# VARIATIONS IN SKIN RESISTANCE AND THEIR RELATIONSHIP TO G.S.R. CONDITIONING

By

**IRENE MARTIN, Ph.D.**

*Senior Research Psychologist*
*Institute of Psychiatry, London*

ANY particular system which is being conditioned is likely to maintain a certain level of background activity throughout the experimental procedure; either of a discontinuous nature, as, for example, with eyeblink, heart rate and respiratory cycle, or continuously, as in the case of basal skin resistance and muscle tonus.

This background activity or level of arousal does not remain constant but usually varies in time, presumably as a result of underlying neural excitation or inhibition. It may increase throughout an experiment if the subject becomes highly motivated, as with the gradients of muscle action potentials observed by Bartoshuk (1955), or decrease, if the subject becomes more relaxed and familiar with the set-up, as Duffy and Lacey (1946) found with level of skin conductance.

The activity of a system which is being investigated may be measured in a number of ways, e.g. in *level* of skin resistance, in *frequency* and *amplitude* of cardiac output, or in the *number* of spontaneous eyeblinks during inter-trial periods. Little attention has been given to such matters; surprisingly so, since it seems important for a number of reasons to consider the excitability or general reactivity of the specific system which is being conditioned.

The actual state of underlying neural excitation may, of course, be only imperfectly measured by existing techniques, and this is a difficulty which must be faced (and will be discussed later); on the other hand, even if neural activity is fairly represented in the measures taken, the subjects will not all necessarily express their arousal via the same system (cf. the work by Lacey *et al.* (1953) on response specificity, and that of Malmo and Shagass (1949) on symptom specificity).

It is the purpose of the present paper to draw attention to some of the major variations in skin resistance which occur during GSR conditioning, and to discuss their importance and relationship with the measures of conditioning. The variations which were considered were as follows:

(*i*) Basal level of skin resistance.
(*ii*) Number of spontaneous variations.

Third, relationships between amplitude of the UCR and associated pre-stimulus levels were investigated.

## PROCEDURE

Full details of the experiment and apparatus have been given elsewhere (Martin, 1959). To recapitulate the procedure briefly, the palm to palm skin resistance of 23 normal male subjects was measured throughout the conditioning procedure, using a very small constant current of 10 $\mu$A. Subjects were conditioned to a dim light (CS) in association with a 980 c.p.s., 110 db. tone (the

UCS) with a CS-UCS interval of 5-seconds. Intervals between the 13 reinforced trials varied from ¾ minute to 2½ minutes.

Initial trials of the CS were given to ensure adaptation to this stimulus. Subsequent acquisition of the CR was very rapid and was stably maintained. Thirteen extinction trials followed.

Introversion and neuroticism scores were obtained for each subject by means of a questionnaire which has been previously used a great deal in Eysenck's dimensional programme (Eysenck, 1957). Following his line of argument it was predicted that introverts would condition more readily than extraverts; no significant relationship between neuroticism and conditionability was expected.

## Results

1. *Basal Skin Resistance.* Level of skin resistance usually showed a slight rise during the pre-conditioning adaptation trials but invariably dropped by a very great amount following the first UCS. After this there was a slight tendency to recover, but as a rule the level of skin resistance then remained fairly steady until the end of the experiment.

Two measures of mean resistance were calculated for each subject; the first ($BSR_1$) was based on the level immediately preceding each UCR and is therefore derived from 13 readings. Since the level prior to the first UCS was in some cases extremely high, whereas the remaining twelve did not vary so greatly, a second mean was obtained ($BSR_2$), based on the 12 pre-stimulus readings of UCRs 2–13, that is, after the sudden large drop in basal skin resistance to the first UCS. In fact, both means correlate significantly with the number of CRs given by the subject, as can be seen from Table I. The correlations are negative, and show that when basal skin resistance is high (i.e. when

Table I

*Correlations Between Mean Basal Skin Resistance and Number of Conditioned Responses*

| | r | N |
|---|---|---|
| $BSR_1$ (based on mean of 13 pre-UCR readings) and CRs | −0·5429* | 23 |
| $BSR_2$ (based on mean of 12 pre-UCR readings) and CRs | −0·5553* | 23 |

* Significant at the 1 per cent. level.

sympathetic activity is low) conditioning is less; conversely, when skin resistance is low a greater number of conditioned responses are given.

