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Consistency in Catecholamine and Cortisol Excretion in Males and Females

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FORSMAN, L. AND U. LUNDBERG. *Consistency in catecholamine and cortisol excretion in males and females.* PHARMAC. BIOCHEM. BEHAV. 17(3) 555–562, 1982.—Data from a series of experiments performed on 24 female and 24 male subjects were used to evaluate the consistency in urinary catecholamine and cortisol excretion. Data were available from 8 laboratory situations of varying activity level and content, spaced at intervals of maximum 3 months. Correlational analyses showed that for cortisol, interindividual consistency was higher for measures obtained on the same day than for measures obtained on different days. Interindividual consistency was generally high in catecholamine and cortisol excretion during non-stressful situations in both sexes. During experimental stress, however, consistency was as high as during nonstress for males, while it was lower for females. Analysis of variance components confirmed these results and showed that in males variation due to interindividual differences was high during both baseline and experimental-stress situations, while in females it was high during baseline situations only. During experimental stress, variation for females was due primarily to interaction. It is suggested that the males showed a more generalized stress response over situations than the females.

Adrenaline Noradrenaline Catecholamines Cortisol Response consistency Males Females Correlations Variance components

URINARY measures of cortisol and of the catecholamines adrenaline and noradrenaline are good indicators of stress and coping responses in individuals confronted with various environmental demands (see reviews in [13,21]). Psychoendocrinological responses have also been related to personality characteristics (e.g., [9]) and in these cases it is important to have information about the extent to which individual excretion levels are consistent across different situations. In a previous study of males [11], the interindividual consistency in adrenaline and noradrenaline excretion was found to be high during laboratory situations standardized with regard to e.g., mental and physical activity.

The aim of the present study was to examine the consistency in urinary catecholamine as well as cortisol excretion in both males and females in various "optimal" experimental situations (cf. [18]), i.e., under conditions where the aim of creating a psychologically meaningful situation for the subject somewhat limits the feasibility of exercising detailed control of conceivable extraneous influences on endocrine measurements, e.g., state of hydration of the subject. Consistency was studied by correlational analysis and by estimating the variation in excretion due to subjects, situations and subject-situations interaction.

METHOD

Twenty four male and 24 female university students, ranging in age from 18 to 34 yr (mean=24.5), participated in a series of laboratory experiments originally performed for other purposes [16,19]. The subject attended three laboratory sessions, each one starting at about 8:30 a.m., when the subject had voided. In the first session the subject was tested individually and urine samples were obtained after three experimental situations: a monotonous vigilance task (Sample No. 1), an inactive condition including a 20-min period of nondemanding tasks, e.g., time estimation (No. 2), and a self-paced reaction-time (RT) task (No. 3). In the second session, 1 to 3 weeks later, urine samples were obtained in three individual baseline situations at corresponding hours (Nos. 4–6). In the third session, carried out after another 4 to 12 weeks, the subjects participated in small groups and urine samples were obtained after a color-word conflict (CWT) task (No. 7) and a nonengaging movie (No. 8). Each situation lasted about 70 min. The schedule for urine samples is summarized in Fig. 1. The subject was carefully instructed at each time of voiding to empty his/her bladder completely. It has been shown [10] that residual amounts of urine in the bladder after voiding are of no significance in young healthy adults. At each micturation the subject was allowed to drink a small cup of water (about 100 ml). For further details about the design and procedures see [16,19].

Urine samples were analyzed fluorimetrically [1,6] for free adrenaline and noradrenaline and by radioimmunoassay [8] for free cortisol. If an inability to void or a technical

