Psychophysiology
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Vol. 12, No. 4
Printed in U.S.A.

Habituation and the Structure of the Electrodermal System

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ABSTRACT

The intercorrelations among fifteen common SRR variables were investigated on two samples of male subjects in a standard habituation paradigm. The first group (N = 212) was made up of 149 prisoners and 63 controls (mean age = 28 yrs) while the second group (N = 84) were all twins (mean age = 25 yrs). All subjects received 21 auditory stimuli at an ISI of 33 sec. Each stimulus was sinusoidal, at 1000 Hz, of 1 sec duration and at 95 dB (re 20 N/cm^2). The fifteen SRR measures taken from each subject included mean and change scores for basal conductance, response amplitude, spontaneous fluctuation frequency, number of responses, and onset, peak and half-recovery latencies. The variables were intercorrelated and factor analyzed. The .05 rejection region was adopted in all statistical tests. A fairly simple structure for the variables was demonstrated. The results emphasized the importance of a large general reactivity component in most of these variables. Within-subject correlations were calculated and found to be different from across-subject correlations. It is suggested that under constant stimulus conditions subjects display different but individually typical SCR shapes which reduce in size during habituation.

DESCRIPTORS: SRR variables, Interrelationships, Habituation.

Given that we can measure different characteristics of electrodermal activity—amplitude, frequency of responding, latency, recovery, tonic levels, and spontaneous activity—a number of methodological and conceptual problems arise in studies which set out to measure habituation and conditioning. Which of all the measures is the 'best' for our purpose? How do the measures relate to one another? What are appropriate measures of change? And if we can estimate change which is attributable to learning can such an estimate be differentiated from the ongoing activity of the electrodermal system?

Numerous studies have confirmed the statistically significant relationships which occur between electrodermal measures, estimates of conditioning, and habituation. Typically, counts of spontaneous fluctuations (SFs) correlate with frequency of responding (Bohlin, 1972; Bull & Gale 1971; Cadoret, 1963; Coles, 1970; Corah & Stern, 1963; Crider & Lunn 1971; Johnson, 1963; Lader, 1964; Martin, 1960; Mundy-Castle & McKiever, 1953; Purohit, 1966; Stern, Winokur, Stewart, & Leonard, 1963). There is also substantial support for a relationship between SFs and resistance or conductance levels (Lader, 1964; Martin, 1960; Mundy-Castle & McKiever, 1953; Rust, 1974; Sternbach, 1960), and between SFs and amplitude or magnitude of stimulus-linked responses (Bull & Gale, 1971; Johnson, 1963; Katkin & McCubbin, 1969; Öhman & Bohlin, 1973; Rust, 1974), although there are some reports of nonsignificant findings (Koepke & Pribram, 1966; Wilson & Dykman, 1960). Correlations between response magnitude and other electrodermal variables differ according to whether resistance or conductance units are used (Bull & Gale, 1971).

In the case of response onset latency, Koepke and Pribram (1966) and Bull and Gale (1973) found a negative correlation between spontaneous activity and onset latencies of responses to stimuli. Bull and Gale (1971, 1973), Uno and Grings (1964), and Witting and Wickens (1966) found an inverse relationship between response onset latency and response amplitude. Relationships between amplitude and recruitment have been reviewed by Bull and Gale (1971, 1973) and between recovery and

Support for this research was provided by the Medical Research Council and Home Office (U.K.) to John Rust.

We are indebted to Les Law for his contribution in programming the Linc-8 and for his work in analyzing the latency/amplitude relationships as described in this paper.

The assistance of Judith Kasriel in compiling the twin register and arranging appointments for the twin subjects is gratefully acknowledged, as is the computer assistance of Nona Hemsley.

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amplitude by Edelberg (1972), Lockhart (1972), and Venables (1974).

Most of the reported relationships have been obtained across individuals. Within-individual correlations are less frequently calculated, although these are potentially useful sources of information concerning underlying physiological mechanisms of electrodermal activity and the understanding of relationships between measures (cf. Block & Bridger, 1962; Bull & Gale 1971; Edelberg, 1972).

