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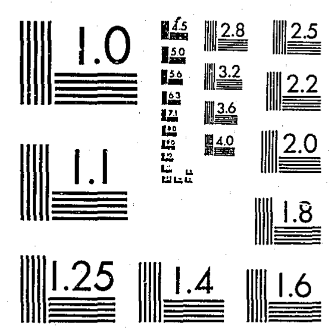

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SKIN CONDUCTANCE, FINGER PULSE VOLUME AND HEART RATE MEASURES AS RELATED TO REAL-LIFE STRESS AND PSYCHOPATHY

by

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SKIN CONDUCTANCE, FINGER PULSE VOLUME AND HEART RATE MEASURES AS RELATED TO REAL LIFE STRESS AND PSYCHOPATHY

S.E. Levander, D. Schalling, L. Lidberg and Y. Lidberg. Rep. Lab. Clin. Stress Res., No. 100, Stockholm, 1979. Skin conductance (SC), finger pulse volume (PV) and heart rate (HR) measures were studied in a group of 24 arrested men in three experimental sessions: two weeks, one week, and immediately before a court trial. The first session was assumed to represent a moderate laboratory stress due to the novelty of the situation, and the last session a real life stress associated with anticipation of appearing in court. The second session represented the sustained real life stress of being in jail, common to all sessions. Tonic level, spontaneous fluctuations, and phasic changes to eleven 93 dB tone stimuli in the psychophysiological measures were analyzed in relation to psychopathy-related personality variables. There were large differences among the psychophysiological variables in respect of stress sensitivity, and in respect of interactions between stress and personality. More psychopathic subjects tended to have a lower level of autonomic activity in most of the psychophysiological measures, regardless of situational stress level. High scores in scales connoting psychopathy and impulsivity were consistently related to large acceleratory HR responses to tones in the most stressful session. This was interpreted as indicating a high efficiency in preattentive filtering mechanisms, suggesting a tendency in psychopathic subjects to "tune out" stimuli in situations of anticipatory stress.

In the last fifteen years autonomic correlates of psychopathy have been investigated in several studies. The most frequently used measures are obtained from skin conductance (SC) and heart rate (HR) recordings. Extensive reviews are given in Hare (1970) and Hare and Schalling (1978). The conception of psychopathy underlying much of this research is based on the clinical description by Cleckley (1941, 1976). Relations obtained

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between estimates of psychopathy and particular patterns of psychophysiological measures have been interpreted in terms of various models of basic neuropsychological disturbances in psychopaths, for instance low conditionability (Lykken, 1957), low cortical arousal (Quay, 1965; Hare, 1970; Schalling, 1970), and high efficiency in "tuning out" disturbing or noxious stimuli (Hare, 1975).

The empirical findings include a tendency to low SC level especially in monotonous situations and during expectations of aversive stimuli (Schalling, Lidberg, Levander & Dahlin, 1973; Schalling, 1978; Hare, 1978 a) and few SC spontaneous fluctuations (Lippert & Senter, 1966; Hare & Quinn, 1971; Schalling et al., 1973). These trends have been interpreted in terms of a low cortical arousal but also as low anxiety or emotion. Further, low amplitude of SC responses to stimuli of high intensity has been reported (Hare, 1978 b). Psychopaths have been shown to be deficient in avoidance conditioning (Lykken, 1957) and have low SC response amplitudes to conditioned stimuli in classical conditioning paradigms (Hare & Quinn, 1971). This low electrodermal conditionability has been related to their real life difficulties in avoiding or inhibiting illegal or immoral acts and the weak deterrent effect of punishment. However, the low conditionability model is valid only for SC measures. Psychopaths have been reported to be superior in acquiring HR conditioned responses (Hare & Quinn, 1971; Hare & Craigen, 1974). On the other hand, they appear to have normal HR responses to simple non-signal stimuli, e.g. a series of tones (Hare, 1978 a). Results concerning HR tonic levels are not consistent (Hare, 1978 a).

The directional fractionation between SC and HR responses in conditioning paradigms has parallells in findings obtained in "quasi-conditioning" paradigms. In conditioning paradigms, the time between the warning signal (CS) and the aversive stimulus (UCS) is short, and the association may be established without the subject being aware of the contingency. In quasi-conditioning paradigms, subjects are explicitly told that an aversive stimulus will be delivered at a specific point in time, and autonomic measures are obtained in the anticipatory period preceding the stimulus. The quasi-conditioning paradigm is more close to a real life stress situation since the anticipatory foreperiod is longer than the CS-UCS interval, and the subject is aware of the stimulus contingency.

In some of the quasi-conditioning studies, count-down procedures have been used allowing the measurement of autonomic responses to a series of warning signals related to the temporal adjacency of a UCS (usually a high-intensity auditory stimulus or an electrical or thermal pain stimulus). In such studies psychopathic subjects do not react with increased SC until immediately before the aversive stimulus (Hare, 1965; Hare & Craigen, 1974; Hare, Frazelle & Cox, 1978). This has been interpreted as indicating a steep temporal gradient of fear arousal (Hare, 1965). When HR responses have been recorded the same tendency towards directional fractionation has been obtained as in the conditioning paradigms, i.e. large HR and small SC responses to the warning signal.

Lower frequency of SC spontaneous fluctuations has been reported in psychopathic subjects during a stimulus-free anticipatory period of a few minutes preceding an aversive stimulus. Such findings have been interpreted in terms of a low cortical arousal (Schalling, 1970) but also as suggesting a deficiency in imagination or anticipatory cognitive processing of expected events (Schalling, 1978).

The autonomic reactivity of psychopaths to anticipatory stress has been studied only for laboratory stress, e.g. high-intensity noise stimuli or electrical pain stimuli, which represent a highly artificial stress. There seems to be no psychophysiological study of psychopathy during anticipation of a real life stressful situation.