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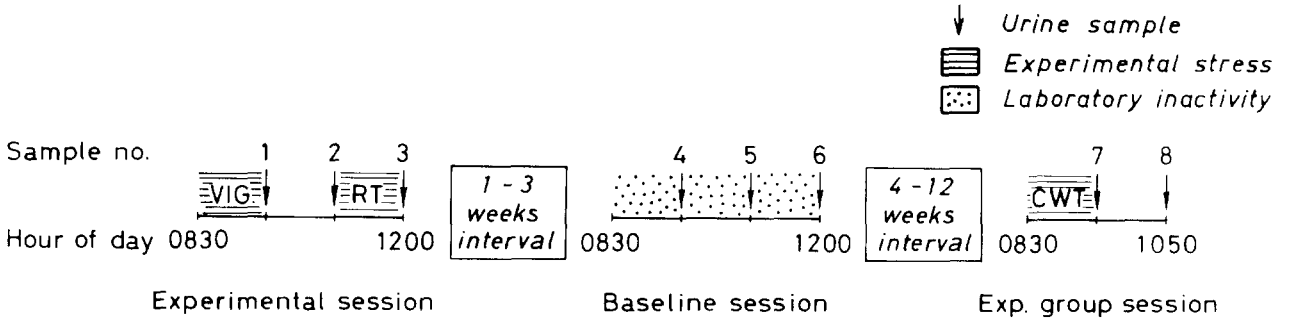

FIG. 1. Time schedule for the collection of urine samples. VIG=Vigilance task, RT=Selfpaced reaction-time task, CWT=Color-work conflict task.

TABLE 1

MEANS AND S.E. FOR ADRENALINE, NORADRENALINE AND CORTISOL EXCRETION IN MALES AND FEMALES IN DIFFERENT SITUATIONS

Time of day	0830–0940		0940–1050		1050–1200		0830–0940		0940–1050		1050–1200		0830–0940		0940–1050	
Sample Number	1		2		3		4		5		6		7		8	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Adrenaline excretion (pmol/min/kg)																
Females	0.58	0.057	0.60	0.051	0.80	0.062	0.36	0.038	0.51	0.048	0.61	0.048	0.69	0.066	0.56	0.051
Males	0.57	0.067	0.71	0.075	0.86	0.084	0.40	0.043	0.52	0.053	0.54	0.056	0.92	0.086	0.55	0.047
Noradrenaline excretion (pmol/min/kg)																
Females	2.88	0.165	2.61	0.237	2.69	0.203	2.62	0.208	2.42	0.200	2.09	0.172	2.70	0.163	2.48	0.629
Males	2.30	0.180	2.57	0.224	2.47	0.180	2.32	0.194	2.24	0.192	1.92	0.166	2.42	0.191	2.20	0.159
Cortisol excretion (pmol/min/kg)																
Females	7.28	1.082	3.88	0.442	3.39	0.651	6.24	1.046	5.61	1.028	4.08	0.536	5.88	0.760	3.29	0.415
Males	6.09	0.802	4.25	0.497	2.61	0.296	4.41	0.606	3.66	0.551	2.99	0.375	4.49	0.369	3.16	0.393

1=Vigilance.
2=Relative inactivity.
3=RT task.
4–6=Baselines.
7=Color-word conflict task.
8=Non-engaging movie.

mishap resulted in a missing value on any occasion, the subject was excluded; this left 18 females and 20 males for the analyses. As for a previous paper [11] two conventional methods for checking consistency were used, correlational analysis and the analysis of variance components, which have been extensively reviewed and evaluated [3,4].

RESULTS

Excretion Level in Different Situations

Means and standard errors for males and females, respectively, in adrenaline, noradrenaline and cortisol excretion in each situation are presented in Table 1. Repeated measures of ANOVA showed that there were no general differences in excretion level between the sexes either in adrenaline, $F(1,36)=2.57$, $p>0.10$, noradrenaline, $F(1,36)=1.35$, $p>0.25$, or cortisol, $F(1,36)=2.84$, $p>0.10$.

Correlational Analysis of Consistency in Catecholamine and Cortisol Excretion

Relative consistency in excretion level. Product-moment correlation coefficients between situations for adrenaline, noradrenaline and cortisol excretion in males and females are shown in Table 2–4. It is seen for both catecholamines that the correlations for males were generally higher than for females, particularly for noradrenaline, except for "unengaging movie" (No. 8), which was uncorrelated with most other situations.