The present study used computer-assisted scoring methods to investigate the relationship among a number of electrodermal variables both across and within subjects during a series of habituation tones.

Methods of scoring were examined in some detail. The detection of SCRs and SFs has presented few problems in the past, but it is comparatively recently that measurement of other response characteristics has been made, and there has been little discussion (with the exception of recovery measures, Edelberg, 1972) of the difficulties they give rise to.

Another methodological problem arises in that no standard procedure exists for measuring the response decrement or increment encountered in habituation and conditioning studies. In the present study estimates of change over trials were calculated for each response variable as linear regression coefficients. These change (habituation) measures were then factor analyzed together with mean reactivity measures in an attempt to summarize the correlations obtained and to define their factorial structure. Only a few studies have been carried out on this problem of whether measures of learning can be distinguished from measures of performance, i.e. general reactivity. One previous attempt (Prescott, Note 1) obtained results indicating a complex factorial structure. A variety of independent factors were demonstrated (e.g. latency, amplitude, tonic resistance level) and conventional measures of conditioning failed to yield a specific variance that could be attributed to learning.

Method

Subjects

Identical analyses were carried out on two separate and independent samples. The first was a sample of N=212, all male, comprising 149 prisoners from a London prison and a miscellaneous group of 63 control subjects (policemen, firemen, postmen, male nurses, etc.). The mean age of this group was 28 yrs (SD=4.9 yrs). No important differences were observed between the prison and control samples in any of the variables discussed here (see Eysenck, Rust, & Eysenck, 1976) and data were therefore pooled. The second sample, N=84, again all male, comprised 40 pairs of twins, 20 pairs monozygotic, 20 pairs dizygotic, and 4 odd twins. These subjects were drawn from a twin register compiled at the Institute of Psychiatry. Mean age was 24.18 yrs, SD 6 yrs (range 17-44 yrs).

Procedure

All subjects received 21 auditory stimuli generated by an audio oscillator and delivered binaurally via headphones. Each stimulus was of 1-sec duration, sinusoidal, at 95 dB (re 20 N/CM^2) and at a frequency of 1000 Hz. Interstimulus interval was constant at 33 sec. Skin resistance was measured by an apparatus delivering a direct current of 10 μA which was built in the Department and is described elsewhere (Venables & Martin, 1967, Model B1). Electrodes were Ag/AgCl and of area 64.19 mm^2. Electrode placement was bipolar, from the first to the second fingertips of the left hand. Adhesive discs (Devices Ltd.) were used to allow a contact area of 79 mm^2 between skin and the electrode gell (Johnson & Johnson lubricating jelly). Skin resistance was recorded on a Mingograf EEG polygraph (Elema-Schonander, Sweden) and on magnetic tape for subsequent computer analysis.

The first stage of data reduction was carried out on a Linc-8 computer. An automatic scoring program processed the data (Martin, Levey, & Slubicka, 1975) which were then output from the Linc onto paper tape. Resistance scores were transformed to square root conductance because this was found to minimize the correlation of score variances with trial number. This is a necessary precondition for the calculation of regression coefficients by the method of least squares. In order to explore a wide range of response variables, a different but overlapping set was generated for the two samples. They were as follows:

1. Prison/Control Subjects (N=212)

(i) square root basal conductance (SCL)

(ii) response onset latency (OL) (responses occurring within 1 to 5 sec of stimulus onset timed from onset of stimulus)

(iii) response peak latency (PL), timed from onset of stimulus.

(iv) response half recovery (½ Rec). This was measured as the latency at which the skin resistance had returned to one half the distance between response onset and response peak timed from onset of stimulus. If a new onset occurred before this point or if no recovery marker existed, a value of zero was recorded which was taken in subsequent programs as representing missing data.

(v) rate of spontaneous responding (SFs). This is estimated from the number of response markers which occur per trial and are not part of the response to the stimulus. For each trial this is a sample taken over a 20-sec period, comprising the 15 sec between 5 and 20 sec after stimulus onset and the 5 sec before it. The measure is output at this stage as the number of such markers which occur.