The present study represents an attempt to extend the laboratory research on psychopaths in quasi-conditioning paradigms to a real-life situation. Psychophysiological measures were obtained in a group of arrested men. The paradigm comprised three identical experimental sessions, characterized by their different time relations to a court trial. Within each experimental session, psychophysiological recordings were obtained in three separate periods, during rest and during a series of tone stimuli. A clinical rating of psychopathy and self-report estimates of psychopathy-related personality variables were obtained for each subject. Some of the results have been reported earlier as concerns urinary adrenaline (A) and noradrenaline (NA) excretion (Lidberg, Levander, Schalling & Lidberg, 1978 b), recovery time of SC responses (Levander, Schalling, Lidberg & Lidberg, 1979) and the result of a figure-ground reversals test, using a Necker cube (Lidberg, Levander, Schalling & Lidberg, 1978 a).

In the present report, the results as concerns SC, PV and HR measures in the three sessions are given. The design of the study makes possible an analysis of the relations between personality, level of situational anticipatory stress and psychophysiological measures, both separately and in interaction. The main objective was to study the patterning of psychophysiological activity in these three physiological systems in the three sessions, as related to personality variables and clinical ratings of psychopathy. One main hypothesis was that more psychopathic subjects would show a lower level of activity in the SC measures since they are assumed to reflect cortical arousal (low cortical arousal model). The difference between more and less psychopathic subjects in SC activity was expected to be most pronounced in the most stressful session (immediately before the court trial), as predicted by the steep temporal gradient of fear arousal and deficient anticipatory cognitive imagery models. Another main hypothesis was that more psychopathic subjects would show a directional fractionation between SC and HR response measures in the last session and large acceleratory HR responses indicating a high efficiency in preattentive filtering mechanisms ("tuning-out") and defensive rather than orienting reflex patterns.

METHODS

Subjects

Twenty-four arrested men, 18-29 years old (mean age 22), participated voluntarily and without payment in the study. They were by decision of the court referred for forensic psychiatric examination. This procedure is used to supply the court with psychiatric information which might influence the sentence (cf. Mayer-Gross, Slater & Roth, 1974, p. 770).

The subjects were informed that the study concerned physiological reactions to being in jail, and were assured that the data obtained would not be analyzed until after the court procedure was completed and would not be included in any official record.

All subjects were in good physical health and of normal intelligence as judged from test results or from their performance at school, and they had been under arrest for at least ten days. None had any sign or symptom of withdrawal from abuse of alcohol or drugs, although five subjects had a record of heavy alcohol consumption and 12 had injected central stimulants, mostly for short periods.

In the trial, five subjects were sentenced for crimes of violence (four for assault and one for inflicted damage). Six were sentenced for dealing with narcotics (central stimulants). Three subjects were sentenced for car theft, and the remaining for crimes involving property, mainly burglary.

Eight subjects were put to probation, 12 were sentenced to prison (four to youth prison), one to preventive detention, and one to borstal care. Two subjects were remanded to closed psychiatric care.

Personality variables

The Gough Delinquency scale (De scale) is based on a role-taking theory of psychopathy (Gough, 1948; Gough & Peterson, 1952; Rosén & Schalling, 1974) with reference to the concept of psychopathy used by Cleckley (1976). A shorter version of the scale with reversed scoring, the Socialization scale, is included in the California Psychological Inventory. These scales have shown an impressive validity against various criteria of socialization and psychopathy (Gough, 1965; Schalling, 1978) and psychophysiological measures (Schalling, Lidberg, Levander & Dahlin, 1973; Hare & Cox, 1978). In the Swedish 64-item version which was used in the present study, the response alternatives were: True, ?, and Not True, scored 2, 1 and 0. High scores indicate low socialization, and low role-taking ability. The items refer to experiences of lack of warmth and satisfaction at home and in interpersonal relations, rule-breaking and non-acceptance of societal norms and values.

The Marke-Nyman Temperament inventory (MNT) comprises three scales: Validity, Stability and Solidity. These scales were constructed by Nyman and Marke (1962) on the basis of a dimensional theory of personality and temperament structure by Sjöbring (1973). English and American versions have been presented by Coppen (1966) and Barrett (1975). Validity tends to be negatively correlated with the Eysenck Neuroticism scale (Coppen, 1966) and may be described as a neuroticism-psychasthenia scale. Individuals scoring low on Validity describe themselves as easily tired, cautious, tense and hurried. Solidity and Stability have been reported to correlate negatively with the Eysenck Extraversion scale (Coppen, 1966). The item content suggests that Solidity is primarily related to the impulsiveness component of extraversion and this has been repeatedly confirmed in studies from our own laboratory (Schalling, 1978). The item content in Stability indicates that the scale is related to the sociability component of extraversion, but also to empathy and warmth in interpersonal relations, and to emotional involvement. Low Solidity subjects tend to be impulsive and thrill-seeking, while high Stability subjects tend to have low empathy and lack warmth in interpersonal relations. Schalling and Holmberg (1970) found that delinquents, compared to matched controls, had significantly lower scores on Solidity and higher scores on Stability.

The Eysenck Personality Inventory (EPI) comprises two scales, Extraversion and Neuroticism (Eysenck & Eysenck, 1964). A Lie scale is included.

Psychiatric rating

On the basis of a psychiatric interview and case records the subjects were rated on nine-point scales on eight variables (Schachter & Latané, 1964) related to psychopathy according to criteria suggested by Cleckley (1976). Suicidal attempts, although included by Schachter and Latané were disregarded in view of the low frequency of such attempts in the present group, and the influence of situational factors, for instance cutting as one mean of obtaining a change in prison treatment. A short description of the eight variables is given in Table 1. A measure of psychopathy was obtained by summing the points on the eight variables.

Table 1. A clinical psychopathy rating scale, comprising eight variables related to psychopathy criteria suggested by Cleckley.

1. Few symptoms of nervousness
2. Little sense of responsibility
3. Disregard for truth
4. Little sense of shame
5. Antisocial behavior without much compunction
6. Little ability to learn from experiences
7. Poverty of affect
8. Little response to special consideration or kindness

Experimental procedure

In the study was included biochemical, psychophysiological and neuropsychological methods. A short description is given of the total procedure.