TABLE 2

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN DIFFERENT SITUATIONS FOR ADRENALINE EXCRETION FOR MALES AND FEMALES

Situations	2	3	4	5	6	7	8
Females							
(1) Vigilance	.56‡	.41	.65†	.34	.32	.59†	.49‡
(2) Relative inactivity		.30	.55‡	.44	.70†	.45	.60†
(3) RT-task			.46	.54	.64†	.38	.55‡
(4) Baseline 1				.66†	.61†	.57†	.56‡
(5) Baseline 2					.82*	.52‡	.61†
(6) Baseline 3						.42	.68†
(7) CWT							.85*
(8) Movie							
Males							
(1) Vigilance	.80*	.69*	.41	.54‡	.53‡	.70*	.52‡
(2) Relative inactivity		.80*	.65†	.64†	.55‡	.62†	.48‡
(3) RT-task			.40	.53‡	.53‡	.45‡	.70*
(4) Baseline 1				.83*	.71*	.36	.08
(5) Baseline 2					.80*	.51‡	.22
(6) Baseline 3						.44‡	.39
(7) CWT							.51‡
(8) Movie							

*$p<0.001$.
†$p<0.01$.
‡$p<0.05$.

For cortisol in both males and females correlations were lower than for the catecholamines. A correlation matrix based on the total sample of both males and females was submitted to a principal components' factor analysis. On the basis of a drop in Eigenvalues three factors were extracted and varimax rotated. Factor loadings and communalitites are shown in Table 5. It is seen that each factor contains situations from the same day, i.e., each factor represented a separate day of urine collection. When catecholamine values were analyzed in the same way, it was found that they were not consistently related to the day of urine collection.

The difference in relative consistency between the sexes suggested in the correlation matrixes is further analyzed in Table 6, where the mean correlation coefficients have been calculated (using Fisher's Z-transformation) for situations characterized as "nondemanding", i.e., samples No. 2, 4, 5, 6, and 8 (see Fig. 1), and for situations characterized as "experimental stress", i.e., samples No. 1, 3 and 7. The differences for each sex between correlations during undemanding and during experimental stress situations have also been calculated. It is seen that for males the correlations were of about the same magnitude during experimental stress as during nondemanding situations, whereas for females the correlations were consistently smaller during experimental stress than during nondemanding situations.

Relative consistency in change scores. In addition to differences in the level of excretion there are interindividual differences with regard to the degree of change from baseline to stressful situations (e.g., [20]). Product-moment correlation coefficients were calculated in each sex group between log transformed data representing experimental-stress situations (Nos. 1, 3 and 7) as percentages of baseline data at the same hours. Table 7 shows that for adrenaline, noradrenaline and cortisol excretion, the correlations were higher for both sexes between the Vigilance and the CWT situations than between either of these two situations and the self-paced RT-task situation. For males this difference in correlational pattern reached significance ($p<0.05$). Thus, the correlation between changes scores was high in the two situations in which the stimulus frequency was predetermined and the subject had no control over stimulus input. Correlations between these two situations and the self-paced RT-task situation, where the subject had full control over the stimulus input, were consistently lower.

Analysis of Variance of Consistency in Catecholamine and Cortisol Excretion

ANOVA was performed on both the male and the female group on the three baseline situations (Nos. 4 to 6) and the three experimental stress situations (Nos. 1, 3 and 7), respectively, and variance-component calculations were made. The same calculations were performed on all eight situations together.

Table 8 shows the percentage of variance components in each sex group due to subjects, situations and subject-situation interaction of total variance component for adrenaline, noradrenaline and cortisol. The percentages of

TABLE 3

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN DIFFERENT SITUATIONS FOR NORADRENALINE EXCRETION FOR MALES AND FEMALES

Situations	2	3	4	5	6	7	8
Females							
(1) Vigilance	.43	.35	.45	.24	.29	.14	.13
(2) Relative inactivity		.19	.64†	.63†	.72*	.39	.14
(3) RT-task			.51	.40	.28	.31	.12
(4) Baseline 1				.72*	70*	.47‡	.02
(5) Baseline 2					.91*	.25	.26
(6) Baseline 3						.24	.27
(7) CWT							.62†
(8) Movie							
Males							
(1) Vigilance	.88*	.85*	.84*	.81*	.72*	.64†	.33
(2) Relative inactivity		.87*	.84*	.88*	.78*	.57†	.25
(3) RT-task			.79*	.81*	.78*	.44‡	.40
(4) Baseline 1				.93*	.78*	.74*	.35
(5) Baseline 2					.87*	.68*	.30
(6) Baseline 3						.53‡	.44‡
(7) CWT							.39
(8) Movie							

*$p < 0.001$.
†$p < 0.01$.
‡$p < 0.05$.

