)	-	-	10	27.0	16	43.2	2.135	.144	2.06	-.16	-.17	2.9	no
	-	+	21	56.8	5	13.5	15.179	.000098[a]	8.40	.43	.45	20.5	yes
	+	-	2	5.4	11	29.7	7.559	.00597[a]	7.40	-.24	-.32	10.2	yes
	+	+	4	10.8	5	13.5	.126	.722	1.29	-.03	-.041	0.2	no

C, cortisol; T, testosterone; +/-, increase/decrease or no change of hormone responses (AUC) from baseline; CON, controllable conditions; UC, uncontrollable conditions; *p*-value, two-tailed *p*-value of χ^2 statistic; *OR* θ, odds ratio; φ, correlation coefficient; φ^2 %, squared coefficient φ * 100; *BES*, binomial effect size estimation; *DT*, discrimination type according to Krauth & Lienert (1973); [a] Bonferroni-corrected significant *p*-values if $p < \alpha/4 = .0125$

Two-sample CFAs resulted in clearly significant differences between groups CON and UC in the mental as well as in the physical stress condition. After mental stress, the response pattern C+T- was found to significantly discriminate between CON and UC (discrimination type) with moderate effect size (e.g., φ = -.34). After physical stress, two endocrine response patterns differed significantly between CON and UC. Again, the response pattern C+T- was significantly associated with the UC condition (φ = -.32), but the inverse response pattern (C-T+) showed an even stronger association with the C condition (φ = .45). Thus, both patterns have to be considered as significant discrimination types.

Testing combined response patterns produced by mental and physical stress

Since the two stressors elicited similar patterns for the controllable as well as for the uncontrollable condition, it was expected that a two-sample CFA based on the patterns of cortisol (C) and testosterone (T) responses combined for the two stressors (d2/E) would result in a general discrimination type even more suitable to separate the CON from the UC group.

The results obtained by a two-sample CFA for all possible C/T response patterns combined for both stressors are shown in Table 4. The global test of the model revealed χ^2 = 25.18, *df* = 15, *p* = .0476.

The results revealed that the endocrine response pattern C-T+ after both stressors (d2 and E) represents a significant discrimination type between controllable and uncontrollable stress with sufficient effect size (φ = .39). After Bonferroni correction the response pattern C+T-C+T- failed to reach significance. This would indicate that increases in testosterone (T+) and no change or a decrease in cortisol (C-) form a reliable characteristic pattern for responses to the attention test d2 as well as for the physical pain of electric stimulation, provided the participant is convinced he has control over stimulus presentation.

Discussion

Summary

It was expected that according to theoretical frameworks of psychoneuroendocrinological stress research (Henry, 1982, 1986, 1997; Henry & Stephens, 1977) derived from animal models uncontrollability of stress would be accompanied by an increase in cortisol (C+) and a decrease in testosterone (T-) in men as opposed to controllable stress which should elicit the opposite pattern (C-T+). It was hypothesized that (1) particular endocrine response patterns are associated with either uncontrollable (C+T-) or controllable (C-T+) stress conditions, and (2) that these response patterns are occurring intra-individually consistently across different types of stressors.

Table 4:
Combined response patterns of cortisol (C) and testosterone (T) obtained for mental (d2) and physical (E) stress: results of two-sample CFA

d2		E		CON		UC		χ^2	Statistics					
C	T	C	T	*n*	%	*N*	%	(*df* = 1)	*p*-value[a]	*OR θ*	*BES*	*φ*	*φ*² %	*DT*
-	-	-	-	8	21.6	11	29.7	0.474	.491	1.53	-.08	-.093	0.9	no
-	-	-	+	8	21.6	2	5.4	3.600	.058	4.83	.16	.237	5.6	no
-	-	+	-	1	2.7	4	10.8	1.800	.180	4.36	-.08	-.162	2.6	no
-	-	+	+	2	5.4	2	5.4	0	1	1	0	0	0	no
-	+	-	-	2	5.4	4	10.8	0.667	.414	2.12	-.05	-.099	1.0	no
-	+	-	+	12	32.4	1	2.7	9.308	.00228[a]	17.3	.30	.391	15.3	yes
-	+	+	-	1	2.7	2	5.4	0.333	.563	2.06	-.03	-.069	0.5	no
-	+	+	+	1	2.7	0	0	1.000	.317		.03	.117	1.4	no
+	-	-	-	0	0	1	2.7	1.000	.317		-.03	-.117	1.4	no
+	-	-	+	0	0	1	2.7	1.000	.317		-.03	-.117	1.4	no
+	-	+	-	0	0	5	13.5	5.000	.025		-.135	-.269	7.2	no
+	-	+	+	1	2.7	3	8.1	1.000	.317	3.18	-.05	-.120	1.4	no
+	+	-	-	0	0	0	0	0	1		0		0	no
+	+	-	+	1	2.7	1	2.7	0	1	1	0	0	0	no
+	+	+	-	0	0	0	0	0	1		0		0	no
+	+	+	+	0	0	0	0	0	1	1.53	0	-.093	0	no