The laboratory was situated within the state prison of Stockholm and consisted of two quiet rooms. The temperature was kept between 20 and 22°C. The recording instruments were placed in a separate room from where the experimenter could observe the subjects through a glass window. All experiments were conducted by the same experimenter. The subjects did not have to walk outside the prison more than about 60 meters to come to the laboratory. Sleeping hours, physical activity and food intake were strictly scheduled. All subjects were smokers. They were not permitted to consume alcohol or drugs. No coffee, tea or smoking was allowed within one hour before the sessions.

Each subject participated in three identical experimental sessions, performed between 8.30 and 10.00 a.m. The first session (Session 1) took place approximately two weeks before trial, and was assumed to represent a moderate laboratory stress due to the novelty of the situation. The last session (Session 3) immediately before trial represented a real life stress associated with appearing in court. The stress level in these sessions is superimposed on the sustained real life stress of being in jail, represented by the second session (Session 2) approximately one week before the trial.

When the subject came to the laboratory he was asked to void his urine. A drink (300 ml of diluted orange juice) was then served. The subject was left alone to rest for half an hour while reading popular technical magazines. After the rest, electrodes for the psychophysiological measurements were applied on his non-dominant hand and the subject was asked to make himself as comfortable as possible. He was told that he was going to see a drawing of a cube (Necker cube) on a projection screen in front of him and that he was going to hear a series of tones to which he was to make no active response. He was then left alone, the main light in the room was switched off leaving a dim illumination. All instructions were then given via tape recorder. A single Necker cube figure was projected onto a screen in front of the subject during two 90-sec periods. The subject was instructed to indicate a spontaneous figure reversal by pressing a button. After five minutes of rest (Period I), eleven randomly spaced fast onset sine tones, each of one second duration, 1000 Hz and 93 dB above hearing threshold (1964 ISO values) were administered via headphones (Period II). Then the subject was asked to rest for another five minutes (Period III). The Necker cube was again projected on the screen for two periods. The session was then terminated and the subject was asked to empty his bladder. This urine was acidified, frozen and stored at -18°C until analyzed for adrenaline and noradrenaline by the fluorimetric method of von Euler and Lishajko (1961).

Physiological measurements

Skin conductance (SC). A constant current ultra-linear active resistance bridge circuit was used with fixed resistance ranges covering resistance values from 10 to 1200 Kohms, and with resolution according to the logarithm of the midrange resistance value. Different values of constant current were associated with each of the five resistance ranges, to avoid extremes of either current or voltage. Bi-polar Ag-AgCl electrodes with an active diameter of 9 mm, noise, drift and polarization less than 1 mV (as seen from 1 Mohm resistance) were applied with Elema EMT 87 electrode paste (0.9 % NaCl). The electrodes were fastened on the volar side of the proximal phalanxes of the second and fourth finger of the left hand after cleaning of the skin. The maximum current density in the subject was 9 microA/cm^2, and the maximum voltage across the electrodes was 2.7 V. The high frequency limit was approximately 10 Hz (3 dB loss).

All skin resistance values were transformed to log conductance units (log micro-Siemens) before further data treatment, to obtain normal distributions.

Pulse volume (PV). A piezo-electric pressure transducer (Elema EMT 510C) was connected to an oncometer cuff via a short rigid plastic tube. The cuff was mounted airtight on the left hand second finger by means of plasticine and a thin rubber tube. The transducer output was amplified in a high sensitivity field effect transistor preamplifier. PV was quantified in mm recording paper, and adjusted for amplifier gain and size of the finger tip inserted in the oncometer cuff.

Heart rate (HR). The amplified pulse volume signal was fed into a linear ramp generator via an adjustable Schmitt trigger circuit and a monostable flip-flop, short circuiting the ramp generator for a specified time for each new ascending limb of the pulse volume signal. The output circuit of the ramp generator was designed with a short time-constant for ascending ramp signals and a long time constant for descending ramp signals, resulting in an output consisting of a series of spikes corresponding to each heart beat. The envelope of the spikes was proportional to the time interval between successive heart beats. All HR measures were transformed to instant heart rate, expressed in beats per minute (bpm).

Respiration was recorded by a strain gage transducer round the chest. The respiration recordings were used to exclude respiratory artefacts in the psychophysiological recordings due to for instance yawning.

Recording instruments. Skin resistance, pulse volume and heart rate were recorded on a servo-type inkwriter, Rika-Denki 1304 with 250 mm recording width and with 2.5 mm/sec paper speed. Tone stimuli were recorded on an event-marker channel. Pulse volume was also together with respiration and tone stimuli recorded on a Grass antique electroencephalograph (late forties) with 50 mm non-linear recording width and 5 mm/sec paper speed.

Quantification of data

Necker cube data. For the present paper, the rate of apparent change (RAC) was calculated as the mean frequency of figure reversal for each individual over periods and sessions (Lidberg, Levander, Schalling & Lidberg, 1978 a).

SC level (SCL) was calculated as the mean of ten samplings at 30 sec intervals in Period I and III (rest). SCL in Period II (tone stimuli) was the mean of ten samplings immediately before tone stimuli 2 to 11.

The first response in SC (SCR-1) was the maximal response amplitude to the first tone stimulus, expressed in units of log micro-Siemens. The mean SC response amplitude was calculated on the non-zero responses to tones 2 to 11. A response was defined as a deflection of at least 0.0043 in units of log micro-Siemens, starting in the interval 1.5 to 5 sec after onset of the tone and reaching a maximum within 8 sec.

The recovery time of SC responses (rec t/2) was calculated as described by Levander, Schalling, Lidberg and Lidberg (1979 a). All rec t/2 values were subjected to a logarithmic transformation before further data treatment. Rec t/2 was scored separately for the response to the first tone and for the non-zero responses to tones 2 to 11.

The number of spontaneous fluctuations in SC (SCSF) was calculated as the number of response-like fluctuations larger than 0.0043 in units of log micro-Siemens. Only fluctuations that did not coincide with a response to a tone stimulus were counted in Period II. The numerical value was expressed in fluctuations per minute.

