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Final Report on Project on An Examination of Response Parameters of Electrodermal Responding to Standard Stimuli

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ABSTRACT

This report contains the results of two studies of the relative merits of using skin conductance or skin resistance to evaluate the amplitude of electrodermal responses to external stimuli. The studies also addressed the relative merits of correcting responses for baseline, rather than using raw amplitude measures. The first study employed an oddball paradigm to determine whether skin resistance or skin conductance, or baseline corrected ratio measures are best suited to discriminating oddball stimuli from a background of frequently occurring standard stimuli. The results indicated that there is no empirical basis for assuming that any particular measure has any advantage in allowing for reliable indexing of response differences between oddball (i. e., "novel") and standard stimuli. This suggests the possibility that the use of uncorrected amplitude measures in field applications may be as reasonable as any other technique. The second study attempted to determine if any electrodermal index was more well suited than others for assessing the magnitude of response to external stimuli differing in intensity. The data indicated that there was no apparent advantage to using any particular index of electrodermal response magnitude in favor of any other. All indices showed the same response curves with respect to stimulus intensity and subjective magnitude estimation of stimulus intensity.

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I. Introduction

This report contains the results of two studies of the relative merits of using skin conductance or skin resistance to evaluate the amplitude of electrodermal responses to external stimuli. The studies also addressed the relative merits of correcting responses for baseline, rather than using raw amplitude measures.

II. Recapitulation of the Aims of the Project

The physiological detection of deception (PDD) has employed measures of “galvanic skin response,” now generally known as the electrodermal response, as a primary index of a subject’s physiological reactivity. From its earliest applications to the most recent automated and computerized examinations, the evaluation of electrodermal reactivity has been a central feature of PDD. Yet, there are a variety of basic parameters of the assessment of electrodermal activity that are not well understood, despite decades of basic and applied research (Boucsein, 1992; Edelberg, 1971; Fowles, 1986; Fowles, Christie, Edelberg, Grings, Lykken, & Venables, 1981).

Two basic issues are addressed in this report. First, does skin conductance or its reciprocal, skin resistance, better represent the amplitude of electrodermal response to equivalent stimulation? In the case of PDD we can ask more specifically what is the effect of changes in tonic skin conductance or skin resistance level on the amplitude of phasic responses to transient stimuli? Do electrodermal responses to relevant questions in a PDD examination mean the same thing if they are obtained against the background of tonic levels that differ by significant amounts? Which mode of expression, skin conductance or resistance, yields the desired invariance of outcome independent of tonic level. Second, what is the function relating magnitude of electrodermal response to strength of the stimulus? Is there a simple function like the function that describes judgments of subjective magnitude evoked by sensory stimulation (Stevens, 1975)? If we compare electrodermal responses to physical stimuli with judgments of magnitude for the same stimuli will we find a greater correspondence for EDR based on conductance or on resistance measurements?

Skin Potential, Skin Resistance or Skin Conductance?

Circuitry. The electrodermal response can be measured either endosomatically or exosomatically. Endosomatic measurement involves the assessment of the voltage difference that exists between two different loci on the surface of the skin. It is well known that the skin surface is not isopotential, and that there is a voltage drop between, say, the surfaces of the first and second fingers. The skin potential changes with changes in psychological experience such as orienting to the environment, fear, or other emotional states. For a variety of reasons, but primarily because the endosomatic, or skin potential, response to stimulation is biphasic and the underlying meaning of the positive and negative phases are not understood, endosomatic measurement has been quite uncommon, and most applications of electrodermal measurement have focused on exosomatic measures.

Exosomatic measurement refers to the measurement of the electrical resistance (or its reciprocal, conductance) of the skin surface to a current flow associated with an externally applied voltage. Two common ways to assess electrodermal activity exosomatically are the “constant current” and the “constant voltage” techniques (Boucsein, 1992). In the constant current technique a voltage is applied to the skin through a very high resistance (up to 10 megohms) in series with the subject. The current flow through the entire system, I_t, is equal to the total voltage impressed, E_t, divided by the sum of the two resistors in the circuit, R_1 (the subject) and R_2, (the very large fixed resistor). As changes in the subject’s resistance are only a tiny proportion of the total resistance in the circuit, the current flow is said to be constant. In such a circuit the measurement of the voltage drop across the subject’s skin, E_1, is directly proportional to the subject’s resistance: $E_1/E_t = R_1/(R_1 + R_2)$. Thus constant current circuits are used to measure skin resistance directly. For most of this century, until the 1970s, (Lykken & Venables, 1971) constant current measurement of skin resistance was a widely accepted standard in both basic research and in practical applications such as PDD.

In the constant voltage technique a similar series circuit is employed, but a very low fixed resistance is placed in series with the subject, and a low voltage, usually 0.5 V (Lykken & Venables, 1971) is impressed across the circuit. In this circuit, the voltage drop across the small fixed resistor, E_2, rather than the voltage drop across the subject, E_1, is measured. It can be seen that the current flow through the system now varies inversely with changes in the subject’s skin resistance, and that the voltage drop across the fixed resistance is proportional to the reciprocal of the subject’s skin resistance, i.e., skin conductance. Thus constant voltage circuits are used to measure skin conductance directly. It may be seen that from a purely statistical point of view resistance and conductance are reciprocal, and that the use of constant current or constant voltage circuits can be used to determine either variable. However, there are a variety of technical advantages (see Boucsein, 1992; Fowles et al., 1981) that have led to the adoption of constant voltage circuitry as a standard technique in psychophysiological laboratories (but not in field use for PDD).