TABLE 4

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN DIFFERENT SITUATIONS FOR CORTISOL EXCRETION FOR MALES AND FEMALES

Situations	2	3	4	5	6	7	8
Females							
(1) Vigilance	.34	.29	.28	.31	.28	.12	.03
(2) Relative inactivity		.17	.50‡	.49‡	.42	.17	.04
(3) RT-task			.45	.45	.18	.03	.08
(4) Baseline 1				.86*	.62†	.36	.31
(5) Baseline 2					.76*	.08	.17
(6) Baseline 3						.42	.59‡
(7) CWT							.79*
(8) Movie							
Males							
(1) Vigilance	.68*	.51‡	.18	.50‡	.22	.30	.31
(2) Relative inactivity		.69*	.63†	.31	.31	.35	.30
(3) RT-task			.32	.03	.10	.40	.55‡
(4) Baseline 1				.45‡	.47‡	.21	.11
(5) Baseline 2					.58†	.17	.07
(6) Baseline 3						.15	.23
(7) CWT							.67*
(8) Movie							

*$p < 0.001$.
†$p < 0.01$.
‡$p < 0.05$.

TABLE 5

ROTATED FACTOR LOADINGS AND COMMUNALITIES FOR CORTISOL UNDER DIFFERENT SITUATIONS FOR THE TOTAL SAMPLE OF MALES AND FEMALES

Situations	Loadings 1	2	3	h^2
Baseline 2	0.89			0.87
Baseline 3	0.85			0.80
Baseline 1	0.77			0.74
Vigilance		0.77		0.61
RT-task		0.74		0.58
Relative inactivity		0.69		0.59
Movie			0.91	0.85
CWT			0.88	0.81
Variance explained	28%	23%	22%	

Loadings less than 0.35 have been omitted from the table.

TABLE 6

MEAN PRODUCT-MOMENT CORRELATION COEFFICIENTS (r) (BASED ON Z-TRANSFORMATIONS) BETWEEN NONDEMANDING AND BETWEEN EXPERIMENTAL-STRESS SITUATIONS FOR ADRENALINE, NORADRENALINE AND CORTISOL IN THE MALE AND THE FEMALE GROUP, AND THE DIFFERENCES IN r BETWEEN NONDEMANDING AND EXPERIMENTAL-STRESS SITUATIONS FOR EACH SEX

	Nondemanding situations r	Experimental stress situations r	Differences between situations
Females			
Adrenaline	.63	.47	.16
Noradrenaline	.60	.27	.33
Cortisol	.52	.13	.39
Males			
Adrenaline	.58	.63	−.05
Noradrenaline	.75	.68	.07
Cortisol	.35	.41	−.06

TABLE 7

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN LOG PERCENT CHANGE SCORES DURING EXPERIMENTAL-STRESS SITUATIONS (VIGILANCE, SELF-PACED RT AND CWT) IN ADRENALINE, NORADRENALINE AND CORTISOL EXCRETION FOR THE FEMALE AND MALE GROUPS

Situations	Females	Males
Adrenaline		
Self-paced RT/Vigilance	.41	.13
Self-paced/CWT	.19	.21
Vigilance/CWT	.55†	.81*
Noradrenaline		
Self-paced RT/Vigilance	.02	−.10
Self-paced/CWT	.19	−.20
Vigilance/CWT	.28	.43
Cortisol		
Self-paced RT/Vigilance	.16	.13
Self-paced/CWT	.19	.13
Vigilance/CWT	.38	.65*

*$p<0.001$.
†$p<0.02$.

variance components for baseline situations and the experimental-stress situations are also shown in Fig. 2. It is seen that for both sexes the proportion of variance in catecholamine excretion due to subject-situation interaction was greater in the experimental-stress situations than in the baseline situations. With respect to catecholamines in males, subjects accounted for most of the variance in both types of situations, the subject-component being particularly high during baseline situations. As shown in Fig. 2, there were differences between the male and female groups: (1) Looking at adrenaline excretion in males, the variance component due to situations was greater during experimental stress than during baseline; the opposite pattern appeared for the females; (2) For both catecholamines, the interaction component during experimental stress was smaller than the subject-component for the male group; again the opposite pattern appeared for the female group.