(vi) square root response amplitude (SCR Amp). This was calculated from the difference in μmho units between the amplitude of the peak and the amplitude of the onset of the stimulus-tied response. Where no response occurs, the value is set to zero. The amplitude measure excludes zero responses.

(vii) square root response magnitude (SCR Mag). Calculated as for (vi) but including zero responses.

2. Twin Subjects (N=84) Variables generated were identical to those given above, with the following exceptions.

(iii) the PL measure was replaced by a measure of rise time, i.e. PL-OL.

(iv) response half recovery timed from the onset of stimulus (½ Rec) was replaced by another recovery measure, i.e. the time between response peak (PL) and the point of 50% amplitude recovery.

In addition, the amplitude of the SCR to Trial 1 was generated as a separate variable.

The data were then further analyzed on the University of Lon-

don CDC computer. All the variables were transformed from trial by trial data to mean values and linear trends over trials. This was done with a modified version of a program for calculating means and polynomial trends (Rust, 1974). This program can take zero values either as scores of zero or as missing data so that, for example, both SCR amplitude (without zero responses) and SCR magnitude (with zero responses) were calculated. Since the amount of missing data varies from subject to subject and since the orthogonal polynomial coefficients are not independent of the number of observations, these scores were then transformed back into the usual geometric trends over trials.

Thus, all change scores are the slopes of the least squares fitted linear component with allowance for missing responses when appropriate. For SCL, spontaneous fluctuations, SCR amplitude, and SCR magnitude a negative score indicates decreasing responsivity, the lower the score the steeper the decrement.

Results

The data obtained from the two samples are in close agreement. Means and SDs of the electrodermal data for both samples are given in Tables 1 and 2. As can be seen, the electrodermal variables behave as expected during habituation. SCL, spontaneous activity, SCR amplitude, and SCR magnitude decrease during the session, while onset latency times increase and rise times decrease. It will be noticed that response half-recovery from the twin sample shows a significant decrease over trials, while in the other sample there is a slight increase. This difference presumably reflects the different recovery measurements of the two studies. The half-recovery measure in the prison sample includes onset latency. Because this tends to show an increase over trials, it will cancel out the effect of the half-recovery trend as measured from response peak.

TABLE 1

Summary statistics of electrodermal data over 21 habituation trials (N=212)

Variables	Means (SDs)	Direction of Change of Linear slope
1. Mean SCL (sq. root conductance)	3.301(1.08)	—
2. SCL Slope	−0.552(0.02)	Decrease*
3. Number of SCRs to Tones	14.377(5.44)	—
4. Mean Onset Latency (OL) (Sec)	2.054(0.54)	—
5. Slope of OL	0.013(0.16)	Increase
6. Mean Peak Latency (PL) (sec) (timed from stimulus onset)	4.432(1.32)	—
7. Peak Latency Slope	0.001(0.46)	No change
8. Mean ½ Recovery (sec) (timed from stimulus onset)	7.199(2.82)	—
9. ½ Recovery Slope	0.017(0.32)	Increase
10. Number of SFs	0.926(0.70)	—
11. Slope of SFs	−0.021(0.05)	Decrease*
12. Mean SCR Amplitude	0.711(0.38)	—
13. Slope of SCR Amp	−0.039(0.07)	Decrease*
14. Mean SCR Magnitude	0.514(0.39)	—
15. Slope of SCR Mag	−0.030(0.03)	Decrease*

*$p < .05$

TABLE 2

Summary statistics of electrodermal data over 21 habituation trials (N=84, twin data)