Which index best reflects the psychological state? Based upon research by Thomas and Korr (1957), which suggested that skin conductance varies linearly with the number of active sweat glands at the electrode site, it has become fashionable to report skin conductance rather than skin resistance in studies of electrodermal activity (Fowles, 1986). However, there are a number of reasons to question whether this is always advisable. Edelberg (1971) noted that the process of sweat gland duct filling is entirely too slow to explain the variability of phasic electrodermal response (EDR) amplitude, and he suggested that the EDR may be related to the permeability of the sweat gland membrane. Further, Blank and Finesinger (1946) demonstrated that the sweat glands show graded rather than all-or-none reactions to neural impulses of differing frequencies. Boucsein (1992) has interpreted these findings, along with the fact that Thomas and Korr measured EDR from dry, heated, skin to suggest that the linearity assumed between sweat gland number and conductance may be called into question. There are other considerations which suggest that the question of whether to measure phasic electrodermal activity as a change in conductance or resistance is still open. Among these considerations is the question of the effect of tonic levels on phasic response sizes. Lykken and Venables (1971) presented a data set (see Table 1) that shows a phasic response in skin conductance of 1 μS, superimposed on tonic levels ranging from 10 to 16 μS. The table also contains the reciprocal values of the skin conductance,

Table 1

Trial	SCL μS	SCR μS	SRL k Ω	SRR k Ω
1	10	1	100	9.09
2	11	1	91	7.57
3	12	1	83	6.41
4	13	1	77	5.49
5	14	1	71	4.76
6	15	1	67	4.17
7	16	1	62	3.68

expressed in kilohms (kΩ). Table 1 displays a situation in which a constant phasic skin conductance response (SCR) of 1 μS is elicited over a range of different tonic skin conductance levels (SCL). It may be seen that as these tonic levels are reciprocated and expressed in units of skin resistance level (SRL) the corresponding changes in phasic resistance (SRR) associated with the 1 μS conductance change vary systematically as a function of tonic level. Whereas the SCR is uncorrelated with the SCL, the SRR is correlated almost perfectly with the SRL.

Conversely, Table 2 displays a situation in which a constant phasic SRR of 10kΩ is elicited over a range of different tonic SRLs. It may be seen that as these tonic SRLs are reciprocated and expressed in units of SCL, the corresponding SCRs vary systematically with tonic level. In this example the SRR is uncorrelated with the SRL, whereas the SCR is almost perfectly correlated with the SCL. These are simple consequences of the reciprocal relationship between the two measures of electrodermal response. The conclusion that may be drawn from these demonstrations is best summarized by Boucsein: “In summary, an empirical explanation of the relationship between tonic and phasic EDA has not yet been reached, and the application of baseline corrections of the EDR and EDL is problematical. Furthermore, the connection of questions concerning level dependence to those concerning an adequate unit of measurement for exosomatic EDA is not justified on the basis of the existing data.” (1992, p. 205).

b. Relationship to Personnel Security Issues

The data contained in Tables 1 and 2 epitomize the nature of the problem that might be faced by a professional polygrapher in interpreting the electrodermal responses elicited during a PDD examination. Assuming that the tonic level of resistance or conductance of the subject changes over the time course of the examination, how does one determine the meaning of a phasic response? Using the examples given in Table 2, an examiner employing a constant current skin resistance recorder might feel confident that a phasic response of 10 k Ω to a control question has the same meaning as a 10 k Ω phasic response to a relevant question, even if the tonic level of skin resistance differed by as much as 50 k Ω at the time of questioning. However, if the same examiner were using a constant voltage skin conductance recorder, he would have observed that one of the phasic responses was five times greater than the other, given exactly the same subject reactivity. The problem becomes even greater if the examiner is using one of the widely available standard polygraphs that do not report tonic levels, and in which it is unclear whether the recording circuitry conforms to the standard constant current or constant voltage procedures. Given the relationships described above, it seems likely that the value of the information yielded to an examiner from the electrodermal channel could be improved significantly by parametric data on the relationship between stimulus events and the amplitude of phasic electrodermal responses. This proposal aims to address these issues empirically.

Table 2

Trial	SCL μS	SCR μS	SRL kΩ	SRR kΩ
1	10	.11	100	10
2	11	.13	90	10
3	13	.18	80	10
4	14	.24	70	10
5	17	.33	60	10
6	20	.50	50	10
7	25	.83	40	10

c. Specific research questions to be explored

Throughout the literature on electrodermal activity one can find a number of suggestions to deal with the effects of tonic level on phasic response, beginning with Wilder's (1931) classic paper on the “law of initial values” through the suggestions of Lykken, Rose, Luther, and Maley (1966) on range correction. Unfortunately, none of these suggestions deals with a critical psychophysical question: If there is a lawful relationship between the intensity of a stimulus and the amplitude of a phasic electrodermal response to it, what is the most appropriate measure of the electrodermal response, and to what extent is that measure dependent on the tonic level from which it deviates?

The first specific research question to be explored will concern the effect of tonic level of electrodermal activity on amplitude of phasic response. This will be examined using the “oddball” paradigm” that has been productive in research on event-related potentials (ERP: Donchin, Kramer, & Wickens, 1986).

The second specific research question will address the fundamental question of the psychophysical relationship between stimulus intensity and response amplitude. A fundamental assumption underlying the use of the control question technique in PDD is that for the innocent subject the control questions should inherently be at least as arousing, if not more arousing, than the relevant questions to which they are matched. If it were the case that the relevant questions were inherently more arousing than the control questions, then the credibility of the examination would be in doubt. By the same token, if it were the case that the amplitude of phasic electrodermal response was not lawfully related to the "emotional intensity," or significance of the questions, the credibility of the data would also be in doubt. It is not likely that an experiment can easily equate relevant and control questions for their intensity, but we propose to evaluate the extent to which there is a lawful psychophysical relationship between discrete physical stimulus intensity, a subject's estimation of its magnitude (using traditional psychophysical methods) and its associated electrodermal response amplitude. Such a determination would eliminate one major possible source of confounding in the interpretation of phasic electrodermal responses in a PDD examination.

d. Methods

Experiment 1

Subjects

The subjects were 54 undergraduates recruited from the student body at State University of New York at Stony Brook. They received credit toward a course requirement for their participation.