Stressor type: d2, mental stressor; E, physical stressor; C, cortisol; T, testosterone; +/-, increase/decrease or no change of hormone responses (AUC) from baseline; CON, controllable conditions; UC, uncontrollable conditions; *p*-value, two-tailed *p*-value of χ^2 statistic; *OR θ*, odds ratio; *BES*, binomial effect size estimation; *φ*, correlation coefficient; *φ*² %, squared coefficient *φ* * 100; *DT*, discrimination type according to Krauth & Lienert (1973); [a] Bonferroni-corrected significant *p*-values if $p < \alpha/16 = .003125$

The influence of controllability or uncontrollability (CON/UC) on endocrine short-term stress responses was studied by means of a 10 minutes mental test (d2) and a 10 minutes physical (E) stressor applied in a cross-over design to 74 healthy male students randomly assigned either to CON or UC conditions. Saliva cortisol and testosterone concentrations were assessed at baseline and after stress exposure. The areas under the endocrine response curves (AUCs) were calculated and dichotomized (+/-) with respect to baseline. Inspection of hormone levels revealed that all endocrine concentrations of cortisol and testosterone were within normal ranges. Conventional χ^2 tests were used to explore the frequency of univariate and bivariate hormone responses after mental and physical stress in controllable and uncontrollable conditions. Two-sample CFA was applied to test the hypotheses that (1) bivariate response patterns C+/T- and C-/T+ could discriminate between CON and UC conditions; and (2) that these response patterns are observed consistently across both types of stressors.

The evaluation of univariate response patterns of cortisol and testosterone (C+/- or T+/-) indicated that an increase in cortisol (C+) or a decrease in testosterone (T-) responses was observed more often with uncontrollable stressors as compared to controllable stressors. Analyses of bivariate response patterns (C/T) revealed that the combination C+T- was more prevalent in uncontrollable conditions (d2: 27 %, E: 30 %) than in controllable conditions (d2: 3 %; E: 5 %). However, the non-specific decrease in cortisol and testosterone (C-T-) was the most prevalent pattern observed in 51 % (d2) and 35 % (E) of participants of both groups (CON and UC combined) and has to be attributed to the circadian decline of both hormones.

Two-sample Configural Frequency Analysis (CFA)

After mental stress (d2), the response pattern C+T- constituted a significant discrimination type sensu Lienert (Krauth & Lienert, 1973). After physical stress, both theoretically specified endocrine response patterns C+T- and C-T+ could significantly discriminate between controllable and uncontrollable conditions. Moreover, the response pattern C-T+ constituted a significant discrimination type between CON and UC across both stressors (d2: C-T+ and E: C-T+) with a higher frequency in CON (12/37 = 32 %) than in UC (1/37 = 3 %). Thus, the results corroborate the general hypothesis put forward in question (1) and give a tentatively positive answer to question (2), asking if the endocrine response patterns discriminating controllable and uncontrollable conditions are valid for different types of stressors.

Conclusions

For a mental as well as for a physical stressor the patterns of cortisol and testosterone responses expected according to psychoneuroendocrinological theory derived from animal models could be corroborated. However, when the type of stressors was included into CFA analysis results only partially confirmed the hypothesis: The pattern of a cortisol decrease and a testosterone increase was observed more often after controllable stress, but the reverse pattern for uncontrollability was evidently less consistent across types of stressors.

The experiment demonstrates that controllability and the lack of controllability (uncontrollability) have a clear impact on endocrine response patterns under both types of stressors applied as short term stimuli in a laboratory setting to young healthy men. CFA has been demonstrated to be highly suitable for analyzing the distribution of dichotomized response patterns in samples with $n < 100$.

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