This is an interesting relationship, for many autonomic measures—in particular that of palmar sweat gland activity—have been shown to vary quite closely with the level of the subject's arousal (Duffy, 1957). During relaxation or sleep, autonomic activity is reduced, but it is very high during alert, excited states. Insofar as basal skin resistance is an index of arousal (the point will be discussed below) it appears that subjects who are more relaxed do not condition as well as those who are fully aroused and alert.

2. *Spontaneous Responses.* Some subjects produced many spontaneous responses, others practically none. Two typical examples of this are reproduced in Figure 1. Any fluctuation in basal skin resistance greater than 2 kilohms was counted as a spontaneous response, and the total number of such responses given during acquisition was correlated with the number of conditioned responses given. This correlation was very high (+0·62) and significant beyond the 1 per cent. level.

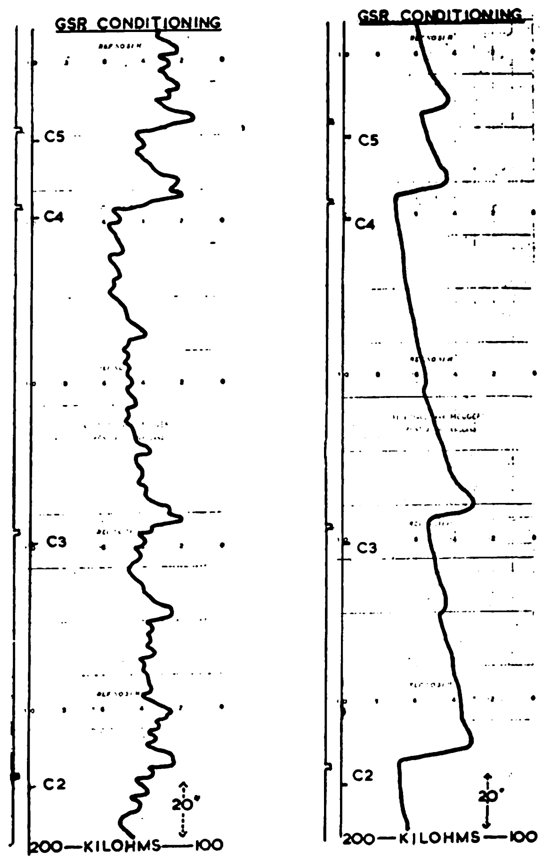


FIG. 1.—Two records obtained during acquisition, illustrating the differences between subjects in the occurrence of spontaneous responses.

What is the origin of this type of response? Mundy-Castle and McKiever (1953) drew attention to them and suggested that they arise through lack of cortical inhibition of lower autonomic centres. There is no direct experimental evidence in support of this, and the possibility that they are spontaneous discharges from end organs should not, perhaps, be ignored. More spontaneous responses occur when skin resistance is low: the correlation of —0·487 obtained in the present study is significant at the 5 per cent. level. Lacey and Lacey (1958) found a negative and similarly significant correlation between the two variables in one of their two samples, but not in the other.

These authors incline to the view that "level of tonus" and frequency of spontaneous responses are independent variables, a conclusion which seems premature in the light of the present evidence.

3. *Relationship of UCR Amplitude to Basal Levels.* There is hardly any need to draw attention to the close relationship which has been observed between GSR amplitude and pre-stimulus levels, nor to the statistical ingenuity which has been spent on the problem. The size of the relationship varies greatly from sample to sample, but it has also been shown to decrease considerably within a single study involving successive responses. Martin (1960) found in an experiment on GSR adaptation that the size of the correlation between

GSR amplitude and basal levels was very high for the first response but zero by the twentieth response.

Correlations were therefore calculated between amplitude in kilohms of unconditioned and conditioned responses, and their associated pre-stimulus levels, throughout the acquisition procedure. The results are given in Table II.

