New Technique for Recording Skin Resistance

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Since there is growing evidence that GSR and BRL are indices of a central state of arousal or nonspecific neural activity, a simple reliable inexpensive recording technique is of some interest.

A recording system is described which utilizes any 10-millivolt, high-impedance servo recorder and a control unit designed for the purpose. A particularly important feature of this system is the wideband rectilinear writeout of the servo recorder. This results in a record from which both BRL and GSR can be scored, and eliminates the need for an operator and/or automatic scale-shifting necessary for certain widely used skin-resistance recording systems. A number of technical advantages of the system are also discussed.

The use of the system is described not only for human and rat experiments in which skin resistance is a central variable, but also for many other experiments where arousal variations may be produced unintentionally. It is concluded that such auxiliary recording could lead to new insights and discoveries.

THE RECORDING of electrodermal phenomena can hardly be considered a novel undertaking. Landis, reviewing the literature in 1930, listed over 300 references[1]. In his review of the period 1930 to 1950, Grings[2] lists an additional 300 references and *Psychological Abstracts* lists over 350 references since then.

This extensive research has not, however, yielded complete agreement on the definition of the measure. The hypothesis that electrodermal recording provides a measure of the organism's alertness, vigilance, readiness, or arousal has recently been supported by direct physiological evidence. Bloch and Bonvallet[3] have demonstrated that facilitory reticular formation controls the electrodermal reaction. Since reticular formation is also known to function as a nonspecific activator of the cortex, the value of electrodermal measurements in the assessment of nonspecific activation or arousal is apparent.

Traditionally, electrodermal recording has focused on the galvanic skin reaction (GSR), the usually small, brief change in skin resistance‡ following the presentation of a stimulus. Thus most recording has involved the use of sensitive scales and high chart speeds. Any slow, larger changes in skin resistance tend to be obscured by this technique. Recently, a new technique[4,5] has been developed for recording these slow, base-level changes in resistance. They demonstrate that this usually ignored aspect of the skin resistance pattern is a meaningful indicator of the subject's alertness. Possible applications for space research are particularly emphasized by these authors.

The GSR and the basal resistance level (BRL) may be seen as extremes of a sensitivity continuum. The techniques and apparatus described here represent a compromise between these extremes. Through the use of a wide-band recording system, an attempt is made to retain many of the best features of both procedures.

Two Basic Units in Apparatus

Two basic units comprise the recording system shown in Fig. 1. A standard 10-millivolt servo recorder provides amplification and a rectilinear writeout on a five-inch

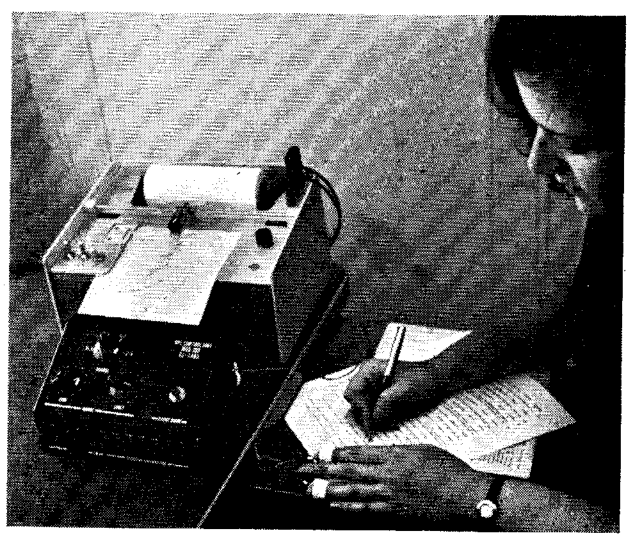

Fig. 1. Human subject and skin-resistance recording system **(see text).**

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‡ Although electrodermal reactions can be measured with the imposition of an external current (i.e., by measuring potential rather than resistance), this procedure is less commonly used. This article will concern only recording with an imposed current.