Apparatus

Electrodermal activity was detected by two Ag-AgCl electrodes placed on the medial phalanges of the first and second fingers of the non-dominant hand. Contact with the skin was made with .05 M NaCl solution in Unibase, as recommended by Fowles et al., 1981. A constant-voltage coupler was used to obtain electrodermal activity. The signals were amplified by a Grass Instruments low level DC preamplifier and then digitized (250 Hz) and stored on disk for analysis. A microcomputer controlled all aspects of the experimental procedure and also generated auditory stimuli, which were presented binaurally through a set of matched Sony headphones. All stimuli had a duration of 1000 ms and were presented at intensity levels of 80 dB SPL with a rise/decay time of 25 ms.

Procedure

Subjects were placed in a sound-deadened, electrically shielded room and instrumented for EDR recording. They provided informed consent, and they understood that they could resign from the experiment at any time without penalty. The headphones were placed on them and adjusted for comfort. All subjects were told to sit still and listen to a series of tones. They were instructed that most of the tones would be identical, but there would be an occasional tone that does not fit. They were asked to keep count of the "odd" tones, and let us know how many they heard.

After a 10 min resting period the subjects were presented with three separate series of 30 tones each. The order of presentation of the 30-tone series was randomized. In all three series the "standard" tone was 660 Hz; the "oddball" was 440 Hz in one series, 880 Hz in a second series, and 1100 Hz in a third series. There are six possible orders of presenting the three series; nine subjects each received each of the six possible orders. For each of the three 30-tone series, the first ten tones were standard, and then during each of the two following sets of ten tones, there was one “oddball” placed randomly. The intertone interval varied from 20 to 40 sec., in steps of 5 sec., with a mean of 30 sec. At the conclusion of the first set of 30 tones there was a 5-min rest followed by a second set of 30 tones. The second series was followed by a 5-min rest period, after which the third and final series of tones was presented.

The logic of this design is based upon two considerations. First, the oddball stimulus may be seen roughly as analogous to the unexpected (or undesired) question posed during a PDD examination. It is clear from the ERP literature that oddball stimuli evoke late brain potentials (e.g., P300), associated with judgment and decision making. It was expected that the oddball in this design would elicit a relatively large phasic EDR, compared to the EDRs elicited by the repetitive standard stimuli. Second, it was expected that the tonic electrodermal level of the subjects would vary systematically across the time covered by three repetitions of the series. Thus this experiment allowed us to evaluate responses to similar changes in stimulation at differing tonic levels of activity.

Results

Two uncorrected measures and one baseline-corrected measure were compared. The two uncorrected measures were: 1) amplitude of conductance change; and 2) amplitude of resistance change. The baseline corrected measure was the ratio of peak amplitude level to onset amplitude level. This ratio, which corrects the response amplitude for tonic level, yields scores that are similar to each other, although not identical, using either conductance or resistance. Further, the conductance ratios and the resistance ratios have exactly the same variances, and when the variances of these ratios are analyzed they yield identical results. It is obvious therefore, that the use of ratio scores, whether using resistance or conductance circumvents the difficulty inherent in evaluating difference scores, as described in Tables 1 and 2. Unfortunately, the use of ratio scores requires knowing the tonic level, and many field polygraph instruments are not calibrated for tonic level assessment, rendering the use of ratio scores impossible.

Habituation. The phasic responses to the first ten tones of each of the three series were evaluated for conductance change, resistance change and peak to onset level ratio. Figure 1 depicts the habituation of skin conductance across the first, second and third series of first ten trials. Figures 2 and 3 represent the same data for resistance and for the ratio index of response magnitude. It may be seen that for all three measures, the response magnitude seemed to habituate during the first ten standard stimuli, and that during the second and third sets of standard stimuli the responses remained at a relatively habituated level. Analyses of variance of the data in these three figures do not fully confirm these observations. The raw conductance measure showed more consistent evidence of response habituation over ten trials than the