TABLE II

*Correlations Between Amplitude of UCRs and CRs and Pre-stimulus Levels of Basal Skin Resistance*

| | r | N |
|---|---|---|
| $UCR_1$ and BSR .. .. .. .. .. | +0·9220† | 23 |
| $UCR_6$ and BSR .. .. .. .. .. | +0·8257† | 23 |
| $UCR_{13}$ and BSR .. .. .. .. .. | +0·2603 | 23* |
| $CR_3$ and BSR .. .. .. .. .. | +0·4734‡ | 23* |
| $CR_{10}$ and BSR .. .. .. .. .. | +0·3138 | 23* |

* Only 20 of the subjects gave a response in these groups, but correlations were calculated on the total N of 23.

† Significant at the ·1 per cent. level.

‡ Significant at the 5 per cent. level.

The size of the correlation drops in a very clearcut way, the first being highly significant, and the last failing to reach statistical significance.

Table II also gives correlations between two of the conditioned responses (CRs 3 and 10) and their skin resistance levels. These are both small and of borderline statistical significance.

The size of the first UCR during acquisition was in every case the largest given by the subject. Auditory thresholds were obtained prior to the conditioning experiment, and they were found to fall within a very narrow range, so that differences between subjects in responsiveness to the first UCS could not be attributed to differences in receptor sensitivity. It seems unlikely, moreover, that this factor could account for the greatly differing effects that sudden, startling tones or noises have upon individuals with normal hearing, such that they are ignored by some but produce violent reactions in others.

It is reasonable to suppose that the size of the first UCR measures the subject's reaction to the first UCS, and it is obviously important to consider whether there are any individual differences in this connection. For varying the intensity of the UCS in a conditioning experiment changes level of drive, and this, theoretically, should affect the degree of conditioning. Lacey's (1956) formula was applied to these data, to ascertain whether a given subject's first UCR was *greater* or *smaller* than that which would be predicted from his pre-stimulus level of skin resistance, and the resulting autonomic lability scores were then correlated with the number of CRs given during acquisition. The resulting coefficient was $-0\cdot2218$, which was not significant but in the predicted direction*, i.e. subjects giving comparatively larger UCRs were those giving more conditioned responses.

## DISCUSSION

There is ample evidence that palmar skin resistance varies with the level of sympathetic nervous system activity and with the subject's central state of arousal (Kleitman, 1939, Richter, 1926), but there is also evidence to suggest

* Skin resistance was measured in kilohms; skin resistance decreases following a stimulus so that low autonomic lability scores in this case indicated a greater reaction to the tone. The correlation between autonomic lability scores and number of conditioned responses was, therefore, negative in direction.

that the state of the end organs may be modulating the measurement of neural impulses (Davis, 1930; Davis *et al.*, 1955).

The significant negative relationship between level of skin resistance and number of conditioned responses may, therefore, show that conditioning of this modality is partly a function of arousal, but it may also point to an *increase in threshold at the periphery* during high skin resistance, whereby weak impulses which under other conditions would produce a CR are not able to excite the end organs into making a response. When skin resistance is high the peripheral sweat gland cells are highly polarized and may be more difficult to activate. The important point to emphasize is this: if end organ involvement is considerable, then the *same number of neural impulses passing along autonomic nerves may produce a CR in one subject but not in another.*

Presumably another kind of threshold is reached in cases of extremely low skin resistance, where local sweat glands are so highly active that further responsiveness even to strong stimuli is difficult to achieve. This factor was not marked in the present experiment, but it has been very clearly observed in subsequent studies which have been carried out during very warm weather. Obviously, these are important problems to resolve in order to maximize the effectiveness of skin resistance measures as indicators of *central* change. Malmo (1958) has recently argued for the use of measurements of physiological activity as indicators of drive level, and this offers a singularly promising lead in the problem of assessing strength of drive. His thoughtful paper should be consulted, for it deals with a number of relevant experimental findings and theoretical issues in this connection.