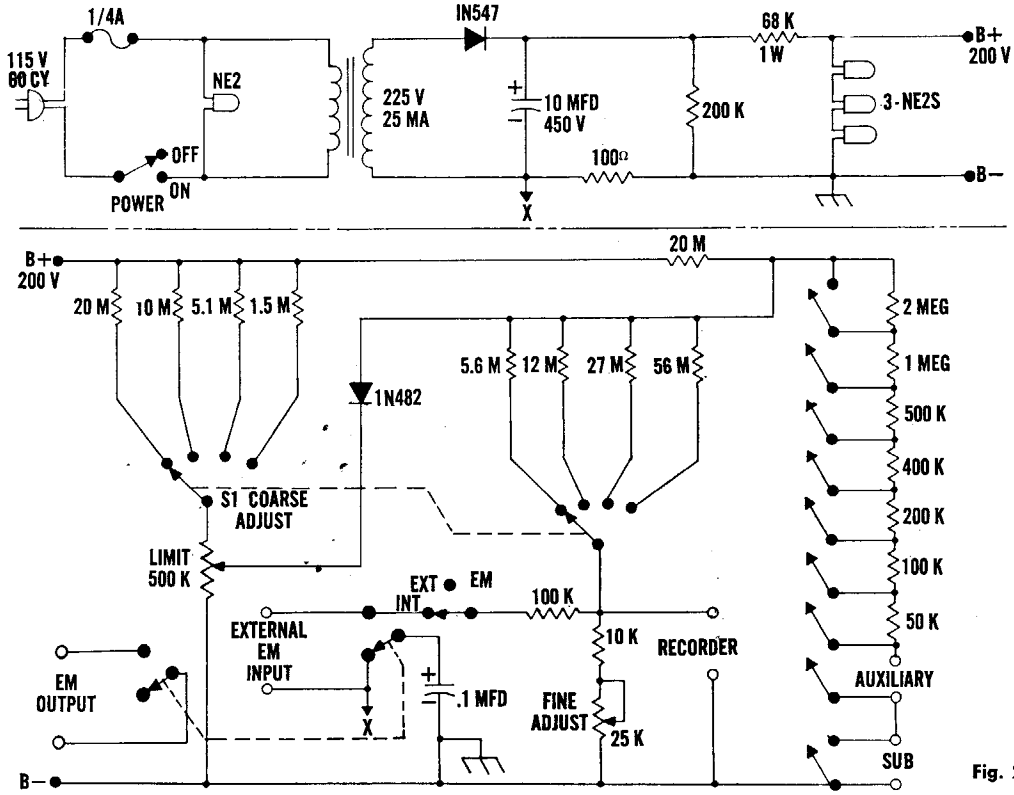

Fig. 2. Control unit circuit diagram.

chart. A control unit provides the constant measuring current, permits selection of an appropriate resistance scale, and has provision for calibration and "internal" event marking (as described below).

The subject is wearing the Kaplan-Fisher modification[6] of the Lykken zinc electrodes[7]. These are connected to the control unit[§] which in turn is connected to a graphic recorder[¶].

Circuit Description

The main considerations in the design and construction of the control unit circuit (Fig. 2) were reliability, ease of operation and low cost. To this end, the design has been kept as simple and straightforward as possible.

Subject current is provided by a 200-volt, halfwave power supply which is filtered and regulated by three NE-2 neon bulbs. A 20-megohm resistor, in series with the supply, provides a 10-microampere current. For subjects whose resistance does not exceed one megohm, the current is constant to within five per cent.

The voltage across the subject, developed by the 10-microampere current, is attenuated by a high-impedance voltage divider, the output of which goes directly to a 10-millivolt servo recorder. The servo recorder has a large input impedance to avoid loading the divider.

In many situations, it is desirable to limit the voltage that may be developed across the subject and as a consequence, limit the upward deflection of the servo recorder. This is accomplished by a silicon diode (Type 1N482), chosen for its very low reverse current. The anode of the diode is connected to the subject and the cathode to a variable divider across the power supply.

§ Model BRL-300, Psychotronics, 2235 S. Circle Dr., Ann Arbor, Mich.
¶ Nesco, JY-100.

The voltage limiter introduces a controlled nonlinearity into the upper portion of the scale. This makes it possible to use a fairly sensitive setting, since the occasional extreme subject will be prevented from going off scale and overdriving the recorder. A typical human scale (Fig. 3) corresponds to 500K ohms full scale except that it is limited at 600K ohms, introducing a degree of nonlinearity into the upper quarter of the scale. Limited at infinity, a useful rat scale is two megohms full scale. When the rat momentarily loses contact with the grid (which serves as electrodes) no overdriving of the recorder results[8].

Various precision resistors are switched in, in place of the subject, to accomplish scale calibration. The resistors and the subject are connected in series with a shorting switch across each; thus by opening the appropriate switch, any desired combination can be selected.

The recorder pen may also be used as an event marker. A controlled, momentary shorting across the subject can be initiated from the button on the control unit, or remotely. This produces a rapid pen deflection clearly distinguishable from the rest of the record (Fig. 3). This feature is particularly helpful for use with recorders lacking a separate event marker. Since the inking system for a separate event marker is often quite inferior to that of the recorder pen, we have used this feature in preference to a separate event marker even when one was available.