With cortisol excretion in males, the interaction component was greater than the subject-component and the situation-component in the baseline as well as the experimental-stress situations. For the female group there were large differences between baseline and stress situations; in baseline situations, subjects accounted for most of the variation, while during stress the main part of the variation was due to interaction.

DISCUSSION

Methodological Considerations

The consistency of hormonal excretion in urine is likely to be influenced by e.g., the state of hydration of the subjects, variation in the interval between bladder-emptyings, etc. However, as mentioned in the introduction, our aim was to examine what degree of consistency one can expect to find in a psychoendocrinological study on human subjects (e.g., [9, 19, 22]) with optimal [18] experimental control, rather than controlling the influence of all conceivable factors.

Hormonal changes during the menstrual cycle and the use of contraceptive pills may affect catecholamine and cortisol excretion in women. Some studies [17,25] have disclosed slightly elevated catecholamine levels during the premenstrual phase, while others showed no marked changes in catecholamine [23] or cortisol [7] excretion during the menstrual cycle. Only three women in the present sample were using contraceptive pills. It is unlikely that these three subjects contributed significantly to the differences in consistency found between males and females.

TABLE 8

PERCENTAGE OF ESTIMATED VARIANCE COMPONENTS DUE TO SUBJECTS, SITUATIONS AND INTERACTION BETWEEN SUBJECTS AND SITUATIONS AND TOTAL VARIANCE COMPONENTS FOR ADRENALINE, NORADRENALINE AND CORTISOL IN BASELINE SITUATIONS, EXPERIMENTAL-STRESS SITUATIONS (VIGILANCE, SELF-PACED RT-TASK AND CWT) AND ALL 8 SITUATIONS FOR MALES AND FEMALES (VARIANCE COMPONENTS IN PARENTHESES)

	Variance components							
	Females				Males			
	Subjects	Situations	Interactions	Total	Subjects	Situations	Interactions	Total
Adrenaline								
Baseline	48.3	30.9	20.8	100.0	70.4	8.4	21.2	100.0
	(72.5)	(46.4)	(31.2)	(150.1)	(184.3)	(22.0)	(55.4)	(261.7)
Experimental-stress	40.1	11.3	48.5	100.0	44.0	22.2	33.8	100.0
	(111.1)	(31.4)	(134.3)	(276.8)	(316.3)	(159.4)	(243.3)	(719.0)
All	39.6	22.5	37.9	100.0	39.9	23.8	36.3	100.0
	(85.7)	(48.8)	(82.1)	(216.6)	(203.8)	(121.9)	(185.6)	(511.3)
Noradrenaline								
Baseline	67.9	10.5	21.7	100.0	79.9	5.7	14.4	100.0
	(1,354)	(209)	(432)	(1,995)	(3,411)	(243)	(615)	(4,269)
Experimental-stress	27.1	0	72.9	100.0	64.1	0	35.9	100.0
	(469)	(0)	(1,264)	(1,733)	(2,551)	(0)	(1,427)	(3,978)
All	35.9	6.4	57.8	100.0	64.4	3.8	31.8	100.0
	(696)	(124)	(1,121)	(1,941)	(2,695)	(160)	(1,328)	(4,183)
Cortisol								
Baseline	64.7	8.0	27.6	100.0	42.2	9.1	48.7	100.0
	(25,848)	(3,190)	(10,931)	(39,969)	(11,351)	(2,442)	(13,095)	(26,888)
Experimental-stress	11.3	18.0	70.7	100.0	22.3	35.6	42.1	100.0
	(5,967)	(9,445)	(37,192)	(52,604)	(6,726)	(10,726)	(12,680)	(30,132)
All	25.3	14.9	59.8	100.0	26.4	17.8	55.9	100.0
	(9,534)	(5,634)	(22,560)	(37,728)	(6,463)	(4,354)	(13,697)	(24,515)

Validation of Previous Findings on Consistency in Catecholamine Excretion in Males

Our previous findings on consistency in catecholamine excretion in males [11] are supported by the present results. (A) The degree of interindividual consistency in excretion level varied, depending on which situations were compared, but the general level of consistency was high, i.e., a majority of the intercorrelations were statistically significant. This high consistency occured not only in situations of the same activity level and content, occuring on the same day (baselines), but also in several situations dissimilar in activity level and content, occurring weeks apart. It is important to note, however, that the correlations in adrenaline between some of the situations were non-significant. (B) Analysis of variance components confirmed these findings and showed that the main part of variation in catecholamine excretion could be attributed to interindividual differences, and that during experimental stress the part attributable to interaction was larger than during baseline conditions.