As with basal skin resistance, so spontaneous responses may be central in origin, or, conceivably, discharges occurring at a lower level. Lacey and Lacey (1958) have discussed these responses at length. They argue that such autonomic responses act as stimuli which feed back to energize the cortex, and that "episodes of autonomic discharge may be paralleled by episodes of changes in cortical arousal, whether the autonomic discharge is spontaneous or stimulus evoked". Both sets of variations, autonomic and cortical, may, they suggest, be produced by the same neural mechanisms.

There is a great deal of individual variation in the number of spontaneous responses given, some subjects producing many and others hardly any at all. Most subjects give the greatest number after the first and second unconditioned stimuli, after which there appears to be a decrease in their occurrence. If these spontaneous responses act as stimuli to energize the cortex, as Lacey and Lacey argue, they may be considered as drive stimuli in the sense that this term is used in current learning theory (Estes, 1958).

The overall evidence is not clear concerning the relationship of spontaneous responses to basal levels of skin resistance. The correlation between number of spontaneous responses and conditioned responses is very significant; it is paralleled in an interesting way by the results of Willett (1960) who observed correlations, not quite significant at the 5 per cent. level, between number of spontaneous eyeblinks and eyeblink conditioning to a tone followed by a puff of air.

The activity level of the system being conditioned seems, therefore, to play some part in the conditioning process, although this part may be more or less important in the different modalities. It is a factor which has been undeservedly neglected, particularly in theories which are concerned with individual differences. A given subject may not condition well in a particular modality simply because his general "activity" or "arousal" of responsiveness to stimuli is *not expressed in that system*. It might, therefore, be necessary to condition several systems before reaching a justifiable conclusion that a subject could not be conditioned.

The results also have implications for general theories of learning. In the basic Hullian equation, drive acts on habit strength to produce learning, and it is accepted that one of the ways to vary drive level experimentally is to vary the intensity of the UCS (Spence, 1958). A *standard* UCS is likely to affect subjects differently for a number of reasons (Eysenck, 1960). One is the differences in subjects' receptor threshold, but in addition to this there are differences between subjects in central reactivity, especially to sudden and startling noises. This factor was taken into account in the present experiment by calculating autonomic lability scores and correlating these scores with the number of conditioned responses. The resulting r was not significant (the number in the sample was only 23) but it was in the predicted direction, and partially supports the expectation that those subjects who react greatly to the UCS are those who condition well.

These findings should be repeated before firm arguments are based on them, for, regrettably, many of the results in this field do not accord with one another. But if they are valid, some consequences arise which are especially relevant to theories which attempt to deal with individual differences in behaviour.

One such theory is that proposed by Eysenck (1957), and one of the specific predictions arising from this theory is that introverts will, among other things, condition more rapidly because excitatory potential is dominant in this type. So far most of the work carried out in this connection has been with eyeblink conditioning. As Eysenck has himself pointed out on many occasions, there are undoubtedly a large number of factors operating in any given experiment which could attenuate the observed correlations between the personality measures and conditioning. In the first place the criterion of "introversion", which depends upon questionnaire measurement, is unsatisfactory in many ways. Not only this, but, as the present results show, it may be unwise at the present time to depend too heavily upon results from one particular type of conditioning. The correlations obtained in the present study between number of CRs and introversion (as well as between CRs and neuroticism) were very low and non-significant; but there are many other, and possibly more relevant, measures of conditionability which might be used in this connection, and this aspect of the experiment will be followed up in subsequent studies using larger groups.

Again, it needs no emphasis that theories within psychology at the present time are not highly organized systems, and one of the consequences is that they generate only weak and imprecise hypotheses for experimental test. Their value in stimulating and directing experiments cannot be denied, but there are clearly some urgent experimental problems ahead. One is to determine how widely the generalizations of learning theory hold, and to specify the conditions under which such general laws as there may be will operate.

## Summary

1. Level of basal skin resistance was measured continuously throughout the conditioning procedure and was found to correlate negatively and significantly with the number of CRs given by the subjects. Two explanations were considered: the first, that conditioning relates to level of arousal, the second

that there is an increase in threshold at the periphery during high resistance such that CRs are less likely to occur.