Advantages

Eliminates Scale Shifting

The narrow band and high sensitivity in traditional GSR recording lead to certain problems. First, to achieve high sensitivity, part of the subject's resistance is balanced out. Thus the bottom of the scale never represents zero resistance, but a different value depending on the level of the particular subject. Since BRL changes of any magnitude take the subject out of the recording band, the scale must be either automatically or manually adjusted to again include the subject's level. Using the potentiometric approach the subject's BRL can be read directly, since the lowest point of the scale represents zero resistance. Because the scale is less sensitive and the chart wider, the shifting of scales is also eliminated. Thus the full-scale value is selected to be greater than the highest value reached by the vast majority of subjects. With the Lykken zinc electrodes, and under experimental conditions, fewer than five per cent of our subjects exceed 500K ohms.

Although we use a higher chart speed than that used by Levy et al[4,5] (1 inch per minute as opposed to 2 inches per hour), the identical information can readily be obtained, albeit in somewhat less compact form. At the same time GSR's of one per cent or greater can be measured on the same record. Of course it is possible to vary the chart speed and sensitivity to more closely approximate either extreme. It is even possible to balance out part of the subject's resistance, if desired, with the "zero adjust" on the potentiometric recorder. For finer resolution, a wider band recorder (e.g., 10 inches) could also be used.

Compatible With Lykken Electrodes

In addition to recording GSR and BRL on the same record, this technique offers a number of technical advantages. Not the least of these is its compatibility with other recent advances in skin-resistance recording technique. The matter of suitable electrodes has been shown to be particularly critical[7].

Several problems arise here. First, certain electrodes or electrode-electrode paste combinations are particularly prone to drift because of polarization or other electrical artifacts. This is unfortunately true of some of the most widely used and readily available electrodes, and may be very important in explaining some past failures in skin-resistance research.

A second problem is the effect of movement on the skin-resistance record. Although electrodes entirely immune to this artifact have been developed, much research is still carried out with electrodes highly sensitive to this source of noise. Perhaps even more critical than the extraneous activity of the recorder pen is the drastic restriction often imposed on the activity of the subject. By making the experimental situation even more unnatural and uncomfortable than would otherwise be necessary, the subject's arousal, and in turn, his skin resistance pattern, is undoubtedly affected.

Current Only 10 Microamperes

The size of electrode contact is also an important variable. This is partially determined by the electrode size and by the degree to which sweat on the palm or finger permits the area of effective conduction to spread beyond the area of actual electrode contact. This problem, as

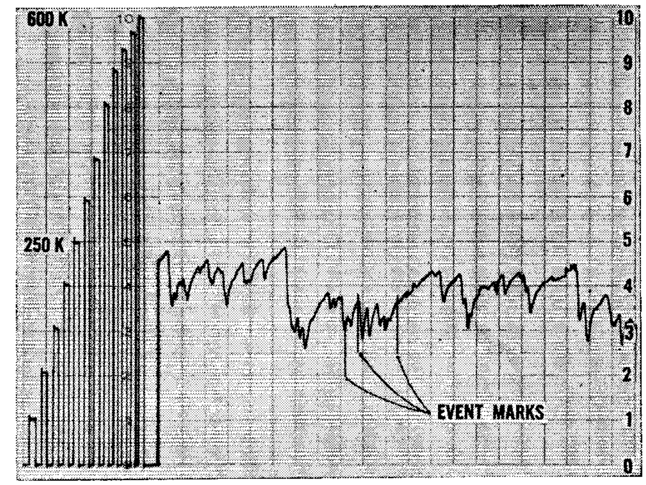

Fig. 3. Skin-resistance record for a human subject on a 500K-ohm scale limited at 600K ohms. Each calibration interval represents 50K ohms.

well as the first two problems, is simply and effectively handled by the use of the Lykken zinc-zinc sulphate electrode[6,7]. Electrically stable and immune to movement artifact, their small size and application to the fingertip with a corn pad and electrode jelly effectively restrict and control the area of electrode contact. However, use of these electrodes requires a considerably smaller measurement current than is provided in most commercial recording systems. In contrast to the popular 60, 70, or even 80-microampere current, our system uses 10-microampere current. Recently there have been signs of a trend in this direction[9].