Figure 1

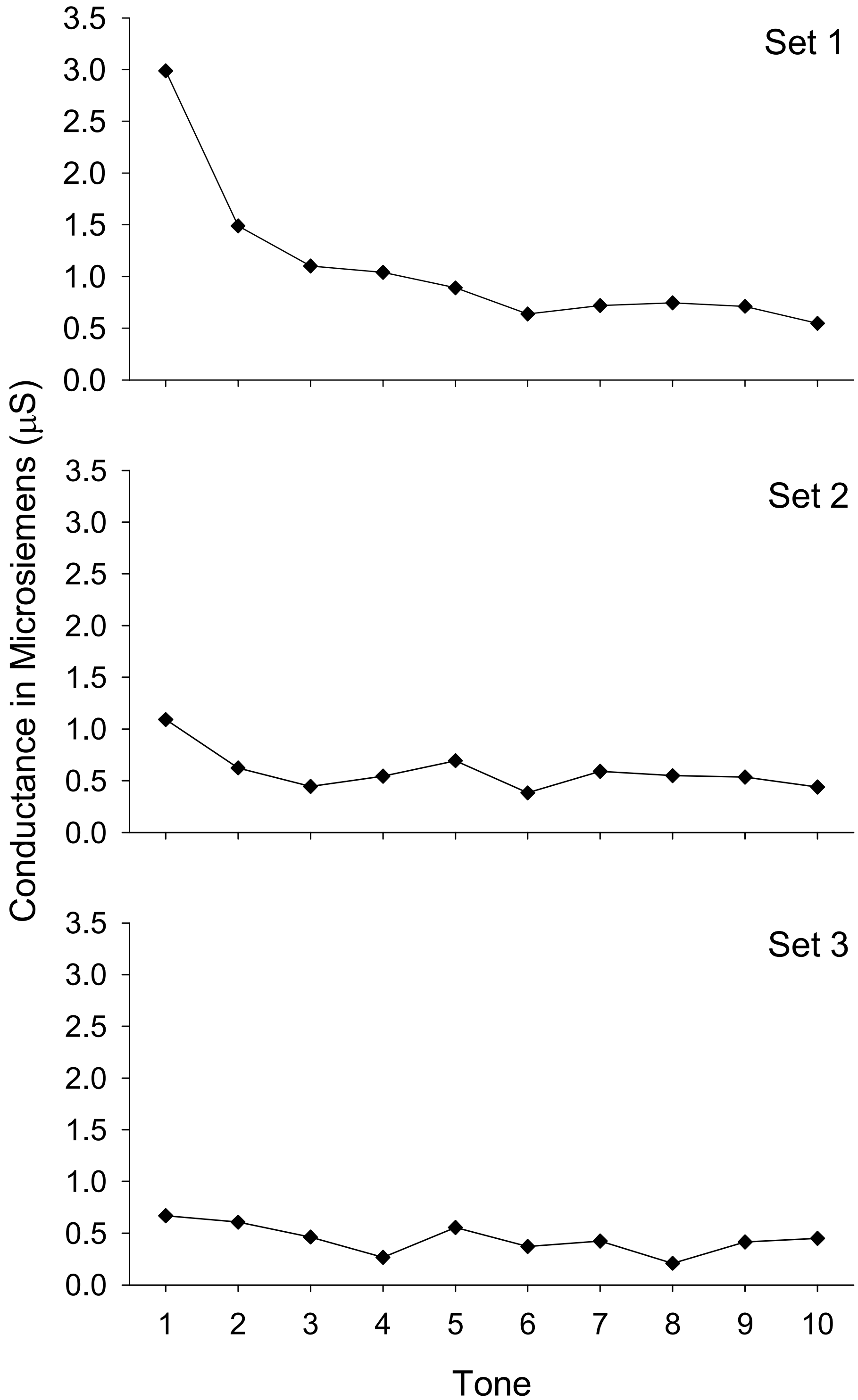

Set 1
Set 2
Set 3
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Conductance in Microsiemens (μS)
1 2 3 4 5 6 7 8 9 10
Tone