2. Spontaneous responses were counted throughout acquisition: they correlated positively and significantly with the number of CRs produced. It was suggested (*a*) that they were probably central but possibly peripheral in origin, and (*b*) that they might act as cortical energizers.

3. Correlations between amplitude of UCRs and basal level diminished throughout acquisition. The amplitude of the first UCR was considered to indicate degree of responsiveness to the UCS. On the hypothesis that different amplitudes might reflect differences in drive level produced by the UCS, autonomic lability scores were calculated, and correlated with number of CRs given by each subject. The resulting coefficient was in the predicted direction, but was not statistically significant.

## References


BARTOSHUK, A. K., "Electromyographic gradients in goal-directed activity", *Canad. J. Psychol.*, 1955, **9**, 21–28.

DAVIS, R. C., "Factors affecting the galvanic reflex", *Arch. Psychol.*, 1930, No. 115, 5–64.

*Idem*, BUCHWALD, ALEXANDER, and FRANKMANN, R. W., "Autonomic and muscular responses and their relation to simple stimuli", *Psychol. Monogr.*, 1955, No. 405, Vol. 69.

DUFFY, ELIZABETH, "The psychological significance of the concept of 'arousal' or 'activation' ", *Psychol. Rev.*, 1957, **64**, 265–275.

*Idem*, and LACEY, O. L., "Adaptation in energy mobilization: changes in general level of palmar skin conductance", *J. exp. Psychol.*, 1946, **36**, 437–452.

ESTES, W. K., "Stimulus-response theory of drive", in *Nebraska Symposium on Motivation* (Ed. Jones), 1958, pp. 35–69. Lincoln: University of Nebraska Press.

EYSENCK, H. J., *The Dynamics of Anxiety and Hysteria*, 1957. London: Routledge & Kegan Paul.

*Idem*, "The place of theory in psychology", in *Experiments in Personality* (Ed. Eysenck), 1960. London: Routledge & Kegan Paul (to be published).

KLEITMAN, N., *Sleep and Wakefulness*, 1939. Chicago: University of Chicago Press.

LACEY, J. I., BATEMAN, DOROTHY E., and VANLEHN, RUTH, "Autonomic response specificity. An experimental study", *Psychosom. Med.*, 1953, **15**, 8–21.

*Idem*, "The evaluation of autonomic responses: toward a general solution", *Ann. N.Y. Acad. Sci.*, 1956, **67**, 123–164.

*Idem*, and LACEY, BEATRICE C., "The relationship of resting autonomic activity to motor impulsivity", *Res. Publ. Ass. nerv. ment. Dis.*, 1958, **36**, 144–209.

MALMO, R. B., "Measurement of drive: an unsolved problem in psychology", in *Nebraska Symposium on Motivation* (Ed. Jones), 1958, pp. 229–265. Lincoln: University of Nebraska Press.

MALMO, R. B., and SHAGASS, C., "Physiologic study of symptom mechanisms in psychiatric patients under stress", *Psychosom. Med.*, 1949, **11**, 25–29.

MARTIN, IRENE, "Central depressant drugs and palmar skin resistance: a study of adaptation", in *Experiments in Personality* (Ed. Eysenck), 1960. London: Routledge & Kegan Paul (to be published).

*Idem*, *G.S.R. Conditioning: A Description of the Conditioning Process*, 1959 (to be published).

MUNDY-CASTLE, A. C., and MCKIEVER, B. L., "The psychophysiological significance of the galvanic skin response", *J. exp. Psychol.*, 1953, **46**, 15–24.

RICHTER, C. P., "The significance of changes in the electrical resistance of the body during sleep", *Proc. Nat. Acad. Sci.*, 1926, **12**, 214.

SPENCE, K. W., "A theory of emotionally based drive (D) and its relation to performance in simple learning situations", *Amer. Psychol.*, 1958, **13**, 131–142.

WILLETT, R. A., "The effects of Doriden and meprobamate on some psychological processes", in *Experiments in Personality* (Ed. Eysenck), 1960. London: Routledge & Kegan Paul (to be published).