Variables	Means (SDs)	Direction of Change of Linear slope
1. Mean SCL (sq. root conductance)	4.052 (1.312)	—
2. SCL Slope	−.0015(0.0215)	Decrease
3. Number of SCRs to Tones	17.893 (3.519)	—
4. Mean Onset Latency (OL) (sec)	1.874 (0.387)	—
5. Slope of OL	0.015 (0.0276)	Increase*
6. Mean Rise Time (sec)	1.967 (0.547)	—
7. Slope of Rise Time	−0.023 (0.033)	Decrease*
8. Mean ½ Recovery (sec)	4.595 (1.426)	—
9. Slope of ½ Recovery	−0.125 (0.157)	Decrease*
10. Number of SFs	1.153 (0.699)	—
11. Slope of SFs	−0.016 (0.037)	Decrease*
12. Mean SCR Amp	0.8130(0.409)	—
13. Slope of SCR Amp	−.0344 (0.026)	Decrease*
14. SCR Amp (Trial 1)	1.650 (0.709)	—
15. Mean SCR Mag	0.724 (0.437)	—
16. Slope of SCR Mag.	−0.035 (0.022)	Decrease*

*$p < .05$.

The intercorrelations between all the variables were calculated. Again, there was close agreement between the two samples; the matrix obtained on the twin sample is given in Table 3. SCR amplitude and magnitude slopes correlate highly with one another and with SCL change, and to a lesser extent with onset latency, rise time, and recovery slopes. Mean SCL, mean SCR amplitude and magnitude, and SCR Amp Trial 1 are highly correlated with one another as are number of responses to the stimuli and spontaneous activity. Mean SCR amplitude correlates negatively with half-recovery time, onset latency and rise-time, and positively with spontaneous activity. Thus high amplitude responses are associated with high SCL, short onset and recovery latencies, fast rise times, and more spontaneous activity.

A useful way of summarizing results from a large number of correlations is through factor analysis.

TABLE 3

Correlations (twin data (N = 84)

Variables	Correlations														
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1 Mean SCL	-														
2 SCL Slope	237	-													
3 No. SCRs	180	250													
4 Mean OL	175	015	429	--											
5 OL Slope	052	- 205	047	192											
6 Mean Rise Time	- 304	008	- 300	.597	325	-									
7 Rise Time Slope	219	259	206	009	059	- 307	--								
8 Mean ½ Rec	- 268	- 174	- 390	735	- 313	796	- 160	-							
9 ½ Rec Slope	127	110	416	- 085	098	138	.531	- 136	--						
10 SFs	.271	454	531	- 520	.116	- 413	178	- 617	133	--					
11 SFs Slope	.101	325	- 011	249	- 219	178	- 059	205	- 115	042	—				
12 Mean SCR Amp	- .619	215	464	- 547	.086	- 390	087	- 429	062	461	- 060	--			
13 SCR Amp Slope	052	543	330	169	- 235	072	273	- 049	348	418	108	- 046	--		
14 SCR Amp Trial 1	.541	- 043	349	- 470	058	- 308	031	- 238	027	222	- 062	817	- 303	--	
15 Mean SCR Mag	542	245	639	- 572	071	384	093	- 440	127	523	055	971	052	788	
16 SCR Mag Slope	- 117	451	129	184	301	185	201	028	188	315	014	- 196	862	- 417	110

*A correlation of ± .215 is sufficient to reject the null hypothesis at $p < .05$

However, much more caution has to be exercised in the interpretation of this latter type of analysis, since the form it takes depends to a large extent on the number and type of variables which are included. For both samples a factor analysis was carried out on the variables as listed in Tables 1 and 2. Preliminary analyses revealed that the measures of peak latency (PL) and rise time were highly correlated; as were the two measures of recovery. SCR Amp Trial 1 was excluded since it already correlated highly with other variables in the analysis and might therefore lead to their overemphasis in the factor structure. An oblique promax solution to the factor analysis was sought on those components which had eigenvalues greater than one. This produced five factors which between them accounted for 78% of the variance. An oblique rather than an orthogonal solution was found because it was felt that the latter would have imposed an artificial structure on the data. The factor loadings obtained for the larger sample appear in Table 4.