Figure 2

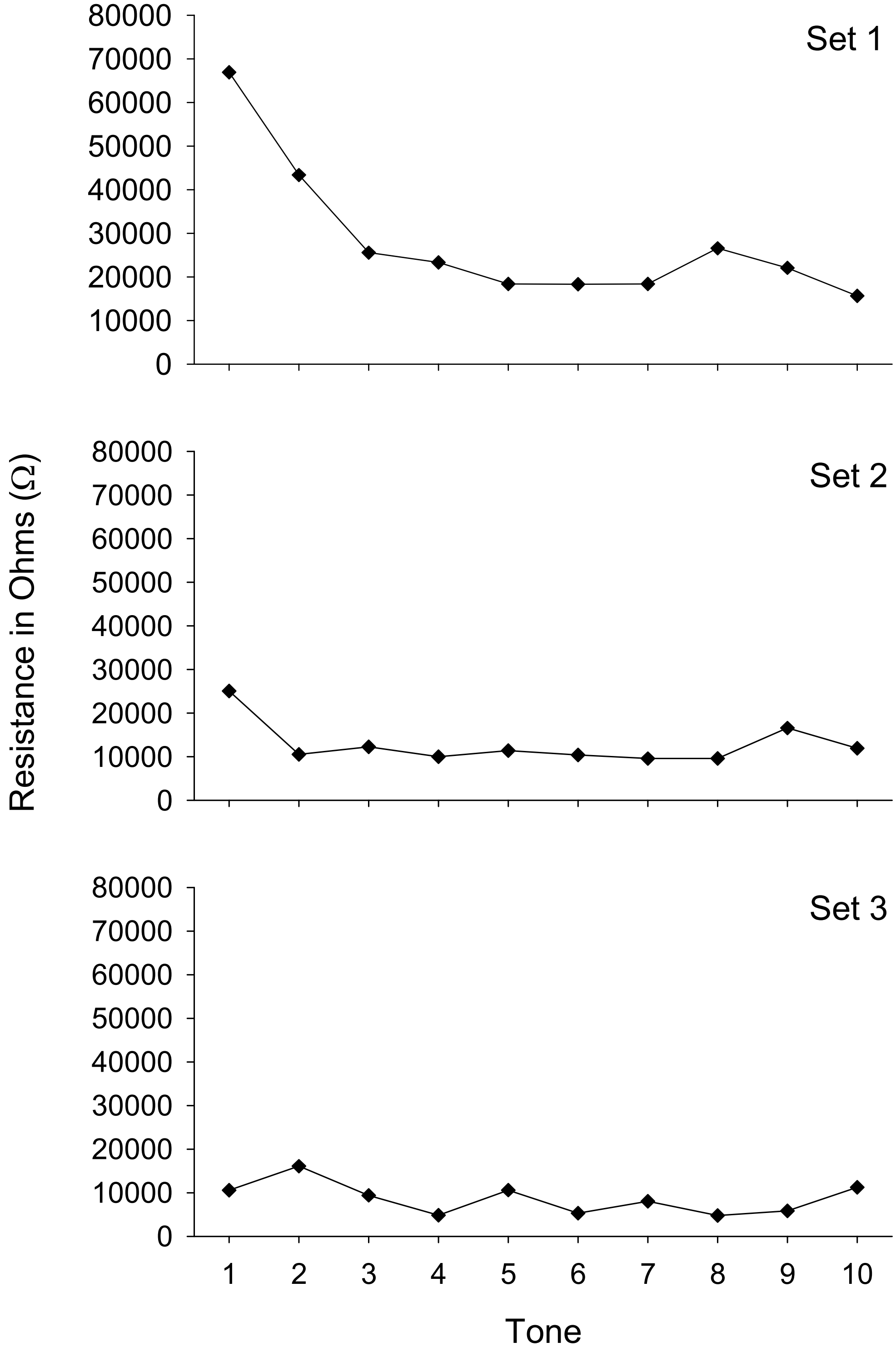
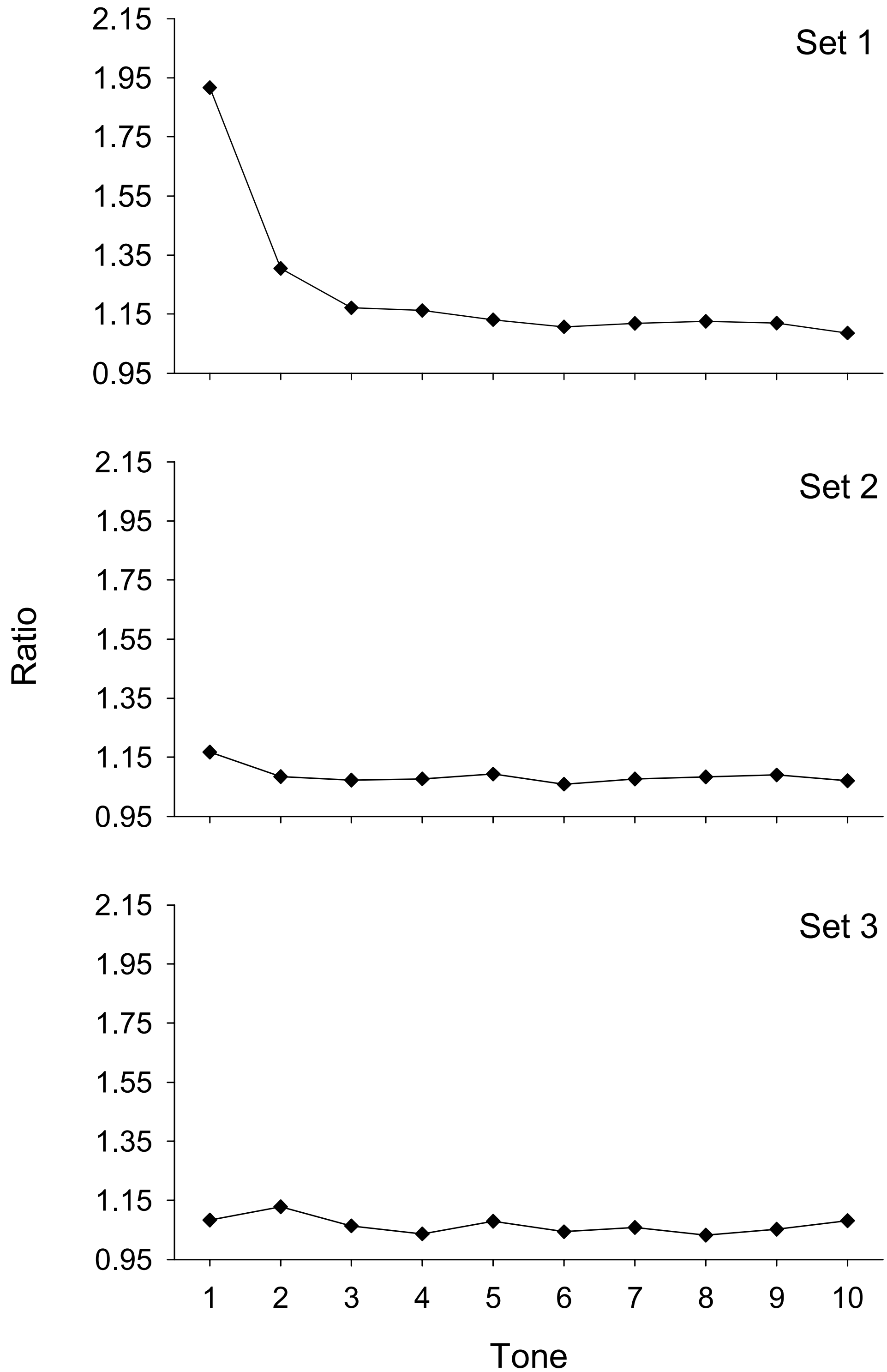

Set 1
Set 2
Set 3
80000
70000
60000
50000
40000
30000
20000
10000
0
Resistance in Ohms (Ω)
1
2
3
4
5
6
7
8
9
10
Tone

Figure 3


Set 1
Set 2
Set 3
Ratio
Tone
2.15
1.95
1.75
1.55
1.35
1.15
0.95
1
2
3
4
5
6
7
8
9
10

resistance or ratio responses did. For conductance, habituation was significant for the first ($p < .04$) and second ($p < .03$) series, but not for the third series. For resistance, habituation was significant only for the first series ($p < .01$) but not for the second or third series. For the ratio responses, habituation was statistically significant only for the second series, although the data in Figure 3 do not, on the face of it, reflect these findings. The within-subjects variance in the first series was sufficiently large to render the apparent habituation curve for that series non-significant.

Correlations also were obtained for response amplitudes and tonic levels for all the measures during habituation. Appendix 1 contains the correlations between the amplitude of each response to the first ten tones and the tonic level at tone onset. It may be seen that for skin conductance and skin resistance, there was a general tendency for response amplitude to be significantly correlated with tonic level during the first two series, but less so in the third series of tones. For resistance especially, the response magnitude and tonic level were uncorrelated on every trial during the third series. The correlations between the baseline-corrected responses (ratios) and tonic level were generally uncorrelated, except for the first two responses in the first series, in which case there was a negative correlation between response amplitude and tonic level.