Pulse volume (PV). Pulse volume level (PVL) was sampled at 30 sec intervals in Periods I and III (ten samplings each) and immediately before tone stimuli 2 to 11 in Period II. The sampling points coincided with those for SCL. PVL was calculated in each sampling point as the median of three successive pulse volume deflections.

The first response in PV (PRV-1) was the difference between the median of the three smallest deflections during 8 sec before the first tone stimulus and the median of the three smallest deflections during 8 sec after stimulus onset. The difference was expressed in percent of the pre-stimulus level (dimension-less unit). The mean response amplitude in PV (PVR-m) was calculated on the non-zero response to tones 2 to 11. Responses smaller than 0.1 (10 % change in pulse volume deflections relative to the basal level) were disregarded.

The number of spontaneous fluctuations in PV (PVSF) was calculated as the number of response-like fluctuations larger than 0.1. Only fluctuations that did not coincide with a response to a tone stimulus were counted in Period II. The numerical value was expressed in fluctuations per minute.

Heart rate (HR)

Heart rate level (HRL) was calculated in each sampling point as the median of seven successive heart beats, centered around the sampling point, in order to compensate for effects of sinus arrythmia. The sampling points coincided with those for SCL and PVL.

Heart rate responses. Due to the dual nature of HR responses, the criteria for evaluation of these responses in the present study were based on a preliminary evaluation of a subset of recordings. The successive instant heart rate second by second in an interval from 10 sec before to 20 sec after stimulus onset was plotted and averaged over ten randomly chosen subjects and sessions and for tones 2 and 3. Thus the average was based on 20 epochs.

The averaged curve showed a maximum in instant heart rate 2 seconds after stimulus onset and a minimum 9 seconds after stimulus onset. For the present study the HR responses were calculated as an acceleratory and a deceleratory response separately. The acceleratory response was defined as the difference in bpm between the median of the seven beats immediately preceeding the tone and the fastest beat during 4 sec after stimulus onset. The deceleratory response was defined as the difference between the prestimulus median of seven beats and the slowest beat in the time interval 5 to 15 sec after stimulus onset. The peak-trough (p-t) HR response (i.e. the sum of the acceleratory and deceleratory responses) is used throughout in the results section except when there were significant differences between the two components of the heart rate response. The first response in HR (HRR-1) was calculated as described above to the first tone. The mean HR response size (HRR-m) was calculated on the non-zero responses to tones 2 to 11.

The number of spontaneous fluctuations in HR (HRSF) was calculated as the number of 5 sec episodes with a peak difference between successive episodes greater than 6 bpm (Lacey & Lacey, 1958). Only fluctuations that did not coincide with a response to a tone stimulus were counted in Period II. The numerical value was expressed in fluctuations per minute.

Data reduction and statistical methods

The abundance of psychophysiological raw data made necessary a significant data reduction before the final statistical analyses. There was a very high homogeneity of level and spontaneous fluctuation measures within and over the three periods as estimated by "Latent Profile Analysis" (Mårdberg, 1975), a multivariate method which can be used to detect profile differences in a set of measures. Thus, subjects tended to retain their rank, for instance in terms of being low or high in SCL, throughout a session. Level and spontaneous fluctuation measures were therefore averaged over periods to a mean session value. Data concerning four measures (level, first response, mean response size and spontaneous fluctuations) within three physiological systems (SC, PV and HR) and in three separate sessions (an introductory session, a neutral session and a stress-anticipation session) are reported.

A correlational approach was used in most of the statistical analyses. All variables were plotted before calculation of correlations, and inspected for non-linearity and out-liers. Two-tailed tests of significance were used throughout with $p < .10$ being regarded as almost significant and $p < .05$ as significant in planned comparisons.

RESULTS AND COMMENTS

The psychophysiological measures - interrelations and situational effects

Correlations between measures within each physiological system separately. Intercorrelations were calculated between the four measures within each of the three physiological systems and within the three sessions. The highest integration among the four measures (level, first response, mean response size and spontaneous fluctuations) were obtained for the PV measures. Within each physiological system there were significant positive correlations between the first response and mean response size measures. The SC level, response and spontaneous fluctuations measures were all independent whereas there was a significant negative correlation between HRL and the HRR measures. The acceleratory and deceleratory components of the HR response measures showed a significant and positive correlation in Session 1 (.41), no significant correlation in Session 2 (-.04) and a negative correlation in Session 3 (-.45), suggesting that these two response measures are functionally dissociated as concerns effects of situational factors.

Correlations between SC, PV and HR measures within sessions. Intercorrelations between the psychophysiological measures across the physiological systems in the three sessions were computed. The only significant correlations were obtained between PV and HR (level and first response measures) in Session 1. The level of activation in the three physiological systems appeared to be independent in the most stressful condition.

Correlations between measures in the three experimental sessions. Intercorrelations within each psychophysiological measure between the three sessions showed a great variability. Some measures were highly intraindividually stable over time and situation, i.e. subjects retain their relative position within the group over the three sessions. The highest stability was obtained for HRSF ($r = .79$ to $.87$), HRL ($r = .61$ to $.81$) and SCL ($r = .57$ to $.65$). Some measures, most pronounced for SCSF showed high intercorrelations between Session 1 and 2 ($r = .80$) but smaller correlations between Session 1 and 3 (.23) and 2 and 3 (.58) suggesting a high stability in the low-stress conditions, and a differential effect of stress among the subjects in Session 3.

Changes over sessions

Means over sessions of the measures within the three physiological systems are shown in Table 2. Analyses of variance (one-way for repeated measures) were performed for each of the 16 measures. There were significant differences among the sessions for SCR-1 ($F(2.23) = 4.65$, $p < .05$), SCR-m ($F(2.23) = 3.53$, $p < .05$), SCSF ($F(2.23) = 3.87$, $p < .05$), HRL ($F(2.23) = 3.12$, $p < .10$) and HRR-acc-m ($F(2.23) = 4.46$, $p < .05$).

The pattern of change over sessions was different for the various measures, some showing a monotonous and numerically similar decrease over sessions (e.g. SCR-1 and SCR-m) whereas others appeared to be affected only in Session 3 (for instance SCSF). All PV measures showed a similar trend over sessions suggesting a high degree of integration within the physiological system, whereas the different SC and HR measures appeared to be differentially sensitive to the level of anticipatory stress.