It can be seen that the five factors are easily identified as:

I) Mean SCL and SCR amplitude.
II) Slopes of SCL, SCR amplitude and SCR magnitude; and spontaneous activity.
III) Slopes of onset and peak latency.
IV) Mean onset latency, peak latency, half-recovery time, and spontaneous activity.
V) Slope of recovery and slope of spontaneous activity.

We thus have two mean factors (1 and 4) and three change factors (2, 3 and 5). The two mean factors have an intercorrelation of - .47. Factor 2 correlates at .19 with factor 4, while factor 4 correlates with factor 5 at .13. All other factor correlations are less than .1. These results emphasize the importance of general reactivity underlying the measurement of SCR variables.

One striking factor in these results is the common effect of the three latency variables. These between subjects relationships contrast strongly with the relationships within subjects for the same variables (discussed below). In view of this a further factor analysis was performed on the twin sample, but with rise time and recovery measurement from response peak as described earlier substituted for peak and recovery latency respectively, since the former variables would clearly have more independence from onset latency. This substitution made very

TABLE 4

Factor analysis of electrodermal data on prison and control subjects (N = 212)
First order promax solution with oblique rotation

Variables	Factor Loadings				
	1.	2.	3.	4.	5.
Mean SCL	.81	- .08	- .01	06	.03
SCL Slope	.42	- 75	- .04	.37	09
No. SCRs to Tones	.36	- 53	- .03	- 22	- .05
Mean OL	- .15	- .01	.11	.79	.05
OL Slope	00	.06	- 91	- .01	.00
Mean PL	.01	- .02	- .05	.96	- .05
PL Slope	- .05	.00	- 90	- .03	.05
Mean ½ Recovery	05	02	.15	.91	.07
½ Recovery Slope	01	- .08	- .05	.12	- 95
SFs	.10	- 47	- .08	46	09
SFs Slope	- 22	13	- 01	25	.34
Mean SCR Amp	92	16	.03	06	- .04
SCR Amp Slope	- 23	- .75	.11	17	.11
Mean SCR Mag	86	- 11	03	- 12	- 03
SCR Mag Slope	.58	- .70	02	.01	04

little difference to the temporal factor (factor 3), the loadings now being .47, .87 and .87 for mean onset latency, rise time and recovery respectively (see Table 5). It thus seems clear that as far as differences between subjects are concerned, the temporal measures are all measuring more or less the same thing. One change in the new factor analysis is that slope of rise time now loads on the same factor as recovery slope, whereas peak latency slope in the previous analysis was more closely related to slope of onset latency.

The correlation of mean SCR magnitude with SCR magnitude change is −.11 and that of mean SCR amplitude with SCR amplitude change −.05. This is in close agreement with Koriat, Averill, and Malmstrom (1973) who also found a large degree of independence from amplitude when habituation was measured in this way. Also in close agreement with the findings of Koriat et al. Trial 1 amplitude correlates significantly with amplitude slope (−.303) and with magnitude slope (−.416).

The relationships among electrodermal variables suggest that rate of habituation might be predicted by levels of electrodermal activity. This was examined by means of regression analysis, using SCR magnitude slope as the dependent variable and seven independent variables: SCR frequency, and mean SCL, SCR magnitude, SFs, OL, PL, and half-recovery. All these variables showed a significant correlation with magnitude change.

It was found that 29% of the variance could be accounted for by these other variables. A step-wise regression was carried out to analyze the contribution of each independent variable. This showed that the contribution of SCR frequency and the three time measures gave no additional predictive value to that provided by SCL, which was 6.08%. However, both SFs and mean SCR magnitude independently contributed further significant amounts of variance (9.24 and 11.88 respectively). This analysis shows that while change in response magnitude may be a good measure of habituation, it is still not independent of SCL, SFs, and mean SCR magnitude.

TABLE 5

Factor analysis of electrodermal data on twin subjects (N = 84) First order promax solution with oblique rotation

Variables	Factor Loadings 1.	2.	3.	4.	5.
Mean SCL	.49	−.26	−.06	.27	−.51
SCL Slope	.09	.62	−.03	−.01	−.53
No. SCRs to Tones	.70	.28	.08	12	.25
Mean OL	−.49	.05	.47	.15	−.29
OL Slope	−.32	−.26	−.75	−.03	04
Mean Rise Time	.02	.12	.87	−.17	−.01
Rise Time Slope	−.17	.07	−.19	.86	−.09
Mean ½ Recovery	−.06	−.13	.87	−.01	−.05
½ Recovery Slope	.12	.11	.11	.81	.29
SFs	29	.54	−.45	−.14	−.11
SFs Slope	−.07	.13	.13	−.17	.76
Mean SCR Amp	1.00	−.20	07	−.05	−.12
SCR Amp Slope	−.06	.89	.10	15	−.06
Mean SCR Mag	1.06	−.08	12	−.06	.03
SCR Mag Slope	20	93	12	02	04

Within-Subject Correlations

Within subject correlations were also calculated for the 84 twin subjects. Measures included were SCL, SCR Amp, OL, SFs, the measures of PL and rise time, and both measures of ½ recovery (½ Rec_1 timed from stimulus onset, ½ Rec_2 from PL as described earlier). The correlation matrices for the 84 subjects were pooled by finding the average of the z-transformations of the correlation coefficients. Chi-square tests were also carried out for each set of correlations to test the hypothesis that they were all estimating the same population parameter. Only four of these Chi-square statistics failed to reach significance, these being for the correlations of SFs with OL, PL, Rise Time and SCR Amp. All other Chi-squares were significant.

The results of these within-subject correlations are given in Table 6. The negative correlation of SCR Amp with OL is in the same direction as the across-subject correlation. Similarly, the ½ Rec_2/Rise Time correlation is high and positive, in keeping with the across-subject result. A number of very marked differences occur, however, and these are summarized in Table 7. The SCR Amp/½ Rec correlation which is significantly negative across subjects becomes positive within subjects; and this reversal of direction occurs in OL/½ Rec_2, OL/Rise Time, and SCR Amp/Rise Time correlations. These findings suggest that under the present stimulus conditions subjects display different but individually typical SCR 'shapes': within a subject, overall response shape presumably remains relatively constant while response size diminishes as a function of repeated occurrence over trials.

The correlation between amplitude and ½ recovery was further examined for individual trials during the habituation series. It was found to be nonsignificant ($r = -.026$ for Trial 1 and $r = -.135$ for Trial 10). This result is consistent with the comparable result of −.03 reported by Lockhart (1972) and illustrates the relative contribution of variation within subjects in correlations of this type.

Amplitude/Latency Relationships

There is a particular interest in the relationship between response amplitude and its associated on-

TABLE 6

Pooled within subject correlations on the 84 twins

	Correlations						
Variables	SCL	OL	PL	½ Rec_1	SFs	SCR Amp	Rise Time
OL	.024						
PL	−.198	.508					
½ Rec_1	−.174	.093	.720				
SFs	.149	−.153	−.146	−.207			
SCR Amp	.081	−.370	.324	.410	.016		
Rise Time	−.231	−.403	.705	649	−.072	.620	
½ Rec_2	−.231	.288	.403	.959	−.207	.493	.611

TABLE 7

Differences in across-subject and within-subject correlations

	Correlations	
Variables	Across-Subjects	Within-Subjects
SCR Amp/½ Rec_2	−.429	.493
OL/½ Rec_2	.734	.288
OL/Rise Time	.596	.403
SCR Amp/Rise Time	−.390	.620

set latency because of a possible connection with the scoring method used on the Linc-8 computer. As outlined previously (Martin et al., 1975) scoring is based on the rate of change of amplitude with time, which must exceed a criterion value for an onset to be defined. For responses of the same shape but varying apparent amplitude the criterion will be exceeded later for the smaller responses. Note that it is the apparent amplitude which is involved, that is, the response amplitude measured in mm of deflection on a chart record or the equivalent analog measurement stored in the computer, rather than the true response amplitude measured, say, in kilohms.