Table 3 Means(SD)

Index	Oddball	Standard	t	Eta^2
Conductance Change (μS)	1.79 (1.70)	0.58 (0.44)	6.16*	.408
Resistance Change (kΩ)	59793.10 (81184)	15415.10 (14502)	4.74*	.290
Ratio of Peak to Onset Level	1.36 (.358)	1.10 (.083)	5.84*	.375

* $p < .0001$

Response to the "oddball". During each of the second and third series of tones presented to each subject there was one "oddball" stimulus presented against the background of the repetitive standard stimuli. Table 3 contains the mean EDR amplitudes to the two oddballs combined and to all the standard stimuli. The response amplitudes are presented in uncorrected conductance and resistance units, and as the ratio of level at peak conductance amplitude to level at onset conductance amplitude. This corrected ratio response yields identical results as an analysis of the ratio of resistance response to baseline resistance, as discussed above. Similar analyses were conducted on the comparison of oddball responses vs. the responses to stimuli immediately preceding the oddball, and they yielded virtually identical results. Similar analyses were also conducted for each of the oddball stimuli separately, that is for the 440 Hz, the 880 Hz, and the 1100 Hz oddballs to determine if one was uniquely more likely to elicit a differential response than the other. The pattern of results was essentially identical for all analyses. As can be noted in Table 3, all three indexes of response amplitude were extremely sensitive to the difference between a standard stimulus and the oddball. It is apparent that all three measures were capable of discriminating oddball from standard stimuli at significance levels beyond .0001. When effect sizes (Eta^2) was calculated, however, it appeared that the conductance difference score and the ratio response showed greater effect size than the resistance difference score.

Discussion

Electrodermal measurement has always been, and continues to be, a mainstay of the PDD examination. There is considerable discussion in the psychophysiological literature about the effect of tonic levels of electrodermal activity on electrodermal responsiveness, and there is virtually no psychophysical evidence that links lawfully the amplitude of a specific index of electrodermal activity to physical stimulus intensity. Despite endless theoretical disputes about the proper way to report measures of stimulus-elicited electrodermal responses, the results of this experiment suggest that there is no empirical basis for assuming that any particular measure has any advantage in allowing for reliable indexing of response differences between oddball (i. e., "novel") and standard stimuli. This suggests the possibility that the use of uncorrected amplitude measures in field applications may be as reasonable as any other technique. Note that these conclusions do not address possible differences that might occur as a function of constant current vs. constant voltage circuits. All the data in this experiment were collected using a constant-voltage circuit.

Experiment 2

Introduction

The psychophysical scaling procedure of magnitude estimation popularized by S. S. Stevens in the fifties and the ensuing more general class of operations he called cross-modality matching have provided overwhelming empirical support for the principle that the perceived magnitude of a sensory stimulus is a simple power function of its physical intensity (Stevens, 1975). This principle is embodied in the following functional form:

$$R = \alpha S^{\beta} \varepsilon$$

where R represents the subject's response, S represents stimulus intensity, α is a proportionality constant, β is the exponent which indexes the degree of curvature of the function (concave up if $\beta > 1$, concave down if $\beta < 1$ and linear if $\beta = 1$) and ε is a multiplicative error term, which accounts for the variability in responding over different presentations of the same stimulus. Stevens believed that this "power law" embraces a family of psychophysical functions, each one descriptive of the dynamic operating characteristics of a particular sensory mode or system or process for a specific individual making meaningful judgments about the psychological aspects of stimuli.

The purpose of the second experiment was to apply Stevens' power law to the relationships among stimulus intensity, perceived stimulus intensity, and amplitude of electrodermal response defined by the variety of measurement conventions described above in Experiment 1. We used the stimulus protocols designed by Cross to present auditory tones with six levels of intensity ranging from very soft (60 db SPL C) to very loud (110 db SPL C) in a magnitude estimation task, and we recorded electrodermal responses to each stimulus presentation. The aim of this experiment was to determine which index of electrodermal response amplitude is most closely related to the magnitude estimation of the stimuli.

Subjects

The subjects were 36 undergraduates recruited from the student body at the State University of New York at Stony Brook. They received credit toward a course requirement for their participation.

Apparatus

Electrodermal activity was detected by two Ag-AgCl electrodes placed on the medial phalanges of the first and second fingers of the non-dominant hand. Contact with the skin was made with .05 M NaCl solution in Unibase, as recommended by Fowles et al., 1981. A constant-voltage coupler was used to obtain electrodermal activity. The signals were amplified by a Grass Instruments low level DC preamplifier and then digitized (250 Hz) and stored on disk for analysis. A microcomputer controlled all aspects of the experimental procedure and also generated auditory stimuli, which were presented binaurally through a set of matched Sony headphones.

Procedure

Subjects were placed in a sound-deadened, electrically shielded room and instrumented for EDR recording. They provided informed consent, and they understood that they could resign from the experiment at any time without penalty. The headphones were placed on them and adjusted for comfort. All subjects were told that the experiment required them to sit still and listen to a number of tones presented at different levels of loudness. Their task was to estimate the loudness of each tone by using a computer mouse to expand and contract a circle that was depicted on the monitor in front of them. They received a period of training in the use of the mouse to reduce the circle to a small dot in the center of the screen, and continuously expand it to a circle that overran the size of the monitor. When they adjusted the circle to the size that they believed represented the loudness of the tone they clicked the mouse, and the computer stored the diameter of the circle in pixels.

All tones had a duration of 500 ms and were presented at 440 Hz at six different intensity levels ranging in 10 dB steps from 60 dB to 110 dB SPL, with a rise/decay time of 25 ms. These levels were chosen because they range from completely comfortable to moderately uncomfortable, or noxious. This is roughly analogous to the PDD examination, in which some of the questions asked are benign, while others may be threatening. All subjects were presented with an initial tone (t_1) used as a starting point, but not scored. The data analysis, which required assessing the influence of prior stimulation on the current response, was carried out on t_2 to $t_{37.}$ Each subject was presented with one of 36 unique different sequences of 36 tones comprising six repetitions of each of the six stimulus intensities. Furthermore, the six stimulus intensities were presented in such a manner that each stimulus appeared at least once in each serial position, and each stimulus followed each of the other stimuli, including itself, once. Stimuli were presented using a mean inter-trial interval of 20 sec., ranging quasi-randomly from 16 to 24 sec in increments of 2 sec. with stimulus onset defining the beginning of a trial and the mouse click denoting selected circle size determining the end of the trial.

Data Analysis

The numerical judgments of loudness and all the possible measures of EDR described above for Experiment 1, were analyzed separately by fitting the following general model to the data of each individual subject separately for each of the dependent variables:

$$R_t = \alpha S_t^{\beta} (S_{t-1} / S_t)^{\gamma} \varepsilon_t$$

where the subscript t denotes trial number (t = 2, ..., 37), R represents the subject's response, S represents stimulus intensity, α is a proportionality constant, β is the exponent which indexes the degree of curvature of the function, γ is the exponent of the degree of influence of the intensity of the preceding stimulus on the current stimulus, and ε is a multiplicative error term, which accounts for the variability in responding over different presentations of the same stimulus. Using doubly logarithmic coordinates, this equation reduces to the linear model:

$$Y_t = a + mX_t + \gamma X_{t-1} + e_t$$

where Y = log(R), X = log(S), a = log(α), e = log(ε), m = β - γ. The goodness of fit of this model for each dependent variable was evaluated by an analysis of residuals including tests of homogeneity of variance, normality and the independence of e_t and e_{t-1}. This model has been shown to be appropriate for judgments of loudness (Cross, 1973; DeCarlo & Cross, 1990).

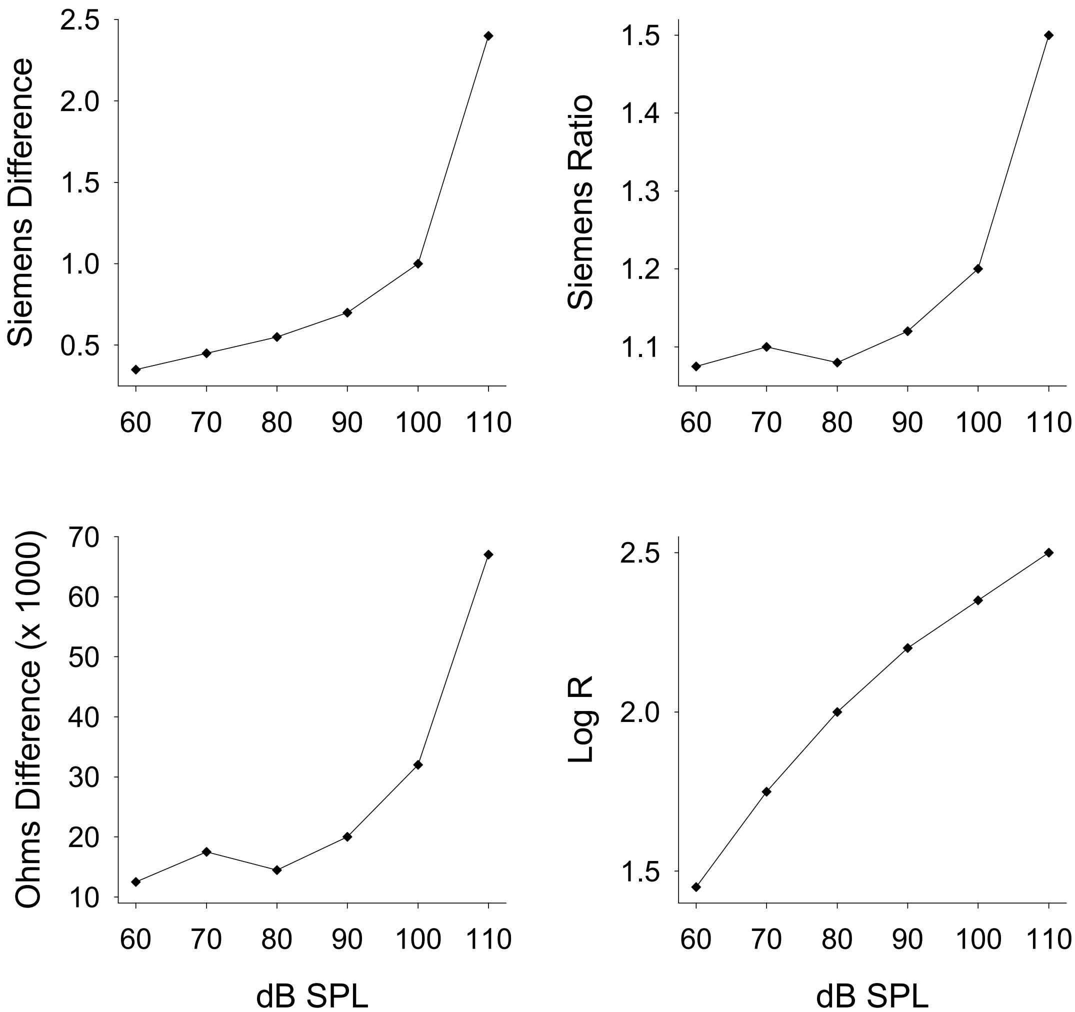
Results

Figure 4 depicts the relationship between tone intensity (db SPL) and magnitude estimation of intensity (logR) for all subjects across all tone presentations, as well as the relationship of tone intensity to uncorrected conductance change (siemens diff), uncorrected resistance change (ohms diff) and the baseline corrected measure, ratio of response amplitude (siemens ratio). The lower right quadrant indicates that the relationship between tone intensity and magnitude estimation of intensity is a smooth, primarily linear function, confirming that the subjects were able to discriminate the six intensities in a lawful and predictable manner.

The three graphs of electrodermal response as a function of tone intensity are essentially identical, and all three indicate that there was virtually no EDR response to tones lower than 90dB, and that the sharpest inflection in the curves occur between 100 and 110 dB.

Table 4 contains data for each of the 36 subjects individually describing the amount of variance of tone intensity that can be accounted for by subjective magnitude estimation (LogR) and the three indices of electrodermal response. The highlighted numbers represent the best fit of electrodermal index on tone intensity for a given subject. No particular index is consistently a better predictor than any other, although it appears that only 8 of the 36 subjects showed the best relationship between tone intensity and the baseline-corrected index of electrodermal response.

Figure 4



Discussion

The data indicate that the magnitude of electrodermal responses to auditory stimuli can be described as a positively accelerating function of intensity, and that they conform to a threshold law, with little or no response below 90db. The response magnitude increases rapidly between 100 and 110 dB, an area commonly described as “noxious.” The data on subjective magnitude estimation confirm that subjects discriminated the six stimulus intensities in a linear fashion; therefore, the lack of discriminative electrodermal responsiveness to low intensity tones may not be interpreted as a result of nondiscrimination of the stimuli.

The data also indicate that there is no apparent advantage to using any particular index of electrodermal response magnitude in favor of any other. All indices showed the same response curves with respect to stimulus intensity and subjective magnitude estimation of stimulus intensity. The data in Table 4 show clearly that for 13 of the 36 subjects the raw skin conductance measure accounted for more variance with respect to stimulus intensity than raw skin resistance or baseline corrected ratio responses. For 14 of the 36 subjects the raw skin resistance measure accounted for most of the variance with respect to stimulus intensity. For 8 of the 36 subjects the baseline corrected ratio response accounted for most of the variance. Finally, for one subject both the uncorrected skin conductance and the baseline corrected ratio responses were equally effective in accounting for maximum variance with respect to stimulus intensity. It should be noted that the differences in amount of variance accounted for between indexes was quite small, and the data indicate that there is no a priori reason to assume that any measure is more useful than any other for assessing the electrodermal response to stimulus presentations. This may be seen as general support for the current practices used in field polygraphy. Despite the preponderance of opinion within psychophysiological research publications that there is an advantage to assessing skin conductance responses, and a frequent admonition to account for tonic level when doing so, the current data do not confer an advantage to this procedure. Indeed, it is likely that any reliable assessment technique is as valid as any other.

Table 4. Variance of Response (R-squared) to Tone Intensity Accounted for by Magnitude Estimation and by Each of the Three Electrodermal Indices for Each of the 36 Subjects

Subj	LogR	Ohms Diff	Siemens Diff	Siemens Ratio
1	0.891	0.270	0.366	0.360
2	0.888	0.359	0.400	0.363
3	0.805	0.618	0.642	0.642
4	0.916	0.622	0.721	0.674
5	0.797	0.226	0.259	0.244
6	0.902	0.433	0.438	0.445
7	0.892	0.612	0.540	0.600
8	0.849	0.265	0.179	0.214
9	0.891	0.304	0.321	0.335
10	0.799	0.512	0.602	0.576
11	0.906	0.203	0.229	0.225
12	0.901	0.430	0.402	0.417
13	0.840	0.670	0.713	0.718
14	0.923	0.066	0.064	0.064
15	0.937	0.350	0.474	0.385
16	0.892	0.639	0.576	0.602
17	0.819	0.260	0.398	0.346
18	0.864	0.403	0.320	0.367
19	0.845	0.269	0.231	0.256
20	0.852	0.252	0.223	0.177
21	0.867	0.149	0.146	0.143
22	0.828	0.542	0.453	0.473
23	0.856	0.393	0.375	0.381
24	0.867	0.012	0.019	0.010
25	0.872	0.442	0.365	0.407
26	0.853	0.574	0.648	0.625
27	0.908	0.594	0.600	0.610
28	0.871	0.410	0.476	0.465
29	0.906	0.500	0.311	0.426
30	0.880	0.423	0.223	0.226
31	0.941	0.235	0.398	0.344
32	0.868	0.276	0.217	0.308
33	0.922	0.620	0.726	0.700
34	0.862	0.057	0.022	0.059
35	0.926	0.787	0.841	0.847
36	0.883	0.803	0.747	0.790

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Appendix 1

Correlations Between Tonic Electrodermal Levels and Response Magnitude for Conductance, Resistance, and Ratio Responses For Each of the Three Series of Standard Tones

Stimulus Tone Number	Tone Series 1 (N = 56) *r*	α	2 (N = 52) *r*	α	3 (N = 53) *r*	α
Conductance Response Amplitude						
1	-.184	.174	.313	.024	.449	.001
2	.289	.031	.294	.034	-.104	.459
3	.416	.001	.251	.073	.425	.002
4	.344	.010	.287	.039	.137	.328
5	.426	.001	.309	.026	.237	.087
6	.323	.015	.346	.012	.369	.007
7	.264	.049	.506	.000	.360	.008
8	.477	.000	.123	.385	.074	.599
9	.305	.022	.441	.001	.262	.058
10	.392	.003	.410	.003	.062	.660
Resistance Response Amplitude						
1	.867	.000	.415	.002	-.056	.690
2	.816	.000	-.023	.873	.173	.217
3	.485	.000	.329	.017	.016	.908
4	.265	.049	.004	.975	-.086	.538
5	.184	.174	.104	.463	.014	.922
6	.238	.077	.235	.094	-.083	.555
7	.053	.696	-.038	.789	-.018	.899
8	.516	.000	-.089	.532	-.061	.666
9	.415	.001	.299	.031	-.094	.502
10	.254	.059	.260	.063	.025	.858
Ratio Response Amplitude						
1	-.270	.044	-.067	.638	.203	.145
2	-.264	.050	.064	.654	-.200	.152
3	-.067	.621	-.087	.539	.011	.938
4	.011	.937	.075	.596	.032	.821
5	.174	.200	.147	.298	.028	.841
6	-.016	.905	.072	.614	.272	.049
7	.047	.729	.284	.041	.082	.559
8	-.056	.682	.064	.652	-.035	.804
9	-.013	.925	-.080	.575	.175	.210
10	.085	.532	-.022	.877	-.124	.376