Table 2. Means of SC, PV and HR measures in the three sessions (N=24). For units, see Quantification of data. p-values refer to one-way analyses of variance for repeated measures.

	Session			
		2	3	p
SCL	.874	.804	.827	N.S.
SCR-1	.051	.044	.029	< .05
SCR-mean	.024	.018	.015	< .05
SCSF	.98	1.01	1.35	< .05
PVL	114	115	104	N.S.
PVR-1	29.3	20.8	17.5	N.S.
PVR-mean	16.5	15.6	12.0	N.S.
PVSF	.75	.75	.61	N.S.
HRL	78.9	80.1	82.7	< .10
HRR-1 p-t	14.1	12.0	15.0	N.S.
acc	6.9	4.2	6.9	< .05
dec	7.1	7.7	8.1	N.S.
HR-mean p-t	10.3	9.4	12.2	N.S.
acc	4.3	3.2	5.1	< .05
dec	5.9	6.1	7.2	N.S.
HRSF	.95	.99	1.00	N.S.

Correlations between change scores from Session 2 to 3. In order to evaluate the pattern of change in the three physiological systems from Session 2 (neutral condition) to Session 3 (stressful condition), individual change scores were computed as the difference in each measure, expressed in standard scores ($z_i=(X_i-X_m)/SD$) between Session 2 and 3. Intercorrelations were computed among the change scores. A considerably higher number of significant correlations were obtained than would be expected by chance. Most of these significant correlations could be interpreted as reflecting a theoretically meaningful pattern of relations among the variables, related to adrenergically or cholinergically mediated activity.

Change scores within each physiological system (level, amplitude of first response, mean response amplitude and number of spontaneous fluctuations) tended to covary, except for SCL. SCL change scores were not related to any other SC, PV or HR change scores. An increase in SCR covaried with an increase in SCSF (r = .46). The intercorrelations among the PVL, PVR and PVSF change scores were all positive, with four of six coefficients significant (median r = .48). The sign of the intercorrelations among the HR change scores were different for HRL and the other HR measures. An increase in HRL from Session 2 to 3 covaried with a decrease in HRR and was not related to any change in HRSF. A decrease in HRR covaried with a decrease in HRSF, with four of six coefficients significant (median r = .45).

There were some significant correlations between change scores across the physiological systems. An increase in SCR and SCSF covaried with an increase in HRL and a decrease in HRR and HRSF. A decrease in any of the PV measures covaried with an increase in HRL and a decrease in HRR and HRSF. The relations among the change scores suggest that the pattern of activation of those subjects in the present group who reacted to real life stress in Session 3 comprised an increase in SCR and SCSF, a decrease in all PV measures, an increase in HRL, and a decrease in HRR and HRSF.

Correlations between SC, PV and HR measures and urinary adrenaline and noradrenaline. The intercorrelations between the SC, PV and HR measures and urinary excretion of adrenaline (A) and noradrenaline (NA) are shown in Table 3. The most consistent significant correlations were obtained between HRL, HRR-m and the two catecholamines. Subjects with a high HRL and small HRR-m had a high excretion both of A and NA in all three sessions. The significant correlations with the peak-trough HRR was mainly dependent on the deceleratory component of the HRR.

Table 3. Intercorrelations between SC, PV and HR measures and urinary excretion of adrenaline (A) and noradrenaline (NA) in the three sessions (N=24).

		Session 1		Session 2		Session 3	
		A	NA	A	NA	A	NA
SC	SCL	-.22	.00	.12	-.05	-.03	.08
	SCR-1	-.13	-.13	-.09	-.08	.21	.04
	SCR-m	-.09	-.14	-.17	-.23	.23	-.07
	SCSF	-.08	-.04	.17	$-.40^{+}$	.12	.04
PV	PVL	-.36	$-.50^{x}$	-.13	$-.38^{+}$	-.23	-.30
	PVR-1	-.06	-.03	-.13	-.29	-.16	-.35
	PVR-m	.06	-.02	-.06	-.09	-.21	-.34
	PVSF	-.30	-.32	-.07	-.19	-.03	-.35
HR	HRL	$.42^{x}$	$.41^{+}$	$.43^{x}$	$.60^{xx}$	$.49^{x}$	$.46^{x}$
	HRR-1	$-.39^{+}$	$-.48^{x}$	.13	$-.48^{x}$	$-.53^{x}$	-.22
	HRR-m	-.36	-.34	.16	-.31	$-.39^{+}$	-.11
	HRSF	.23	.02	.12	-.07	.23	.05

\+ $p < .10$
x $p < .05$
xx $p < .01$

There was a trend that subjects with a high PVL had higher urinary excretion of NA, most pronounced in Session 1. There were no significant correlations between any of the SC measures and the two catecholamines. The results may be summarized to indicate that a sympathetic activation as manifested by a high level in urinary A and NA is reflected mainly in heart rate and pulse volume (digital blood flow) measures, but not in electrodermal activity. The pattern of correlations between change scores in SC, PV and HR measures and corresponding A and NA change scores were in line with the findings above. An increase in A and NA from Session 2 to 3 covaried with a decrease in PVR and PVSF. However, an increase in A and NA covaried with an increase in HRSF, highly significant for NA (.67, $p < .001$) and significant for A (.46, $p < .05$), which is unexpected since the pattern of activity in HR measures in Session 3 comprised a high HRL, small HRR and few HRSF.

Comments on the characteristics of the psychophysiological measures.
The variance of a psychophysiological measure may, according to an analysis of variance model, be subdivided into various additive parts. One part of the variance is not related to any characteristic of the subject or situation. This part may be described as error variance. A second part is an individual variance part, which can be referred to measurable parameters of an individual, for instance thickness of the palmar epidermis, distribution of sweat glands and habitual cortical arousal level, which are factors relevant for the SC measures. A third part of the variance can be referred to the situation. Finally, some variance can be attributed to interactions between individual and situational factors. Each psychophysiological measure is unique in respect of the patterning of variance components. The specific usefulness of a particular psychophysiological measure must be determined empirically, for instance with reference to the typical patterning of variance components.

In the present study, the PV measures were characterized by large error variance components. There were high intercorrelations among the four PV measures (high integration) but no significant or consistent relations with the personality variables, and a low sensitivity to stress. The use of PV measures in the present type of research appears to be of limited value.

In contrast to the PV measures, both SC and HR measures displayed a certain independence within the physiological system. This is reasonable in respect of HR, which represents an immensely complex homeostatic system, doubly innervated (sympathetic and parasympathetic fibres), sensitive to circulating humoral agents (for instance adrenaline), and dependent on mechanical conditions within the thoracic wall, peripheral resistance against the pumping effect and amount of blood returning from the venous side. The importance of a continuous CNS integration and control of the heart has been emphasized (Folkow & Neil, 1971; Korner, 1971). In such a complex system various aspects of the HR measures may be expected to be independent, i.e. uncorrelated, and functionally different, i.e. show different patterns of correlations with other variables.

Although the basic physiology of the ANS regulation of heart rate is well understood through the use of invasive methods in clinical physiological research, the interpretation of HR measures in differential psychophysiological research is difficult (Hare, Frazelle & Cox, 1978), particularly as concerns the balance between vagal tone and sympathetic drive.

In the present work the HR measures displayed an interesting pattern. The tonic HR level was sensitive to the type of stress used in the present study (situational variance component) but there was also a large individual variance component, i.e. subjects have a "habitual" heart rate which probably to some extent reflects the genetically determined dimensions and design of the circulatory system (cf. Theorell, de Faire, Schalling, Adamson & Askevold, 1979) and the degree of habitual physical activity. The relations between tonic and phasic heart rate measures, the higher the tonic level the smaller the phasic changes, suggest an "inverse law of initial values" in line with previous studies (Graham & Clifton, 1966). The two components of the phasic heart rate response, the acceleratory and the deceleratory component were independent and showed a complex pattern of relations with the other heart rate measures. The acceleratory response displayed the greatest individual variance component and was more sensitive to stress than the deceleratory response. Both measures displayed individual-situation interaction variance components, differentially related to personality variables.

An interesting finding in the present group of subjects was the high stability of the HRSF measure, and the trend towards a higher number of HRSFs in the psychopathic subgroup. The scoring procedure, adopted from Lacey (Lacey & Lacey, 1958), probably constitutes an indirect way to assess sinus arrythmia. Sinus arrythmia is a manifestation of the highly complex regulation of the pumping characteristics of the heart, and probably reflects both peripheral (balance between vagal tone and sympathetic drive) and central integrative mechanisms (Melcher, 1976).

Also within the SC physiological system there was a dissociation among the four measures. SCSF was the most stress-sensitive measure, whereas SCL showed a high stability over sessions (cf. Katkin, 1965; Matthews & Lader, 1971; Kilpatrick, 1972). The high correlation between Session 1 and 2 SCSF measures, and considerably lower intersession correlations involving Session 3, suggest that subjects tend to display a habitual level in this measure in neutral conditions, but that there is a differential individual effect of stress.

Intercorrelations within sessions among measures from the three physiological systems were low and non-significant supporting the view that the arousal concept should not be regarded as unidimensional (Eysenck, 1967; Lacey, 1967). However, for the change scores between sessions, there were a considerably higher number of significant correlations among measures from the three physiological systems. This suggests that an external stressor may induce a higher degree of integration of activation in different parts of the autonomic nervous system than during rest or in neutral conditions (cf. Matthews & Lader, 1971). The association between PV, HR and urinary A and NA excretion change scores may indicate that the variance of PV and HR measures is mainly dependent on adrenergic transmission and reflects changes in autonomic arousal. Another cluster of correlations among change scores was formed by the SC measures. The latter may be assumed to reflect cortical-reticular arousal. The level of activation in these two "compartments" of arousal may covary in some experimental settings, but may be independent or negatively related ("directional fractionation") in other settings.

Correlations between SC, PV, and HR measures and the RAC of the Necker cube

Intercorrelations between SC, PV and HR measures and the RAC of the Necker cube were computed. There were no signficant correlations except for HRR-acc in Session 3 ($r = .58$, $p < .01$). In respect of change scores, subjects with high RAC scores showed a large increase in HRR-acc from Session 2 to 3 (.49, $p < .05$). As reported in Lidberg, Levander, Schalling and Lidberg (1978 a) subjects with high RAC scores showed a small increase in A (-.46, $p < .05$) and NA (-.44, $p < .05$), and a small decrease in SC rec t/2 (-.45, $p < .05$) from Session 2 to 3.

The psychophysiological measures as related to psychopathy

Correlations between SC, PV and HR measures and the personality variables. Intercorrelations were computed between the psychophysiological measures in the three sessions and the personality variables. Most of the coefficients were non-significant, and the number of significant correlations did not exceed the number that would be expected by chance. There was a low consistency of relations between the physiological measures and the personality variables over sessions, i.e. a significant correlation obtained in one session was rarely reproduced in any of the other two sessions. This may either reflect that there were no consistent relations between the physiological measures and the personality variables, or be due to an interaction between the physiological measures and the personality variables. One finding which may reflect such an interaction was an association in Session 3 between HRR and personality variables related to psychopathy, the clinical psychopathy rating, and an association in Session 2 and 3 between HRR and personality variables related to neuroticism. Subjects high in De, those low in Solidity and those high in Extraversion had a large HRR-acc in Session 3 ($r = .40$, $p < .10$, $r = .43$, $p < .05$ and $r = .43$, $p < .05$ respectively). Subjects with high psychopathy ratings had small HRR-dec in Session 3 ($r = .54$, $p < .05$). Subjects low in Validity had large HRR-dec in Session 3 ($r = .51$) and those high in Neuroticism had small HRR-dec in Session 2 ($r = .51$) and large HRR-dec in Session 3 ($r = .59$, $p < .01$).