Automatic Operation

A further advantage of the combined GSR-BRL technique is the lack of need for an operator. Many skin-resistance recording systems require an operator to shift scales to follow BRL changes in the subject, or to record the new level if such changes occur automatically. With our relatively insensitive, wideband recording system, a single scale accommodates all normal variation in the subject, and shifting can be dispensed with. Thus after the electrodes are applied, the system calibrated, and the subject switched in, the subject's skin resistance is recorded automatically and with no further attention from the experimenter.

Flexibility

Besides measuring human skin resistance under a wide range of conditions, it is adaptable to the measurement of rat skin resistance as well. A recently developed technique[8] utilizes a simple floor grid without any electrodes or other restriction applied to the rat. This procedure has been used successfully in several studies[10].

Further flexibility is provided by the separation of the control unit from the recorder. The control unit is compatible with any high-impedance, 10-millivolt potentiometric recorder. Thus it is possible to tailor the system to the particular requirements of the user. The recorder can be selected on the basis of fast pen-response, multiple chart-speed, event-marker, budgetary considerations, etc. Note that since the control unit weighs approximately 2½ pounds and many potentiometric recorders weigh under 15 pounds, the system is quite portable.

Performance

The recording system described here has been used successfully in numerous studies[10,11,12,13]. In our laboratory, over the last four years over 700 subjects have served in a variety of experiments in which this skin-resistance recording procedure was used. Perhaps more important than the fact that the system has proved a simple and effective method for recording GSR and BRL in numerous studies is the fallout of unanticipated information it has provided. By routinely using this system even in studies where we are not primarily interested in skin-resistance factors, we have acquired new insights into many neglected facets of the experimental setting.

To compare skin-resistance levels of experimental subjects to those of individuals in a more relaxed, normal setting, research assistants were encouraged to record their own skin resistance while they worked. Several recordings of skin resistance were also taken by members of the research group at home. While experimental subjects tend to record between 100 and 300K ohms, students serving as research assistants, rather than as subjects, ranged between 300 and 500K ohms. Recordings taken in the home setting suggest that these same individuals may reach 700 or 800K ohms in a relaxed environment, even when they are working. Thus the typical experimental subject may be far from typical in his arousal level due presumably to his reaction to serving as a subject. Procedures to increase the subject's arousal level may be of limited effectiveness since the subject is already at a high level when he enters the experimental situation.

As we became aware of the unnatural tension-state characteristic of the subject, we made a special effort to put the subject at ease. In the process we discovered that as an experimenter becomes more experienced, the subjects tend to show higher skin resistance (i.e., be more relaxed). Some experimenters are more successful than others, even when experience is held constant.

We also found that certain task variables had an unexpected effect on skin resistance measures. In one experiment, for example, half the subjects read nonsense syllables first and anecdotes second while estimating elapsed time. For the other half, the order was reversed. This simple control for order effect had a far more pervasive influence than had been anticipated. Subjects who read the nonsense material first were tense throughout the experiment, while subjects who read the anecdotes first quickly relaxed and remained so throughout the experiment. Other data also indicated that the subjects' attitude toward the entire experiment was based on their initial experience. Needless to say, although many experiments control for order in this way, the simple recording procedure that would reveal unintended effects of this kind is rarely used.

Skin-resistance recording indicates that subjects tend to become more relaxed both within a single experimental session and across several sessions. This is hardly a surprising conclusion. Nonethless, various effects attributed to practice, fatigue, or other variables may be contaminated by arousal changes of this kind.

Other Applications

Besides the value of the procedure in evaluating the effects of subject, experimenter, and task variables, skin-resistance recording can lead to a variety of useful yet unanticipated insights. For example, we used the skin-resistance measure during a tracking task in which the tracking periods and rest periods were timed automatically, and, we believed, accurately. The subjects' skin resistance showed such a marked drop at the onset of each tracking interval and such a marked increase at the onset of each rest interval that it was evident from the records that the timing of both tracking and rest intervals was highly variable. (Replacement of several faulty capacitors eliminated the difficulty.)

Another interesting finding is the characteristic decrease in skin resistance that follows any reinforcing event. The presentation of a "correct" signal light after a long period of no reinforcement, the reliable reaction to the experimenter's telling the subject "that's all' at the end of the experiment, and the reaction of the subject to being given a cookie, all evoke this reaction. A related observation was made by one of our research assistants who was recording her skin resistance while scoring skin-resistance records. She found that as each decision was approached there was a gradual increase in skin resistance, followed by a sharp drop when she made the decision. This appears on the record as a fatigue-like effect, but with a very rapid recovery.

Thus there appears to be a great deal yet to be learned about a large variety of experimental situations and procedures through the use of auxiliary skin-resistance recording.

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