Psychological Reports, 2003, 93, 907-920.

RESPIRATION-RELATED ARTIFACTS IN EDA RECORDINGS: INTRODUCING A STANDARDIZED METHOD TO OVERCOME MULTIPLE INTERPRETATIONS[1,2]

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Summary.—When electrodermal activity (EDA) recordings are controlled for artifacts, i.e., electrodermal reactions [EDRs] elicited by breathing irregularities, several problems arise. For example, respiration is difficult to evaluate because there are no clear-cut criteria for its values, e.g., wave form, depth. Furthermore, respiration and EDA are rather complexly intertwined, and there is no established or standardized method for evaluation. Especially when subjects are not stimulated, i.e., when nonspecific EDRs are taken, EDR recordings elicited by irregular breathing may overestimate the subject's arousal and bias any given research question. Moreover, incidences of concurrent consecutive EDRs and changes in respiratory activity may encourage multicausal interpretation due to both signals' having a common central causation. To circumvent such problems, we developed a method which provides rule-based guidelines to identify potential artifacts. Two experiments ($N = 14$ and $N = 12$) were conducted to test the accuracy of the judgments of three independent raters. The reliability coefficients for the number of electrodermal reactions and the sum of their amplitudes yielded satisfactory coefficients of convergence for each individual experiment (.87 and .82 in Exp. 1 vs .94 and .95 in Exp. 2) as well as for the two experiments combined (.92 and .91).

Recordings of electrodermal activity (EDA) are useful in many psychophysiological experiments due to the signal's ease of recording and its functional significance for human behavior (Boucsein, 1992). Largely under control of the sympathetic nervous system, EDA is regarded as a valid indicator

[1]The authors very much acknowledge helpful comments from W. Boucsein, Wuppertal, as well as J. Fahrenberg, Freiburg, on earlier drafts of this paper.
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of emotional, motivational, and cognitive states (Boucsein, 1995). However, electrodermal phenomena can have different central nervous sources, i.e., premotor, limbic-hypothalamic, and reticular, and, therefore, changes in EDA can either be concomitants of varying emotions, of motor action preparations, or of an altered general arousal (Edelberg, 1972; Boucsein, 1992). Consequently, EDA covaries with other physiological parameters like respiration or body movements. However, the label 'artifact' may not be appropriate because it reflects a conceptual or definitional differentiation between stimulus-dependent EDA, e.g., orienting or defensive reactions, and EDA stemming from physiological reactions in other body systems. In any case, identification of electrodermal reactions (EDRs) stemming from other physiological changes is indispensable to determine whether, for instance, specific EDRs should be discarded or whether they can be deemed additional indicators of observed psychophysiological changes.

Basically, there are two ways to control artifacts. When data are visually inspected the investigator decides upon the exclusion of particular EDRs from further evaluation. In paradigms where subjects are given distinct physical stimuli, e.g., a 1000-Hz tone, the distinction between an EDR elicited by the stimulus and an EDR elicited by, say, deep sighing is readily made because there are well-defined latency windows for the former to occur. On the other hand, artifacts caused by pressure on the electrode or by movement of muscles beneath the electrode-skin interface can be automatically distinguished from EDRs by taking into account the characteristic wave form of an EDR (rise time, amplitude, recovery time): the EDR is a rather slow-changing biological signal, and unusually steep rises of the amplitude can be traced back to artifactual causes (Boucsein, 1992). For example, Wilhelm and Roth (1996) developed an ambulatory computer program which plots bivariate distributions of rise time and amplitude and identifies outliers falling outside a range of 20% change in slope of the regression. Alternatively, the exclusion of artifacts can also be achieved by applying an appropriate low-pass filter.

However, when assessing baseline measures the effect of irregularities in breathing is less straightforward because single respiratory events can cause EDA. For instance, a sudden voluntary change in breathing, e.g., change in frequency or depth, significantly increases electrodermal changes (cf. Hygge & Hugdahl, 1985). This 'physiologically' caused artifact is difficult to control for because, first, the pulmonary system is rather complex (cf. Cacioppo, Tassinary, & Fridlund, 1990), and, second, the knowledge about acceptable values for respiratory activity is rather limited (Wilhelm & Roth, 1996). Its parameters (depth, frequency, intervals) can independently covary and change from breath to breath. Also, respiratory activity encompasses a wide intersubject variability, as illustrated in Fig. 1.

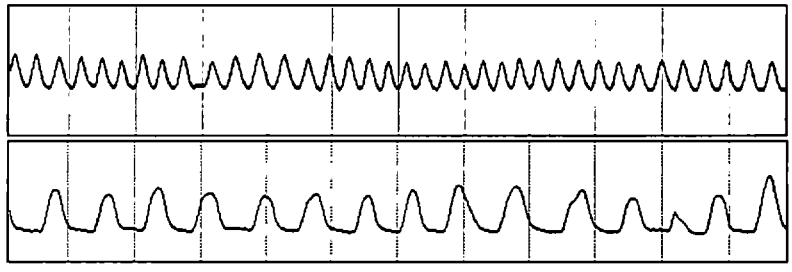

FIG. 1. Two individual recording epochs of respiration under rest conditions (120 sec., segmented by vertical bars of 10 sec. each)

Most psychophysiological researchers who measure EDA simultaneously record respiration to distinguish the latter from the former. Nonetheless, Schmidt and Walach (2000), after a comprehensive literature search of articles published between 1995 and 1999, found that little has been reported about how this is accomplished. Whereas there are automatic ways to assess the extent of movement artifacts on specific features of the respiratory wave form, e.g., by calculating the differential of chest and abdominal respiration as proposed by Wilhelm and Roth, there appears to be no systematic or standardized method to link various respiratory patterns to EDA. This is especially true for experiments in which no external stimuli are presented, e.g., to assess baseline measures, and, consequently, spontaneous electrodermal fluctuations, i.e., nonspecific electrodermal reactions (NS.EDRs) are investigated (Vossel, 1990; Vossel & Zimmer, 1990; Goedert, Rill, & Vossel, 2001; Mikalsen, Bertelsen, & Flaten, 2001). Unlike EDRs caused by movement artifacts, EDRs elicited by alterations in breathing do not differ in wave form from nonspecific EDRs (Boucsein, 1992). Hence, assessing baseline arousal, i.e., recordings of spontaneous electrodermal fluctuations, can be subject to significant overestimation and bias (Schmidt, Schneider, Binder, Bürkle, & Walach, 2001). However, removal of respiration-related EDRs is not obvious. For example, irregular respiratory patterns have to be defined case-wise. As illustrated in Fig. 1, the two individual respiratory recordings differ in both frequency and amplitude. However, within each individual pattern a steady and regular breathing pattern can be observed. Lorig and Schwartz (1990) have introduced a technique which is principally applicable to the interrelatedness of EDA and respiration. According to their approach, deviant characteristics in the pulmonary activity are detected by averaging successive repetitive respiration waves which produces an average repetitive cycle. Upon identifying specific features of the signal to be measured, e.g., peak inspiration or onset of inspiration, data of either side of this feature are furthermore averaged with data around earlier features, thereby forming an

average repetitive cycle around this feature. When other physiological parameters (like EDA) are additionally recorded and averaged for the same segment arranged around this feature detected in the average repetitive cycle, they produce a synchronized event average. When average repetitive cycle and synchronized event average are independent from each other, as indicated by a flat average wave, they do not covary. In contrast, when these shapes are synchronized, there will be a nonflat synchronized event average, indicating interrelatedness. Although this technique provides a sensitive way to detect effects on the signal of interest, one of its main problems is to establish precisely the point in the repetitive cycle which is to be averaged. Since usually many points do qualify and since the analysis is very susceptible to the synchronization of other features in the data, any desynchronization reduces the amplitude of the average repetitive cycle.

In addition, electrodermal reactions often covary with changes in respiration in a rather nonlinear fashion. For example, a deep inhalation can be followed by an EDR, and vice versa. Clearly, in the latter case one will not consider the EDR an artifact. The case is more complex though, when multiple, i.e., several temporally closely related, EDRs are observed, as illustrated in Fig. 2.

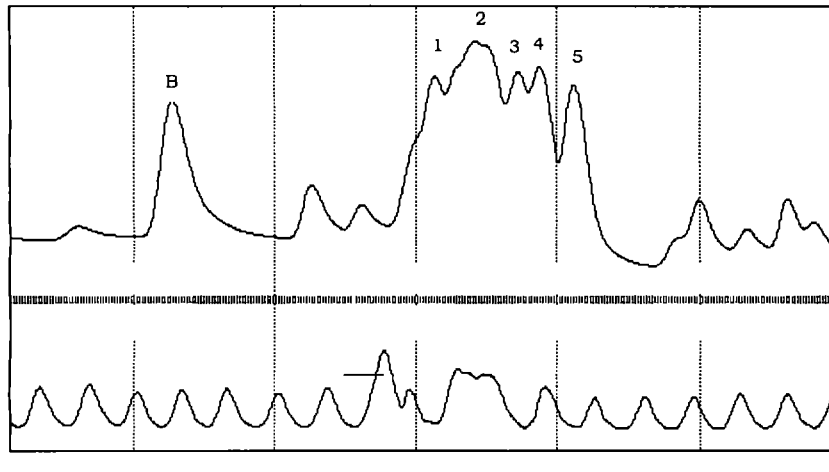

FIG. 2. Recording epoch (60 sec., segmented by vertical bars of 10 sec. each) of nonspecific skin conductance reaction and respiratory activity under rest conditions; EDA recording in the upper half, respiration in the lower half of the figure. Start of marked change in respiration indicated by a horizontal bar.

As depicted, there is a marked alteration in respiratory activity with an onset of about 27 sec. accompanied by a skin conductance reaction (SCR). The alteration of the respiratory activity continues to last for about 10 sec-

onds. Clearly, SCR 1 is very likely to stem from the preceding deep inhalation because its onset is within a latency interval of 1–5 sec. as recommended by Venables and Christie (1980) and would have to be discarded. However, the question is whether and how many of the consecutive SCRs, i.e., 2–5, should also be removed. It is arguable whether all SCRs are due to the changes in breathing or whether some of them reflect unspecific, and thus independent responses which, due to both parameters' common locus of central causation, appear in concurrent or sustained alterations in respiratory activity. Consequently, the bidirectional relationship between EDA and respiration gives rise to quasi-infinite causality loops, for example, any given EDR may be accompanied by irregular breathing patterns which, in turn, elicit successive EDRs and so on.

As long as there is no systematic approach to the problem of how respiratory irregularities should be related to nonspecific SCR recordings, controlling for respiratory artifact will remain a highly intuitive endeavor, and the editing of different independent investigators will not be convincingly reliable. For such purposes, it would be helpful to have clear-cut guidelines which account for the *Gestalt* and interrelatedness of EDA and breathing activity. It should be noted that there are already procedures to identify SCR morphology. For example, Lim, Rennie, Barry, Bahramali, Lazzaro, Manor, and Gordon (1997) developed a multiparameter sigmoid-exponential SCR model which decomposes SCR, e.g., residuals from previous SCRs, SCRs, skin conductance latency, peak latency, and peak amplitude. This model is a useful tool for paradigms where short interstimulus intervals are employed, e.g., in cognitive research, and overlapping electrodermal responses or drifting baselines more often occur. However, decomposing SCRs does not address the question of how to relate changes in respiration to EDA.

Being interested in artifact-free recordings over a longer time period (25 min.) under conditions of rest and mild sensory deprivation, this apparent lack of a standardized procedure of artifact control in EDA research prompted us to find a solution to this problem. Our recordings produced relatively large data sets which allowed us to assess (1) the complexity of patterns of interrelated Skin Conductance–Respiration recordings and (2) the convergence of editing among three independent raters according to rule-based criteria developed by the first three authors.

Method

Subjects

In the first experiment, 14 subjects (9 men and 5 women) age 27 yr. on average ($SD=9.1$; range 18 to 46) and in the second experiment 12 subjects (10 women and 2 men) of age 32 yr. on average ($SD=5.9$; range 26 to 46) were recruited via local newspaper advertisements or by word of mouth.

Participants were remunerated for participation. Informed consent was obtained from all subjects before participating in the study.

Apparatus

Skin conductance was measured by applying a constant voltage of .5V. Skin conductance reactions were coupled to an AC amplifier (EDR/DC.CV by the fourth author) via high pass filter with a time constant of 10 sec. and fed forward to a bioamp system (1-410 BCS by J&J Engineering, USA). The signals were digitised at 16 Hz to a resolution of 12 bit digital signals. Ag/AgCl electrodes (8 mm in diameter) filled with an isotonic paste of 0.5% NaCl electrolyte in a neutral base (TDE-246), distributed by Grass (EC-33 skin conductance electrode paste) according to the recommendations of Fowles, Christie, Edelberg, Grings, Lykken, and Venables (1981), were attached to the thenar and hypothenar eminencies of the nondominant hand. They were pretreated with methyl alcohol (70%) 15 minutes prior to the measurement. Respiration was monitored by applying a strain gauge attached to a velcro belt wrapped around the upper abdominal region for recording of both chest and abdominal respiration. The average ambient temperature for the measurements was 24.5°C (average humidity: 48%).

Procedure

The experimental setting involved EDA recordings at rest for a time span of 30 min. Participants were housed in a sound-attenuated chamber and required to keep a relaxed but alert state. To do so, they were presented a pleasant screensaver which randomly produced patterns of mild colors. The nonspecific SCR frequency and the sum of nonspecific SCR amplitudes exceeding .015 μS were calculated for each experiment by a parameterization software by the fourth author (EDR_PARA, Version 3.71). Each data set of EDA was edited independently and blindly by the first, second, and third authors on the basis of the herein-described catalogue of criteria. The major purpose of the catalogue was to enhance the reliability of editing of nonspecific SCR artifacts. The manual itself had been developed and revised by the same authors on the basis of several databases comparable to the ones described above. Specifically, each rater screened and rated single data sets according to preformulated criteria. Next, all three raters compared their editing and identified diverging features. Different solutions were then discussed and the most adequate one selected. Repeatedly, new databases were independently re-evaluated on the basis of the revised set of criteria, and possible differences subsequently discussed anew until a satisfactory solution was found. This process was stopped once no new problems or divergences occurred between the raters.

Upon completion of the complete set of criteria, the three raters independently performed the ratings. To validate the ratings, two studies were

performed. To avoid learning effects and to validate the raters' judgments, authors RS and MB first rated the data sets of Exp. 1, and author SS those of Exp. 2, and vice versa. The results were only compared after all data sets were rated.

Catalogue for Respiratory Artifact Control

Rationale.—Our procedure was designed to provide an easy-to-handle check form to enhance the reliability of the editing process of nonspecific electrodermal reaction recordings. Its structure resembles a decision tree: any given pattern of co-occurring EDRs and respiratory irregularity are subject to the stepwise identification of the type of the *Gestalt* of the nonspecific SCRs [the complete manual is provided in the Appendix, p. 920; feedback on its usefulness and appropriateness is very much appreciated]. The core of this identification process is to cluster single, though temporally related EDRs. Upon clustering several nonspecific SCRs, they are regarded and treated as one single nonspecific SCR which is then examined with the respiratory irregularity in question. This process simplifies the examination of the relationship between EDA and respiratory variation.

Our line of reasoning is based on the assumption that, under certain conditions, successive, closely related EDRs are very likely to stem from one common, internal or external causal mechanism and are, therefore, conceivable as electrodermal 'after-effects'. For several EDRs to be accepted as one unitary reaction they have to consist of *incomplete* recovery features. The difference between complete and incomplete wave forms is illustrated by the electrodermal reactions in Fig. 2. The typical shape of a single nonspecific SCR, indicated by B, is characterized by a typical wave form consisting of a rise in skin conductance and a *complete* recovery to the approximate initial value. Related multiple EDRs, however, are characterized by incomplete shapes like nonspecific EDR 1, whose decrease in skin conductance (recovery) is disrupted due to the onset of nonspecific EDR 2. We provide several criteria helping to assess the extent of incompleteness of recovery (e.g., peak amplitude, recovery rate, or onset of successive electrodermal reactions). Some of the criteria reported are empirically derived (e.g., the latency windows, onset of consecutive EDRs), whereas others stem from rational considerations (e.g., peak amplitude). However, the latter can be flexibly altered according to the given research interest without deteriorating the efficacy of the procedure.

Catalogue and criteria.—As indicated above, clustering several EDRs is basically to answer the question if they should be regarded as reactions to *one* cause. Therefore, temporal aspects as well as aspects of the amplitude of the electrodermal reaction have to be considered. