

ELECTRODERMAL ACTIVITY (EDA) — STATE-OF-THE-ART MEASUREMENT AND TECHNIQUES FOR PARAPSYCHOLOGICAL PURPOSES

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ABSTRACT: In most of the direct mental interactions with living systems (DMILS)/Remote Staring studies, electrodermal activity (EDA) is the only dependent variable. Therefore the quality of EDA recording is crucial. This is the reason why we studied EDA-related literature and contacted some of the leading psychophysiological labs in Germany to debate critical topics of the EDA measurement. We also checked the Methods section of all studies using EDA data published from 1995 to 1999 in the leading psychophysiological journals. In addition, we surveyed all DMILS/Remote Staring publications using EDA to find out whether parapsychologists adhere to these standards. In the first part of our paper we outline a current state-of-the-art EDA methodology. We also address various technical problems and describe sources for potential artifacts. In the second part we compare 24 DMILS/Remote Staring with a sample of 39 recent psychophysiological studies published in *Psychophysiology* and *International Journal of Psychophysiology*. The analysis reveals that parapsychologists do not meet the current standards. There is not even one study conducted by parapsychologists which refers to psychophysiology's measurement standards published in 1981. Therefore, DMILS/Remote Staring data may either contain artifacts, or, on the other hand, may not detect the supposed effects. Although there is an ongoing trend of finding irregularities in EDA data of DMILS/Remote Staring experiments that can be related to different intentional conditions, there have not been any efforts to understand the results of EDA experiments or to address the origin of the irregularities in detail.

INTRODUCTION

Since the early 1970s psychophysiological variables have been given growing importance in parapsychological research. Electrodermal activity (EDA), with its high lability, freely varying activity (Braud & Schlitz, 1991) and ability to map the orienting response (OR) has shown to be a promising outcome measure in experimental studies such as direct mental interaction with living systems (DMILS) and Remote Staring or pre-sentiment experiments.

¹ We thank all the researchers who helped us in understanding psychophysiological principles and spent their time debating the subject with us. We are especially grateful to Dr. Florian Schaefer, Dr. Jiri Wackermann, PD, Dr. Martin Peper, and Prof. Dr. Jochen Fahrenberg, who also greatly helped us with the literature. This work is funded by the Institut für Grenzgebiete der Psychologie und Psychohygiene, Freiburg.

Therefore, some psychophysiologicalists are getting more and more interested in parapsychological research, and there is an advantageous exchange between those disciplines. But this exchange presupposes that the parapsychological community is willing to use EDA measurement, equipment and techniques that are state of the art from a psychophysiological point of view.

The psychophysiological community developed its standards for EDA measurement in the 1970s and published them in the beginning of the 1980s (Fowles et al., 1981; Lykken & Venables, 1971; Venables & Christie, 1980). In the 1990s, the fast progress in computer processing brought about a change in signal scoring and recording changing from polygraph and ruler to digital data recording and electronic analysis. This development enabled new possibilities of parametrization but left the measurement principles untouched.

In addition to using a technique that is also acceptable for researchers working in other disciplines than parapsychology, it is a required standard in every parapsychological publication to provide a detailed and clear description of the techniques and procedures which have been used. The reason for that is first to meet the scientific standard which in turn ensures a replication of that study with the information provided in the publication. Second, such description is necessary for future meta-analyses. Meta-analyses are becoming increasingly important because, in addition to the mean main effect size over a large body of studies, they provide detailed correlations between study characteristics and effect sizes (see e.g., Bem & Honorton, 1994; Honorton & Ferrari, 1989). For identifying study characteristics and applying quality ratings, detailed descriptions are necessary, even if they look very obvious.

Therefore, we will report the state of the art techniques with regard to EDA measurement in detail as they should be used in any experimental study that wants to meet these criteria. In a following section we will compare the Methods sections of studies using EDA published in psychophysiological and parapsychological journals. Finally, we want to make some suggestions for future publications.

METHODS

We checked and compared the literature on EDA measurement, had international contacts with different psychophysiologicalists and visited two of the leading psychophysiological labs in Germany for debating critical topics of EDA procedures. These labs are the psychophysiological departments of the Universities of Wuppertal (director: Prof. Boucsein) and Freiburg (director: Prof. Fahrenberg). We also checked the Methods section of all studies using EDA published from 1995 to 1999 in the two leading psychophysiological journals (*Psychophysiology* and *International Journal of Psychophysiology*) and checked all DMILS/Remote Staring studies using EDA as a dependent variable.

EDA METHODOLOGY

The EDA measurement itself is not very difficult, if someone understands the underlying basic principles. These are the conditions and characteristics of electric activity of the skin, as well as the principles of recording and scoring electrical signals from the human body.

Physiological Principles

There are two phenomena regarding the electric activity of the skin. One is the skin potential. This stands for the skin's own electric activity without applying any external electric current (endosomatic measurement). The underlying principles of this phenomenon are not yet fully understood.

Exosomatic measurements refer to the phenomenon of changing electrical properties in the skin when an external voltage is applied. The application of a direct current (DC) constant voltage probe signal to the skin results in a current flow that changes over time. This measurement principle is called *skin conductance*. There are three more measurement principles (*skin admittance*, *skin resistance*, *skin impedance*) according to different probe signals (alternating current [AC] constant voltage, DC constant current, AC constant current). This change of electrical properties of the skin is strongly related to the activity of the eccrine sweat glands that are predominant on the palmar surfaces and feet. The production of sweat on these surfaces is ontogenetically related to grasping behavior, and it is quite clear that this moistening of the skin is responsible for the change in conductance. But moistening cannot be the only factor, as the skin's electrical properties often change faster than expected by this hypothesis. For further details on the underlying principles, see Boucsein (1992) and Vossel (1990).

Measurement of Skin Conductance

If EDA is used as the dependent variable, then usually skin conductance is the appropriate method. Since parapsychologists always use EDA as an indicator (e.g., for psi) we will only describe the procedures for skin conductance in detail.

Nomenclature. Skin conductance is usually measured in "Siemens" units although sometimes "mho" is used. As the conductivity of the skin is very small, values are usually given in microsiemens (μS) or micromho (μmho) ($1 \mu S = 1 \mu mho$). In measuring skin conductance, one can distinguish two different principles: *phasic* and *tonic* ones. A tonic value stands for an activity that shows a certain amount of continuity over time. The tonic component of skin conductance is the *skin conductance level* (SCL). SCL is obtained by measuring the total amount of skin conductance and is related to a person's overall arousal. In contrast to tonic values, a phasic value stands for the change of the skin conductance within a short time

period as a reaction toward a discrete stimulus. If a stimulus elicits an orienting response, the skin conductance rises for a certain time period and then returns to normal. This is called a *skin conductance response* (SCR). SCRs can be characterized by four different parameters (see Fig. 1): the amplitude (SCR amp.), latency of response onset (SCR lat.), the rise time up to the response peak (SCR ris. t.), and the half time value of the recovery time (SCR rec. $\frac{1}{2}$).

Sometimes, even if no stimulus is presented, there are some responses in the SC-curve. Those responses are called nonspecific skin conductance responses (NS.SCR).

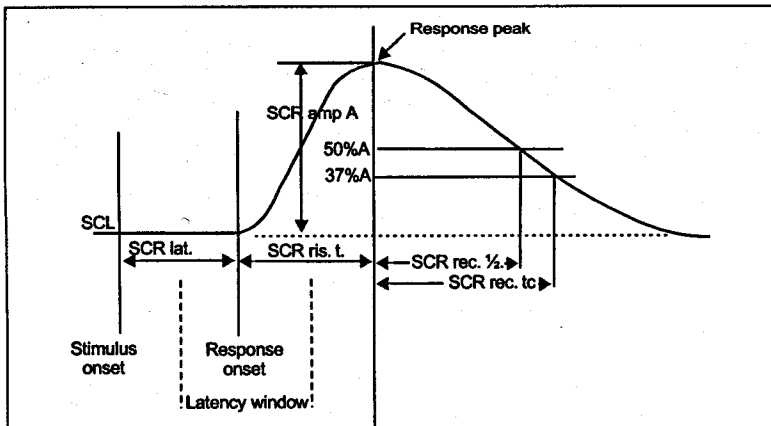


Figure 1. Schematic skin conductance response. Note. From *Techniques in physiology* (p. 9), by I. Martin & P. H. Venables (Eds.), 1980, Chichester, UK: John Wiley & Sons, Ltd. Copyright 1980 by John Wiley & Sons, Ltd. Reprinted with permission.

Skin Resistance (SR) is a variable which was commonly used in EDA measurement until the 1970s. It requires a different measurement principle (see above). Skin resistance is reciprocal to skin conductance. The unit of SR is Ohm (Ω) with $1 \text{ M}\Omega = 1/1 \mu\text{S}$. But for reasons related to the different measurement principles and the electrical properties of the skin, the hypothesis of linear relationship between changes in the skin and the resulting resistance from the measurement cannot be maintained (Lykken & Venables, 1971). Therefore, it is recommended that researchers use skin conductance only.

Additionally, terms like galvanic skin response (GSR) or psychogalvanic response (PGR) should no longer be used, as they do not describe the applied measurement principle in a sufficient way (Schandry, 1989).

Electrodes. There are two important demands on the use of electrodes. One is a minimal bias potential between pairs of electrodes. The other is that the electrodes should not polarize upon the passage of a current (Fowles et al., 1981). The best values for both demands are found

with reversible silver/silver chloride (Ag/AgCl) electrodes (Venables & Christie, 1980). Most commonly, they are used as disk electrodes. There are different recommendations in the literature according to the size of the electrodes. This is not a trivial question, as Venables & Christie (1980, p. 33) report a "... non-monotonic relation between SCL or SCR and electrode area . . .," but they found no changes in electrodes larger than 10mm in diameter. Fowles et al. (1981) recommend an area of 1cm² (= 11mm diameter). Boucsein (1992) cites this recommendation but states that the commercially available electrodes are smaller (8–9mm). A look at recent publications shows that 76% of the researchers reporting their electrode size use electrodes with 8, 9 or 10mm in diameter.

For cleaning and maintaining, it is important to take care of the surface layer of the electrodes. They should never be touched or cleaned mechanically. The paste has to be washed out immediately after use under flowing water or with the use of a water pik. Depending on local water conditions, rinsing the electrodes with distilled water to avoid calcium stains might be necessary. After cleaning the electrodes it is recommended that they be air dried (Boucsein, 1992, p. 106).

Electrode Sites. Possible electrode sites are the feet and palms. Choice of sites is determined by the experimental task. If the participant does not need both hands for the task, attachment to the palms is the most convenient. Usually, the nondominant hand is preferred. Possible sites on the palms are the medial phalanges or the thenar and hypothenar eminences (see Fig. 2). The aim of a good electrode attachment is to obtain a constant contact area. The electrodes must be attached in such a way that

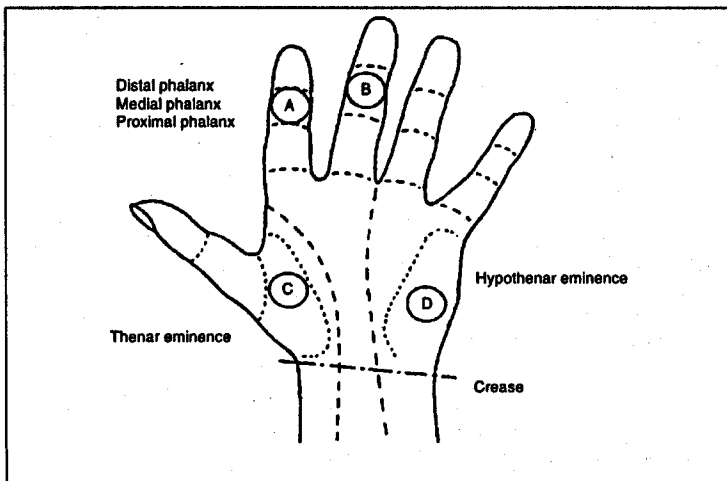


Figure 2. Preferred palmar or volar electrode sites (A-D) Note. From *Electrodermal activity* (p. 97), by W. Boucsein, 1992, New York: Plenum Press. Adapted from I. Martin & P. H. Venables (Eds.), *Techniques in physiology* (p. 29). Chichester, UK: John Wiley & Sons, Ltd. Copyright 1980 by John Wiley & Sons, Ltd. Reprinted with permission.

they do not drop off after a couple of minutes as the result of movement or sweating. Both conditions are easier to achieve at the flat area of the palm than at the fingers. This may be the reason why some researchers now recommend the thenar and hypothenar eminences, although the experiments reported below show a clear trend (71%) toward placement on the fingers.

There are different opinions regarding the pretreatment of the electrode sites. Dawson, Schell & Fillion (1990, p. 302) suggest that participants are "asked to wash their hands with a nonabrasive soap prior to having electrodes attached." With this treatment, the skin gets cleaned from dirt and oil but also from natural sweat. Boucsein (1992) recommends no treatment at all except for participants with very oily skin, where a little bit of alcohol should be used to clean the site for better adhesion of the electrodes.

Electrode Attachment. The electrodes should be attached to the skin by double-sided adhesive collars. Constancy of the contact area is guaranteed by the size of the hole cut into the collar if seepage of the electrode paste can be avoided. A reasonable procedure is to fix the collar to the rim of the electrode first and then to fill the electrode with the electrode paste. A spatula can help to avoid air bubbles in the space between electrode and skin or seepage of the paste over the rim (see Fig. 3). After that the paper on the other adhesive side of the collar has to be removed and the electrode can be glued to the skin.

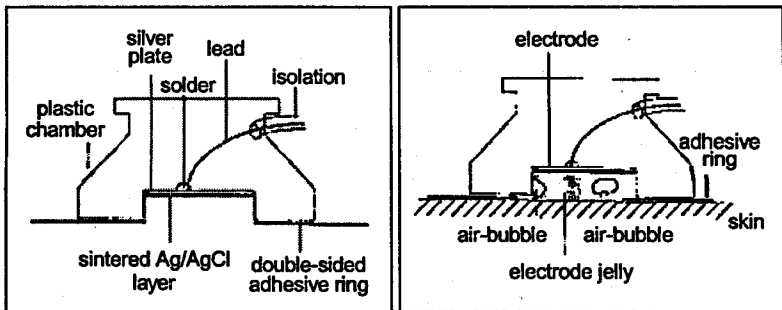


Figure 3. Cross-section of Ag/AgCl electrode (left) and effects of displacement of the electrode chamber on the adhesive ring, and of air bubbles in the electrode paste (right). Note: From *Electrodermal activity* (pp. 102-103), by W. Boucsein, 1992, New York: Plenum Press. Copyright 1992 by Plenum Press. Reprinted with permission.

Attaching the electrodes by a velcro fastener or adhesive tape is not recommended. With this technique, a change of the contact area over time cannot be avoided. Apart from that, any mechanical pressure upon the electrodes produces artifacts in the curve, the so called Ebbecke-waves (Boucsein, 1992, p. 102). If the electrodes are attached by velcro, any tiny muscle movement changes the mechanical pressure upon the electrodes

and can, in addition, elicit variations in local circulation. This might lead to changes in skin conductance which have to be regarded as artifacts (Boucsein, 1992; Schandry, 1989).

For the same reason, any mechanical movement of the electrode by a strain of the cable should be avoided. Therefore it is possible to lead the cable in a loose way from the electrode sites over the wrist to the inner side of the forearm and to fix it there with an adhesive tape. This process needs to be controlled so that there is no mechanical pressure upon the electrodes as the result of strain on the cable or flexing of the wrist.

Electrode Paste. If one wants to record electrical signals produced by the body such as EKG, EEG or EMG, an electrode paste with a high conductivity is required. This is the reason why electrolytes used for that purpose are hypertonic. In contrast, EDA measurement demands an electrode paste that minimizes any interactions between skin and electrolyte. Therefore, EDA electrode gels have to be isotonic (i.e., with the same ion concentration as the sweat). The use of electrode paste for EKG, EEG or EMG is not suitable for EDA measurement and will result in changes in skin conductance (Boucsein, 1992, pp. 106-107).

Most authors recommend the use of an electrode paste that is based on Unibase as a medium. Therefore, Unibase is mixed with a certain amount of NaCl or KCl and distilled water resulting in a paste with 0.05 molar concentration. For detailed instruction, see Boucsein (1992, p. 108), Lykken and Venables (1971, p. 665), Fowles et al. (1981, p. 235), Venables and Christie (1980, pp. 35-36).

A recent message by Prof. Boucsein reports that Unibase is no longer produced. Therefore, Prof. Lykken and Med-Associates (USA) have developed a similar isotonic EDA paste named "EC-33 skin conductance electrode paste." This product consists of 0.5% NaCl in a neutral medium named TDE-246. It is distributed by Grass (USA) and by PAR Medizintechnik (Germany).

The use of 0.05 molar electrode paste does not guarantee, of course, that it exactly matches the skin's ion concentration. Thus, it is necessary to attach the electrodes at least 10 minutes, preferably 15-20 minutes (Boucsein, 1992, p. 108) before the beginning of the recording. By doing so, initial drifts of the skin conductance resulting from adaptation of the skin-electrolyte interface can be avoided.

Environmental Conditions. Boucsein (1992) recommends that EDA data be recorded with an environment temperature between 25-26°C / 77-78.8°F (thermoneutral zone). Other researchers ask for at least 23°C / 73.4°F (Schaefer, personal communication) or 24°C / 75.2°F (Peper, personal communication) but none of these recommendations is based on empirical evidence. A relative humidity of 50% is regarded as suitable. Participants should feel comfortable with climatic conditions.

Signal Recording

Skin conductance is measured by applying a constant voltage to the two electrodes. The change in conductance results in a change in the amount of electrical current flowing between the electrodes. As both electrodes are placed on active sites, this is called a bipolar measurement. For the constant voltage, 0.5V is recommended by Edelberg (1967, p. 25) and all researchers (Boucsein, 1992; Fowles et al., 1981; Schandry, 1989; Venables & Christie, 1980) keep to that standard.

The signal has to be converted from a change in electric current to a change in voltage. This is usually done by the SC measurement unit. If the signal is coded in changing voltage it can be amplified by any conventional bioamp.

Signal Splitting. Since one wants to obtain two different signals, the phasic SCR and the tonic SCL, the signal has to be split up. There are two possible ways to achieve this. In order to record the signal by a computer, it has to be converted from an analog to a digital signal. If the digital signal is recorded with a width of 16 bit (65536 possible values) or higher, the resolution is good enough to record the signal in one channel. The splitting can be done any time later by an appropriate software (off-line method). With a width of 12 bit (4096 possible values) the resolution is too low and the signal has to be split on-line while measuring, resulting in a recording of two channels. For on-line splitting, a special EDA-coupler can be used.

The splitting is done by a special filter using the different characteristics of SCL and SCR. While the tonic SCL shows only a very slow drift over time, the SCR changes much faster. By treating the signal with a time constant of 10 sec, the SCL can be suppressed and the pure SCR remains. A time constant of 10 sec is equivalent to a high-pass filter of 0.016 Hz, suppressing changes which are slower than this frequency and leaving the faster ones untouched.

Amplifying, Digitalization and Recording. Depending on the mode of recording, the signal has to be amplified for feeding a polygraph or digitized for recording on hard disk. Digitalization means breaking down continuous information flow into discrete information spots. For analysis, it should be possible to reestablish the original curve from those spots. For EDA recording, a sample frequency of 15-20 Hz is sufficient. But the signal has to be treated with a low-pass filter not higher than half (Nyquist rate) of the sampling frequency (Shannon's sampling theorem, see Hesselmann, 1991, p. 66), otherwise the reconstruction of the curve from digital data may contain artifacts. The use of low-pass filters down to 5 Hz filters out noise and leaves even fast EDA responses untouched.

Signal Scoring

Parametrization depends on research interest. For DMILS/Remote Staring, only tonic parameters are necessary as there are no specific stimuli and we are usually interested in the participants' arousal during different epochs. Tonic parameters can be derived from both channels.

There are three different tonic parameters: SCL, frequency of NS.SCR, and the sum of all amplitudes of NS.SCR.

Skin Conductance Level (SCL). The actual SCL of a participant can be taken as single spot measurement. If using a single spot measurement, it is necessary to take care that it is not within a SCR. Boucsein (1992) recommends a displacement of 10-30 sec. Another method is to calculate the mean of all data within a certain time interval. This parameter will be somewhat overestimated in very aroused participants due to SCRs within the interval. Venables & Christie (1980) have published SCL-data of large samples sorted by age though they were recorded by very small electrodes (4mm diameter).

Frequency of Nonspecific Skin Conductance Response (NS.SCR.freq). From time to time, the skin conductance curve of participants in resting conditions shows phasic variations which cannot be related to any specific stimulus. The frequency of these nonspecific responses is also related to the participant's arousal and can be regarded as a tonic parameter. To obtain NS.SCR.freq, it is necessary to record skin conductance over a time period where no external stimuli are applied. The length of the time period varies between two and five minutes in different studies (Martínez-Selva, García-Sánchez & Florit, 1995; Siddle, Lipp & Dall, 1997; Vossel, 1990). Most researchers display NS.SCR.freq in number of responses per minute. The number of responses varies between subjects within a wide range. Vossel (1990), who did extensive research on this parameter, divided his sample by median split in stable (low NS.SCR.freq) and labile (high NS.SCR.freq) subjects. To compare values, it is necessary to define a threshold for SCR amp. Every NS.SCR rising higher than this threshold will be taken into account for NS.SCR.freq. Thresholds used in different studies reach from 0.3 μS (Fahrenberg & Foerster, 1982) down to 0.015 μS (Clements & Turpin, 1995), with a majority of researchers using 0.05 μS . The threshold should not be lower than three to four times of the measuring device's highest resolution to avoid noise scored as NS.SCR. Schaefer (personal communication, 1999) recommends thresholds below 0.01 μS should not be used, and states that according to the experimental task and the research interest, it might be reasonable to deliberately choose a higher threshold. There are two large samples with data on NS.SCR.freq published: Vossel (1990) used a threshold of 0.02 μS in 217 subjects, Fahrenberg et al. (1979) present a sample of 125 males with a threshold of 0.3 μS .

Sum of amplitude of NS.SCR. If the parameter NS.SCR.freq is measured and calculated, it is easy to add another parameter. Instead of only counting every NS.SCR exceeding a certain threshold, one can also take into account the size of the reaction by summing up all SCR amp.

All three parameters describe different aspects of arousal; for research interest it is useful to calculate all of them. To avoid multiple testing, it might be reasonable to determine in a preliminary study which parameter is the most sensitive to a certain experimental task (for instance DMILS). Another solution is the calculation of a specific tonic score by combining all three variables in a certain way.

Artifact Control

Artifacts may stem from different sources. Ebbecke waves caused by mechanical pressure on the electrodes or on the skin surrounding the recording sites have already been mentioned. But body movements and irregular respiration may also generate SCRs. In addition, there might be electronic noise generated by the different technical devices which is transmitted through the participant's body and the electrode cable to the coupler.

There are two ways to deal with artifacts. The first one is to avoid any possible source. Therefore, participants should be requested to move the arm or the hand, where the electrodes are attached, as little as possible. Allowing the participants enough time to find a comfortable position for the arm as well as for the whole body at the beginning of the experiment, is helpful for that purpose (Schandry, 1989).

The other way to deal with artifacts is to eliminate them from the data. All artifacts with high frequency characteristics as electronic noise, EMG or AC frequency of the power supply can be filtered out by a low-pass filter. Therefore, a low-pass filter of 5 Hz should be applied in all cases. Depending on the requested parameters, even smaller low-pass filters can be used. Ebbecke waves can be detected by visual control during parametrization. The recording period may be either treated as missing data, or artifacts may be suppressed by low-pass filter frequencies of 1 Hz or smaller (Schaefer, personal communication). SCRs produced by irregular respiration or by setting stimuli to the subject's body like tongue biting cannot be visually detected and therefore filtered out. Thus, for the elimination of respiration artifacts, it is necessary to record respiration activity in a separate channel. It seems to be good standard within the psychophysiological community to record respiration for artifact control although there are no guidelines how to deal with SCRs caused by irregular respiration. Boucsein (1992, p. 125) states that whether these SCRs are regarded as artifacts or "... can be interpreted as covarying indicators of the psychological changes under investigation depends mainly on the question being investigated."

It looks like there were different possibilities regarding the problem of artifacts. In our opinion, it is important that the choice of artifact

treatment is made upon proper understanding of the underlying principles and is well reported in any publication.

The most important literature for the understanding of the electrodermal system and the methodology that can be applied to it, is the book *Electrodermal Activity* by the German psychophysiologicalist Wolfram Boucsein (1992). In this monograph, the author describes almost all possible methods, techniques, procedures and problems without favoring any of them. Nevertheless, there have been certain choices made by psychophysiologicalists in the last 30 years forming today a good standard of EDA methodology. We have investigated these standards by scrutinizing papers which recommend certain methodologies, by evaluating the Methods section of recently published papers and by discussions with psychophysiologicalists. This methodology is widely accepted and also used in the lab of Prof. Boucsein in Wuppertal, Germany. Any writer submitting a paper to an accepted mainstream psychophysiology journal will have to satisfy possible referees subscribing to this standard. The results of our literature survey in the next section will clarify this picture.

EDA IN PUBLICATIONS

Standardization of EDA procedures started in the late 1960s with a number of proposals by Edelberg (1967). In 1971, Lykken and Venables recommended a new terminology using SCL and SCR instead of the less specific GSR or BSR. They also suggested measurement of skin conductance instead of resistance and described a recipe for an isotonic paste. Venables and Christie (1980) addressed almost all procedures for EDA and presented a large sample of EDA data. In 1981, a Committee Report (Fowles, Christie, Edelberg, Grings, Lykken & Venables) entitled "Publication Recommendations for Electrodermal Measurements" was published in *Psychophysiology*. They recommended, among other things: SC measurement, the use of isotonic paste (0.05M NaCl in Unibase), 0.5V constant voltage, sites on medial/distal phalanges or thenar/hypothenar eminences and Ag/AgCl electrodes with a contact area of 1cm^2 ($\approx 11\text{mm}$ \varnothing), if possible.

We checked all DMILS/Remote Staring publications using EDA to see whether they meet these criteria. Furthermore, we also analyzed a sample of recent psychophysiological studies for comparison purposes to find out which standards are predominant in the psychophysiological labs 15 years after the publication of those criteria.

Psychophysiological Studies

We searched the Psychlit database to find all studies published from 1995 to March 1999 in *Psychophysiology* or *International Journal of Psychophysiology* containing EDA or EDA-related terms. We found 39

studies using EDA as a dependent variable, describing 40 methodologies (as two different techniques are described in one study). We checked the Methods section for technical equipment, procedures, measurement principles and scoring methods (see Table 1).

It can be seen from Table 1 that the basic standards proposed in Fowles et al. (1981) were met by these studies. All researchers reported their measurement principle and 36 (90%) out of 40 used skin conductance (SC). Only 64% reported their voltage for SC measurement; 96% of them used 0.5V. Thirty-four (85%) used Ag/AgCl electrodes with a size varying from 4-16 mm in diameter (see section 3.2). Different electrode sites were used. Seventy percent (28 out of 40) preferred electrodes attached to the fingers; 28% (11 out of 40) reported electrodes attached to the palms. Phalanges were chosen 11 (medial) and 10 (distal) times each. Nine experimenters placed both electrodes on the hypothenar eminence; two studies placed the electrodes on the hypothenar and thenar eminence.

Thirty-five authors described their electrode paste, and apparently all of them took care to use a paste with an isotonic character. We were surprised that only two studies described whether there was a sufficient time lag between electrode placement and start of data recording. Site pretreatment was reported only in 20% of all cases and the methods were quite different. It seems that there are still different opinions and that no fixed standard exists. Climatic conditions were reported by only four researchers, and they did not meet the recommended values exactly.

All studies describe exactly which parameters they use. Tonic parameters as required for DMILS studies were calculated in 20 (50%) of the publications. Fifteen authors used NS.SCR with different thresholds ranging from 0.02-0.2 μ S, but a majority of 10 researchers chose 0.05 μ S. Artifact control and correction seems to be a difficult topic within the psychophysiological community. Some researchers report that they recorded respiration for artifact control or that they conducted a movement control. But no one describes an exact procedure of how artifacts were dealt with.

The applied and published techniques in psychophysiological studies were not as homogenous as we expected. Possible reasons for this might be that EDA is very often only one in a set of psychophysiological variables and therefore the description of the procedures is short. Another reason is that only some, but not all, topics are standardized. In our opinion, there are insufficient standards for artifact control, climatic conditions in the lab, and site pretreatment. Furthermore, good publications apparently do not require details on these topics, nor do they ask for specifics on the time lag between electrode attachment and data recording.

DMILS/Remote Staring Studies Using EDA

We found 25 DMILS/Remote Staring publications (including proceedings) describing experiments using EDA as a dependent variable.

Table 1
 Overview on reported EDA procedures in experiments using EDA published from 1995 to March 1999 in
Psychophysiology or International Journal of Psychophysiology.

Study	Year	Prin- ciple	Volt- age	Electrodes	Elec. size ¹	Electrode paste	Site	Sample Scores freq.	Remarks
Ben-Shakhar et al.	1995	SC	0.5	Ag/AgCl	8	physiological saline mix in Unibase	fingers	1000 SCR	electr. paste according to Fowles et al (1981). Electrodes attached by masking tape
Ben-Shakhar et al.	1996	SC	0.5	Ag/AgCl	8	physiological saline mix in Unibase	fingers	20 SCR	electr. paste according to Fowles et al (1981). Electrodes attached by masking tape
Blair et al.	1997	SC		Ag/AgCl	10	KY lubricant jelly	medial phalanges	SCR	
Bryant et al.	1995	SC		Ag/AgCl			distal phalanges	SCL, SCR	
Cuthbert et al.	1996	SC					hypothenar	SCR	
Elaad et al.	1997	SC	0.5	Ag/AgCl	8	K-Y jelly		1000	
2nd Exp. by Elaad et al. in same pub.	SR			steel elec- trodes		electrode paste no paste	fingers	SRR	
Fredrikson et al.	1995	SC		Ag/AgCl	8	isotonic 0.5% NaCl/100ml H2O	medial phalanges	NS,SCR threshold 0.05 μ S	
Fredrikson et al.	1998	SC		Ag/AgCl	8	isotonic 0.5% NaCl/100ml H ₂ O	medial phalanges	NS,SCR threshold 0.05 μ S	
Gati et al.	1996	SC	0.5	Ag/AgCl	8	physiological saline mix in Unibase	fingers	1000 SCR	electr. paste according to Fowles et al (1981). Electrodes attached by masking tape
Globisch et al.	1999	SC	0.5	Ag/AgCl	8	0.05 M NaCl electrolyte	hypothenar	SCR	
Hamn et al.	1997	SC	0.5	Ag/AgCl	8	0.05 m NaCl electrolyte	hypothenar	SCR	
Hamn et al.	1996	SC	0.5	Ag/AgCl	8	0.05 M NaCl electrolyte	hypothenar	SCR	
Honts et al.	1996	SR		steel elec- trodes		no paste	fingers	SRR	
Kirsch et al.	1995	SC		Ag/AgCl	9	0.9% NaCl in Unibase	thenar/hypothenar	SCR	
Kronholm et al.	1996	SC	0.5	Beckman	10	0.05 M NaCl electrolyte	medial phalanges	NS,SCR threshold 0.02 μ S, SCR	electrodes attached 20 min before start of experiment
Laan et al.	1995	SC	0.75 ²	Ag/AgCl	11	0.05 M NaCl Unibase	medial phalanges	SCR	
Lenz et al.	1996	SC		Ag/AgCl			medial phalanges	SCR	
Lipp et al.	1997	SC	0.5	Ag/AgCl		0.05 M NaCl electrolyte	distal phalanges	NS,SCR threshold 0.05 μ S, SCR	
Lipp et al.	1998	SC	0.5	Ag/AgCl		0.05 M NaCl electrolyte	distal phalanges	SCR, NS,SCR	

¹ diameter in mm
² in Hz
³ alternating current voltage

Table 1 (continued)
 Overview on reported EDA procedures in experiments using EDA published from 1995 to March 1999 in
Psychophysiology or International Journal of Psychophysiology.

Study	Year	Prin- cipal	Voltage	Electrodes	Elec. size	Electrode paste	Site	Sample frequ.	Scores	Remarks
				Ag/AgCl	II		distal phalanges		SCL, SCR	used medical tape for electrode attachment
Mangina et al.	1996	SC	0.5	Ag/AgCl	8	0.9% NaCl in 45:46 Unguentum Merck cream	medial phalanges		SCR	
Mason et al.	1997	SC		Ag/AgCl	8	0.05 M NaCl electrolyte	distal phalanges		NS.SCR, SCR	
Mazurski et al.	1996	SC		Ag/AgCl		0.05 M NaCl electrolyte	distal phalanges		SCR, SCL	
Parrick et al.	1995	SC		Ag/AgCl	10	Ke-Y lubricating jelly	hypothenar	200	SCR	
Saban et al.	1995	SC	0.5	Ag/AgCl	8	0.05 M NaCl in Unibase	medial phalanges		SCR	
Schell et al.	1995	SC	0.5	Ag/AgCl	10	0.05 M NaCl paste	distal phalanges		NS.SCR threshold	
Siddle et al.	1997	SC	0.5	Ag/AgCl		0.05 M NaCl electrolyte	distal phalanges		0.05 μ S, SCR	
Siddle et al.	1996	SR	0.5	Ag/AgCl		0.05 M NaCl electrolyte	fingers		SCR, NS.SCR thresh- old 0.05 μ S	
Stieptoe et al.	1997	SR		Ag/AgCl			thenar/hypothenar		NS.SRR threshold 2k Ω	
Taylor et al.	1999	SC	0.5	Ag/AgCl	10	0.5 M NaCl electrolyte in Unibase	distal phalanges		NS.SCR threshold 0.05 μ S SCR	data filtered with 3 Hz low pass
Travis et al.	1997	SR ¹	10 μ A	Ag/AgCl	10	Ke-Y jelly	distal phalanges		SCR	
van Oyen	1995	SC	0.5	standard electrodes		physiological saline mix in Unibase	hypothenar	10	SCR-SCL	electr. paste according to Fowles et al 1981
Witvliet et al.										
Vansteernwegen et al.	1998	SC	0.5	Ag/AgCl	10	isotonic Unibase electrolyte	hypothenar	25	SCR	
Venables	1997	SC		Beckman	4	0.5% KCl in 2% agar-agar	medial phalanges		NS.SCR threshold 0.05 μ S, SCR, SCL	data recorded in early seventies in Mauritius
Venables	1998	SC		Ag/AgCl	4	0.5% KCl electrolyte	medial phalanges		SCR, SCL, NS.SCR threshold 0.05 μ S	data recorded in early seventies in Mauri- tius, refers to earlier publication for recording methods.
Vögle	1998	SC		Ag/AgCl		isotonic cream	hypothenar		SCL	
Vrana	1995	SC	0.5	Ag/AgCl		Ke-Y jelly	hypothenar	10	SCR	
White et al.	1997	SC	0.5	Ag/AgCl	5	NaCl in Unibase	fingers	20	NS.SCR threshold 0.05 μ S	electr. paste according to Fowles et al (1981).
Wilhelm et al.	1998	SC	0.5	Ag/AgCl	16	isotonic electrode paste	medial phalanges	6	NS.SCR threshold 0.2 μ S, SCL	electr. paste according to Fowles et al (1981). Ambulatory recording in airplane. Disposable electrodes
Zahn et al.	1996	SC	0.5	Ag/AgCl	8	0.5% KCl electrode paste	distal phalanges		SCR, SCL, NS.SCR threshold 0.02 μ S	electrodes attached at least 10 min before start of experiment

¹ skin resistance measured then converted to SC

We omitted the two meta-analyses (Braud & Schlitz, 1991; Schlitz & Braud, 1997), but we kept an overview in the *Journal of Scientific Exploration* (Braud & Schlitz, 1989) as it described technical details on EDA recording.

Table 2 shows that the surveyed papers contain only little information of the applied EDA methodology. Only three techniques are described explicitly as SC-measurement; the use of a 0.5V constant voltage system is never mentioned. Forty-four percent (11 out of 25) used Ag/AgCl electrodes on fingers or palms; four studies describe the exact site (distal phalanges). There is only one case where some isotonic electrode paste is explicitly mentioned.

Data recording was mostly done by digital means with three publications reporting sample frequencies of only 1 Hz or 2 Hz. Eight studies describe EDA scoring in a comprehensible manner. Three of them take a sum of amplitudes of all nonspecific responses exceeding a certain threshold (see above). In four studies, a mean over all recorded data spots of the phasic component of skin resistance or conductance is calculated; in one the mean over the tonic component. Two studies also report calculation of means but do not specify whether they took the phasic or tonic component as source. It can be concluded by the description in the meta-analysis (Braud & Schlitz, 1991, p. 12) that all studies by Braud et al. up to 1991 took the phasic component. Two more studies report the use of the tonic component but do not specify the scoring. From our internal knowledge about the technical equipment in the Freiburg and Edinburgh labs we can conclude that another set of three studies which do not report scoring methods used the tonic component only.

This analysis yields an interesting picture. In the early work up to 1993, researchers looked for the DMILS effect within the fast-changing phasic component of the EDA. But seven of the eight studies published since 1997 have used only the tonic component. This shift in the experimental setup was never reported or discussed or even mentioned due to incomplete descriptions of the technical setup until the PA Convention 1999 when an earlier version of this analysis was presented. And one wonders if even the researchers themselves have noticed this change.

The surprising result of our analysis is that there is not even one description of a state-of-the-art EDA methodology within the whole DMILS/Remote Staring literature. Although researchers have been reporting irregularities within EDA data that can be related to experimental conditions for more than 20 years, the nature of these irregularities was never addressed. Most of the researchers interpret these findings as a reflection of changing activity of the autonomic nervous system. But this conclusion cannot be maintained as the applied techniques allow a set of different interpretations. Irregularities within DMILS/Remote Staring data may be as well caused by:

Table 2
 Overview on reported EDA procedures in publications on DMILS/Remote Staring experiments using EDA.

Study	Year	Prin- ciple	Voltage	Electrodes	Elec. size ¹	Electrode paste	Site	Sample freq.	Sample Scores	Remarks
Braud	1978			Ag/AgCl		Spectra 360 elec- trode gel	palm		sum of SRR.amp	threshold for SRR.amp 100?
Braud	1979			hand elec- trodes					sum of amp. of non- specific resp.	
Braud et al.	1979						fingers	10 Hz	sum of amp. of non- specific resp.	electrodes attached by velcro. Threshold for resp. 2mm on polygraph
Braud et al.	1983	SR2	0.24 μ A	chrome-plate finger or pal- mar electr.	27mm	none	fingers	10 Hz	mean of all SRRs values	
Braud et al.	1985			finger or pal- mar electr.			fingers or palms	10 Hz	integrated EDA	refer to other publication for details
Schlitz et al.	1985	SR		palmar elec- trodes			hands	10 Hz	mean of all SRR or SRL values	refer to other publications by the authors for moni- toring and averaging
Braud et al.	1989			Ag/AgCl	7mm	partially conductive electrode gel	palms			refer to earlier publications for EDA equipment and procedures
Braud et al.	1989	SR		Ag/AgCl & chrome plated	7mm & 27mm ¹	none & partially conductive gel	fingers & palms & hands	10 Hz	mean of all SRR values	electrodes attached by velcro, 5min adaption period
Braud et al.	1993a	SR		Ag/AgCl	7mm	partially conductive electrode gel	palms	10 Hz	mean of all SRR values	refer to earlier publication for EDA equipment
Braud et al.	1993b	SR		Ag/AgCl	7mm	partially conductive electrode gel	palms	10 Hz	mean of all SRR values	refer to other publication for EDA equipment
Radin et al.	1993			Ag/AgCl		Signa Creme, con- ductive electr. paste	palms	16 Hz		electrode paste not suitable for EDA
Delanoy et al.	1994			Ag/AgCl	9mm		distal phalanges			refer to earlier publication for EDA equipment
Schlitz et al.	1994	SC		skin elec- trodes			palms	1 Hz	mean of all SCR values	
Wiseman et al.	1994			copper elec- trodes		electro-conductive gel	fingers	1 Hz		
Wiseman et al.	1995			copper elec- trodes		electrode gel	fingers	5 Hz		
Rebman et al.	1996			Ng/NgCl(?)	11mm		distal phalanges	10 Hz		electrodes attached by velcro
Wezelman et al.	1996			Ag/AgCl		conductive elec- trode paste	fingers	10 Hz		

¹ 15 different experiments

² calculated from reported electrode area of 585 mm² if electrode is round.

Table 2 (continued)
 Overview on reported EDA procedures in publications on DMILS/Remote Staring experiments using EDA.

Study	Year	Prin- ciple	Voltage	Electrodes	Elec. size ^a	Electrode paste	Site	Sample frequ.	Scores	Remarks
Schlitz et al.	1997	SC		skin electrodes			palms	1 Hz	mean of all SCR values or SCL ^a	
Wiseman et al.	1997	SR		stainless steel electrodes			fingers	10 Hz	SRL	
Delaney et al.	1998			Ag/AgCl	10mm	Sigma Creme, Femilind Gel	distal phalanges	18 Hz		electrodes attached by velcro. Sigma Creme not suitable for EDA
Radin et al.	1998	SC		Na/NaCl (?)		electrolyte conduc- tive cream	fingers	10 Hz	SCR	electrodes attached by velcro
Delaney et al.	1999	SC	0.15 V	Ag/AgCl	10mm	paste according to boucein formula	distal phalanges	16 Hz		electrodes attached by velcro. Hands cleaned if participants had oily skin
Schneider et al.	1999	SC	0.15 V	Ag/AgCl	10mm	Sigma Creme	finger	16 Hz	mean of SCL	electrodes attached by velcro. Sigma Creme not suitable for EDA. Hands cleaned if participants had oily skin
Watt	1999						fingers			
Wiseman et al.	1999	SR					fingers	2 Hz	SRL	

^a both dependant variables are mentioned. Appendix shows SCL date.

Irregularities within DMILS/Remote Staring data may as well be caused by:

- irregular breathing. Irregular breathing causes a large EDA response.
- drifts. Drifts within the data can be caused by inappropriate electrode gel, insufficient time lag between electrode attachment and data recording or changes in the overall arousal of the participant. Balanced randomization should avoid those drifts, but not all studies were randomly balanced. Any drift starting or stopping within the experiment may create artifacts, although the trials are randomized in a balanced order.
- movement of the hand.
- inadequate filtering process. Potential artifacts can be caused by the reconstruction of the EDA curve by digital recorded data that have not been filtered according to Shannon's sampling theorem (see above). Data may also contain electronic noise as the result of inappropriate filtering.
- Ebbecke waves enforced by inadequate attachment of electrodes by velcro bands or by strain of electrode cable.

On the other hand, it can be argued that DMILS/Remote Staring effects were not detected because the researchers employed inappropriate technology. Existing effects can be covered up by:

- the use of inadequate electrode paste. Hypertonic gels may change the conductivity of the skin in a large scale and remove minor changes caused by the autonomic nervous system.
- inappropriate data recording. Large effects may decrease or even disappear if the sampling rate is below 10 Hz for the phasic component.
- inappropriate measurement principle. If the effects are within the fast-changing phasic component they will not be detected by methods which only score tonic parameters. On the other hand, effects within the overall arousal will be filtered out if the data are only checked for changes in the phasic component.
- inappropriate scoring methods. It is questionable whether it is useful to score the fast-changing phasic curve by calculating the mean over all data. This might be a sensitive procedure but it also might be possible that the conventional measures like NS.SCR.freq or sum of amplitude of NS.SCR (see above) are more sensitive with regard to DMILS/Remote Staring effects.

PIS Score. Most of the results of DMILS/Remote Staring studies are presented by a Percent Influence Score (PIS) (Braud & Schlitz, 1991, p. 5). This score is calculated by dividing the sum of all data of the experimental condition by the sum of all data of both experimental and control conditions. In the absence of any effect, the PIS is 50% and each deviation from

that mean reflects an experimental effect. The PIS is standardized by the mean (50%), but it is not standardized by the standard deviation. Therefore, two different PIS cannot be compared. A PIS of 51% with a small SD might reflect a larger effect than a PIS of 60% with a large SD. Unfortunately only one in 25 DMILS/Remote Staring publications reports a standard deviation of a PIS. Comparing different studies by PIS may result in severe misinterpretation. We therefore recommend effect sizes (preferably r -effect sizes) or z -scores to compare different session or study outcomes.

CONCLUSION

The applied and published techniques in psychophysiological studies are not as homogenous as we expected. This might be because EDA is very often only one in a set of psychophysiological variables and therefore the description of the procedures is short. Another reason is that only some but not all topics are standardized. In our opinion, there is a lack in standards for artifact control, climatic conditions in the lab, and site pre-treatment. Furthermore, it is apparently unnecessary for a good publication to report details on these topics as well as to report the time lag between electrode attachment and data recording.

There is not even one study conducted by parapsychologists which refers to psychophysiology's measurement standards published in 1981. From the viewpoint of psychophysiologicals, the applied and described EDA methodologies are not sufficient. Most of them do not use the required SC-technique (constant voltage method) or the appropriate electrode paste. The scoring method remains unclear in more than half of the studies and does not allow interpretation of the reported effects if additional knowledge from the overviews or meta-analyses is not available. Therefore, all DMILS/Remote Staring studies may contain artifacts or may not have found existing effects because they do not use the appropriate technology. Despite ongoing research for twenty years with EDA as the dependent variable, there have not been any efforts to understand the results of EDA experiments or to address the origin of the irregularities in detail.

One cannot deny that there is an ongoing trend of finding irregularities in EDA data of DMILS/Remote Staring experiments that can be related to different intentional conditions. But high levels of significance in meta-analyses should be acceptable also for researchers outside the parapsychological community. To bridge the gap between the sciences of anomalies and mainstream research, it is necessary to stick to certain standards, and, as most parapsychologists know, the highest methodological standards are demanded for parapsychological experiments to exclude any other source than psi from influencing the data.

Therefore, we recommend the use of appropriate EDA techniques like the ones reported in this paper for future DMILS experiments. We also recommend that published articles describe the applied procedures in detail. In doing so, they will be accepted by researchers from other fields. Furthermore, we suggest an analysis of the irregularities in EDA data in more detail for a better understanding of the origin of the DMILS/Remote Staring effects.

EDA measures also figure prominently in other research paradigms of parapsychology, e.g., in presentiment studies (Radin, 1997). Our conclusions and suggestions also apply to this branch of research, although we did not primarily review these studies.

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APPENDIX

PSYCHOPHYSIOLOGICAL STUDIES

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DMILS/REMOTE STARING STUDIES USING EDA

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