The effect of the interaction between personality variables and situation on the SC, PV and HR measures was studied by computing correlations between the personality variables and the SC, PV and HR change scores (difference between Session 2 and 3). The number of significant correlations obtained did not differ from that expected by chance. Theoretically meaningful patterns of correlations among change scores were again found only for HRR. There was a consistent trend that subjects with high scores in psychopathy-related personality variables showed a large increase in HRR-acc in Session 3, and that subjects with high scores in neuroticism-related personality variables showed a large increase in HRR-dec in Session 3. The relations was close to significance for De and Solidity, and highly significant for Extraversion ($r = .71$, $p < .001$). This correlation was almost exclusively dependent on the partial correlation with a subscale comprising only impulsivity items (.69). Subjects low in Validity, and those high in Neuroticism showed a greater increase in HRR-dec in Session 3 ($r = .40$, $p < .10$ and $r = .61$, $p < .01$ respectively). In conclusion there were no consistent pattern of relations between the personality variables and the SC, PV and HR measures, except for heart rate response measures.

This pattern of relations emerged only when the peak-trough HRR was separated into acceleratory and deceleratory components and when the situational context was taken into consideration.

Analyses of subgroups. Three personality variables, the De scale, Solidity and Stability, which have in earlier studies shown relations with psychopathy and criminality (Schalling, 1978), were conjointly used for the selection of the two extreme groups. The first group (high in psychopathy, HP) comprised five subjects who scored above the total group mean in the De scale (low socialization), below the mean in Solidity (high impulsiveness) and above the mean in Stability (low empathy). The second group (low in psychopathy, LP) comprised four subjects chosen with reversed criteria, i.e. scores below the mean in the De scale and Stability, and above the mean in Solidity. Two-way analyses of variance for repeated measures were performed for each of the four measures (level, first response, mean response amplitude and number of spontaneous fluctuations) in each of the three physiological systems (SC, PV and HR). Mean values for the two groups in the three sessions are shown in Table 4.

Table 4. Mean values in the psychophysiological measures in the three sessions for subjects high (HP, N=5) and low (LP, N=4) in psychopathy. For units, see Quantification of data.

		Session 1		Session 2		Session 3	
		HP	LP	HP	LP	HP	LP
SCL		.882	1.039	.857	.983	.864	.990
SCR-1		.069	.033	.053	.040	.048	.035
SCR-m		.029	.016	.028	.014	.027	.011
SCSF		.84	.87	.86	1.15	1.41	1.41
PVL		124	101	132	86	102	98
PVR-1		25.9	17.0	34.2	13.9	20.0	13.1
PVR-m		16.2	13.1	22.9	11.9	14.7	10.1
PVSF		.88	1.01	.96	.84	.78	.85
HRL		71.1	82.8	71.6	86.1	70.4	87.0
HRR-1	p-t	17.2	13.4	15.7	9.4	17.9	14.6
	acc	9.2	6.0	5.7	5.0	10.4	7.5
	dec	8.2	7.4	10.0	4.4	7.7	7.1
HRR-m	p-t	11.4	12.2	9.6	10.3	14.1	11.1
	acc	5.7	5.4	4.0	4.8	7.7	5.5
	dec	5.7	6.7	5.6	5.6	6.6	5.5
HRSF		.96	.74	1.19	.93	1.19	.76

There were trends in hypothesized directions for most of the analyses, but no significant F-values. HP had numerically a lower SCL, larger SCR-1 and SCR-m and fewer SCSF in all three sessions. Further, HP had a higher PVL, larger PVR-1 and PVR-m, and more PVSF in all three sessions. In HR, the HP group had a numerically lower HRL, a larger peak-trough HRR-1 and more HRSF in all three sessions, but a larger HRR-m only in Session 3. The trends over sessions for the two separate components of the HR response in the HP and LP groups are shown in Fig. 1. The HP group displayed a more pronounced increase in HRR-acc in Session 3 in comparison with the LP group.

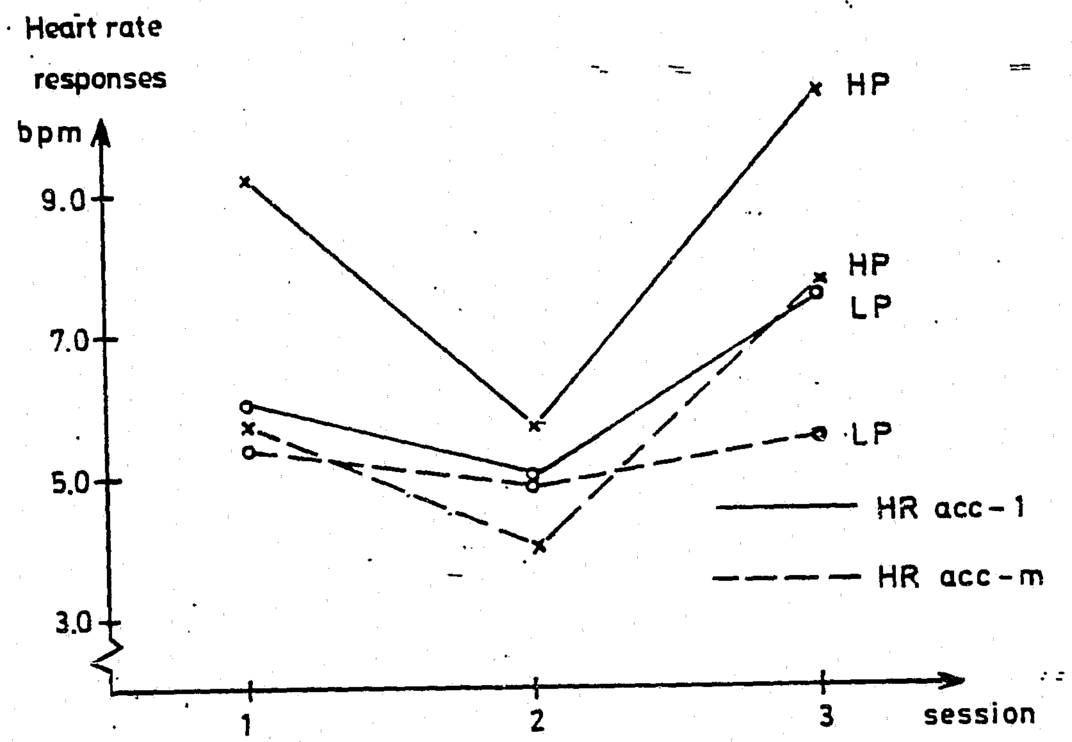

Fig. 1. Heart rate acceleratory responses in two groups of subjects high (HP, N=5) and low (LP, N=4) in psychopathy, in three experimental sessions differing in level of real life stress.

GENERAL DISCUSSION

The most interesting finding in the present study was the relation in the third session between personality measures related to impulsivity and socialization and the HR acceleratory response. During anticipation of trial impulsive and low-socialized subjects displayed large acceleratory HR response to the tone stimuli. It is noteworthy that the significant correlation between Extraversion and an increase in HRR-acc (r = .71) could be ascribed solely to those items in the Extraversion scale which connote impulsivity (r = .69). Further, the positive correlation between an increase in HRR-acc and the RAC of the Necker cube is of great interest since the RAC has been assumed to be related to extraversion and to frontal lobe lesions. Further, a high RAC was related to a long SC recovery time (rec t/2) and to a particular pattern of urinary A and NA excretion suggestive of low involvement (Lidberg, Levander, Schalling & Lidberg, 1978 b). There was however no significant correlation between HRR-acc and SC rec t/2.

There were trends in the expected directions on the group level as concerns the effect of the real life stress of an impending trial on most of the psychophysiological measures, although few significant differences among the sessions were obtained. In the most stressful condition there was a pattern of autonomic activity comprising larger skin conductance (SC) responses and more SC spontaneous fluctuations, lower numerical values in all the pulse volume (PV) measures, a higher heart rate (HR), smaller HR responses and fewer HR spontaneous fluctuations.

There were no consistent significant interaction effects on the psychophysiological measures between the personality variables and the level of anticipatory stress in the three sessions, except in respect of the HR responses. There were however trends towards a lower level of activity in all three physiological systems in the three sessions for the high-in-psychopathy (HP) subgroup. The LP subgroup in contrast showed a pattern of autonomic activity in the three sessions similar to the one observed in the third (stressful) session for the total group, i.e. high SCL, many SCSF, low numerical values in all PV measures, a high heart rate, small HR responses and few HRSF. Thus also for the personality relations the trends were in the predicted directions but few were significant.

Theoretical interpretations

The main finding in the present study was that subjects who were high in impulsivity and low in socialization scales i.e. more psychopathic, showed large accelerative HR responses during anticipatory stress. In interpreting this finding, the results as concerns SC recovery time, Necker cube figure reversals and urinary excretion of A and NA should be taken into consideration.

The present state of knowledge as concerns the psychophysiological interpretation of phasic changes in heart rate has been summarized by Hare (1978 a) as follows: "The anticipatory HR acceleration is, presumably, part of an adaptive process, which helps the individual to cope with, "tune-out" or otherwise reduce the impact of premonitory cues, and the impending aversive stimulus". This interpretation summarizes a set of empirical observations obtained in different theoreticaal models and experimental paradigms: the orienting (OR) vs defensive (DR) reflex model of preattentive filtering mechanisms (Sokolov, 1963), Lacey's baroceptor feed-back theory (Lacey, 1967), and the "directional fractionation" of SC and HR measures observed during count-down procedures in quasi-conditioning paradigms (Hare, Frazelle & Cox, 1978). Common to all these theories and observations is that a phasic increase in heart rate is concurrent with an attenuation of sensory input. Although there are certain conceptual difficulties in reconciling and integrating the different theories, there is a note-worthy consistency of results over a large body of empirical findings. The theories range from assumptions that the phasic heart rate increase reflects a process with a duration of a few seconds, is linked to specific warning signals, and has effects on the attenuation of specific noxious unconditioned stimuli, to assumptions that gross situational conditions may affect stimulus handling towards "intake" or "rejection" (the baroceptor theory). In line with the latter assumption it has recently been shown that ORs to innocuous tones (85 dB) can be modulated towards DRs by varying the level of background noise (Lobstein, Webb & Cort, 1978). In anticipation of an aversive situation, heart rate acceleration to any stimuli (whether noxious or neutral) may reflect and/or facilitate a generalized preference for attenuation of sensory input. Thus, theories of relations between specific aspects of stimuli, handling of sensory input, and acceleratory HR responses may represent subsets of a major characteristic of human information processing and coping with impending stressors. In noxious situations, heart rate acceleration may thus accompany and/or facilitate attenuation of sensory input.

In line with such an interpretation the psychopathic subjects in the present study appear to have been particularly prone to resort to such a coping strategy implying an increased preparedness to ignore environmental cues. This interpretation is consonant with the results as concerns SC recovery time, and with the data on urinary excretion of A and NA. It should further be noted that subjects high in neuroticism showed a reversed pattern during anticipatory stress, displaying an increase of the deceleratory component of HR responses during anticipation of trial. Our findings have interesting parallells in studies by Valins (1967) and Lykken, McIndoe and Tellegen (1972). Valins found that high anxiety subjects consistently showed HR deceleration to stimuli over a wide range of intensities, whereas low anxiety subjects showed deceleration before weak stimuli (i.e. an OR), but accelerated increasingly in anticipation of increasingly strong and painful stimuli (i.e. the OR was exchanged for a DR). In the study by Lykken and coworkers, less anxious subjects showed a greater anticipatory HR acceleration, and more anxious subjects a greater and more sustained postshock HR acceleration.

On the basis of the results in the present group of subjects we suggest that psychopaths have a tendency to resort to "tuning-out" of stimulus input in a wider range of stimuli and situations than normals. This coping style, a kind of ostrich method, may help an individual to avoid seeing and realizing unpleasant things, which in turn protects him from much worrying and anxiety. However, it also deprives him of the possibility to prepare for active and successful coping with those noxious situations which are preceded by warning signals.

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