Interindividual Consistency in Cortisol Excretion in Males and Females

With regard to cortisol excretion, our results strongly suggest that proximity in time is an important factor for the degree of interindividual consistency (particularly for males). Correlations between measures obtained on the same day were higher than between measure obtained on different days (Table 5). This implies that in research where e.g., habitual cortisol excretion is related to personality characteristics, mean measures over different days should be used rather than single-day (e.g., 24 hr) measurements, thus reducing the influence of day-to-day fluctuations.

Consistency in Change Scores

There were higher correlations between change-scores of adrenaline, noradrenaline and cortisol, respectively, in the two situations where the stimulus rate was fixed (the Vigilance and CWT tasks), than between each of these situations and the one in which the individual was able to exert personal control over the stimulus rate (RT-task). This pattern appeared in spite of the fact that the Vigilance task and the CWT were performed several weeks apart. This implies that not only the activity level (cf. [11]) but also the kind of activity, such as the possibility it affords of exerting personal control, is important for the degree of interindividual consistency. The relevance of personal control as a situation characteristic has been discussed, e.g., in [2,14].

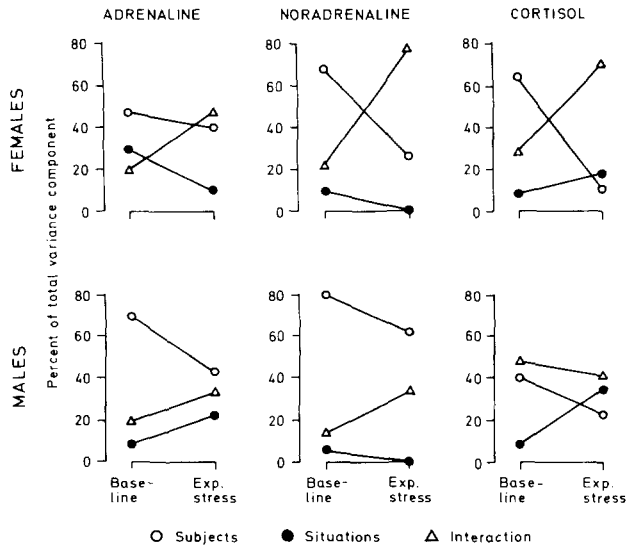

FIG. 2. Percent of variance components during baseline situations and experimental-stress situations due to subjects, situations and the interaction between the two for adrenaline, noradrenaline and cortisol in males and females.

Comparison Between the Sexes

The results show some sex differences in consistency. (A) For the males the interindividual consistency in adrenaline, noradrenaline and cortisol excretion was relatively independent of situational characteristics, while for the females consistency was higher in "nondemanding" than in experimental-stress situations. (B) Also, the analysis of variance components suggests for catecholamines that, whereas for both sexes most of the variation in baseline situations could be attributed to interindividual differences, during experimental stress more of the variation was due to interaction in females than in males. Similarly, for cortisol in females, variation due to interindividual difference was high during baseline situations, and very low during experimental-stress situations. In males, the difference between baseline and experimental stress was much smaller. These results suggest that variation in cortisol as well as in catecholamine excretion during experimental stress is due to interaction to a greater extent for females than for males. It should be noted that interaction in the sense used in this paper is a statistical concept and indicates that the rank order of individuals differ across situations.

Previous studies have shown a lower adrenaline output (in relation to body weight) for females than for males during achievement situations (for reviews see [12,15], but not during baseline or vigilance situations [19,22]. In the present study, the result suggest that the stress responses are more generalized over situations for males than for females. Psychological evaluation of the situations probably plays an important role for these sex differences, as suggested in a longitudinal study of the socialization process in Finnish boys and girls [24], where the results indicate that girls more than boys are taught to pay attention to, and discriminate more closely between, different types of social situations. Results showing that the variance in hostility contributed by situations tends to be less for males than for females [5], are in general agreement with these findings, too.

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