The effect of the scoring method on the connection between response amplitude and latency was examined on a subset of 24 subjects, the records of whom were scored by hand and by the Linc-8 program; in addition, a test program was written which used a typical response selected from the real data and artificially adjusted the scaling to produce variations in amplitude of the response linearly graded in 50 steps ranging from near zero to maximum. This too was scored both by hand and by computer. The following preliminary results may be noted. The effect of apparent amplitude on onset determination appears to be present in hand scored data as well as computer scored data, with the hand scored data showing greater variance and longer mean latencies compared with computer scoring. The effect of response amplitude appears to be greatest at the extremes of the range, that is for responses of nearly full scale deflection (80% F.S.D.) or else barely perceptible (20% F.S.D.), both for hand and computer scoring. Computer scoring was shown to have greater test retest reliability.

The determination of the peak and recovery points of a response is not affected by the scaling of rate of change of amplitude in the computer scoring method and measures based on them will, therefore, not have any artifactual correlation with response amplitude.

Discussion

Evidence for a fairly simple basic structure was found for individual differences within the electrodermal system. This consisted of a general between subjects factor of SCL and SCR amplitude (Factor 1) and mean onset, peak latency, (rise time) half recovery and spontaneous activity (Factor 4 prison data, Factor 3 twin data). These two factors are themselves correlated, suggesting a cluster of high SCL, SCR amplitude, frequent spontaneous activity, and short onset and peak latency. The findings emphasize the importance of general reactivity as a common element in SCR variables. This is particularly clear for the mean scores.

Slopes of SCL, SCR amplitude, and SCR magnitude load on Factor 2 in both samples, and together with the fact that these slopes show significant decrement over time, may be taken to constitute the best indicators of habituation. Edelberg's claim that response recovery is independent of other response components received some support inasmuch as the slope measure loads on a separate factor (prison data) and only with slope of rise time (twin data)

From this summary of the data, there is no completely independent measure of change which could be attributed to learning as distinct from reactivity. It follows that in interpreting results on particular electrodermal variables such as SCR amplitude habituation we should take into account the differences

in general reactivity between subjects. This is particularly true for the influence of SFs on habituation. It can be argued that the differences in spontaneous activity between subjects are dependent on the stimulus situation and are, therefore, secondary to any habituation effect. Öhman and Bohlin (1973), for example, regard the relationship between SFs and response magnitude as centrally mediated by orienting reactivity. It can also be argued, however, that frequency of SFs is a fairly reliable characteristic of subjects' electrodermal activity even over longish periods of time (Bohlin, 1972) and between both rest and stimulation periods (Lader, 1964). Also, in the present experiment, it is mean number of SFs which is correlated with the SCR amplitude slope. The two processes of change, SF slope and SCR amplitude slope, are independent.

In view of recent interest in the measurement of different response characteristics of the electrodermal system, methods of scoring were examined in some detail. In general, the measurement of onset latency seems to be somewhat influenced by variations in amplitude both in Linc and in hand scoring, in the direction of a negative correlation which is most marked at extremes of amplitude. Even allowing for this tendency, however, there still remains a significant negative relationship between the two variables. Other measures, e.g. peak latency and half recovery times, are not affected by these scoring problems. Computer scoring is shown to have greater test retest reliability and is objective and mathematically defined, although the programs allow for manual intervention if required.

One rather striking aspect of the present studies is the large discrepancy in the behavior of the recovery measures in the between and within subject correlations. Between subjects, half-recovery behaves in a similar manner to the other latency measures. However, within subjects a completely different pattern emerges. For the relationship with onset latency a between subject correlation of .734 changes to a within subject correlation of −.288. For amplitude, the correlation with recovery is −.429 between subjects, but .493 within subjects. These within-subject correlations make sense inasmuch as subjects' amplitude measures change from very large to zero over the habituation series, and the relationships are those we would expect if responses got smaller but retained the same overall shape.

The differences in the between and within subject correlations for the recovery variables suggest that different theoretical explanations are needed for the two situations, and mean that more caution than is usual should be exercised in making theoretical use of data from within subject experiments to account for individual differences. For example, Edelberg (1970), Furedy (1972), and Lockhart (1972) relate recovery to the signal value of the stimulus in a within-subject design, whereas Venables' (1974) review of 'high risk' research illustrates a number of studies which use the SCR recovery measure in across-subject designs.

Across subjects, individual patterns of responses are such that high SCL, high amplitude, frequent SFs, and many SCRs are associated with short recovery times. Rise time and recovery are significantly and positively correlated both across and within subjects, and confirm Lockhart's (1972) findings. A number of factors determining the shape of the recovery limb have been proposed by Edelberg (1972, 1973) and discussed by Venables (1974), and the likelihood that some individual patterns of psychophysiological responsivity are genetically determined has been suggested by Rust (Note 2) whose data show a strong genetic influence for electrodermal levels, SCR amplitude, and SF frequency.

The finding that the within subject correlations on many variables differ from the between-subjects correlations is of considerable significance for attempts to eliminate relationships by transformation. It means that there would be no common transformation which could be applied to the data as a whole which would eliminate dependencies for all subjects. Any transformation may well reduce the dependency for some subjects, but only at the expense of increasing it for others.

Edelberg (1970) has argued that amplitude is not an important determinant of recovery rate within subjects; however, the correlations he quotes as evidence are not inconsistent with those of the present study. On this larger sample the relationship is significantly positive. Edelberg has also argued that the recovery of the skin conductance response is exponential. It is, in fact, a mathematical property of an exponential decay curve that it is independent of amplitude, so that our finding that the relationship between amplitude and recovery is significant is evidence that, on average, the decay is not in fact exponential. Of course, on any individual subject we could cause the decay to be exponential simply by transforming the amplitude scale, which would also affect the correlation. However, the present study shows that the size of the correlation, and therefore the degree of exponentiality, differs between subjects, so that there will be no *single* transformation which will cause the decay to be exponential for all subjects. Also, in the situation where the between subject correlation is significant and in the opposite direction to the average within subject correlation (as with recovery and amplitude), any attempt to minimize one of the correlations by transformation would inevitably lead to an increase in the other.

Lockhart (1972) found no correlation between amplitude and recovery between subjects in stimulus conditions comparable to the present. However, he measured the recovery for each subject from only one response. Any across subject analysis inevitably includes variation within subjects, but the relative size of this latter component is a function of the number of samples from each subject, and is maximal with one such sample. It thus seems likely that in Lockhart's single sample study a negative across subject effect may have been cancelled out by a positive within subject effect producing in his analysis a net correlation of zero. This interpretation is supported by a similar analysis in the present study where the across subject correlation between amplitude and half-recovery was calculated again, but using only one sample from each subject. This produced a correlation of −.026 for Trial 1, and of −.135 for Trial 10.

An important methodological problem relates to the way in which the various SCL and SCR measures are assessed as a function of time and/or trials. Koriat et al. (1973) compared the relationship between different measures of habituation (change scores, trials to criterion, regression estimates, and various combinations of these) and demonstrate that some measures are extremely highly correlated while others show only a moderate or poor relationship. They also point out that although some estimates of change have a certain face validity as measures of habituation, they may be empirically and statistically roughly equivalent to mean reactivity over trials. In the present data, SCR amplitude slope is uncorrelated with mean SCR amplitude but is highly correlated with SCR amplitude on Trial 1.

The course of habituation typically shows a quick initial decrement to zero which is often accomplished within very few (up to 6) trials. Following this, responding tends to re-occur in an irregular pattern. The temporal measures show greater consistency over trials, onset latency in particular varying within narrow limits. Our evidence suggests that response amplitude decrement, together with decrement of SCL, SFs, half-recovery and rise time, are the most marked changes which occur during habituation. These decrements tend to be significantly related to one another, although the size of the correlations is not high, and suggest that during habituation the overall response shape within subjects tends to remain constant.

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(Manuscript received November 3, 1975; revision received April 19, 1976; accepted for publication June 2, 1976)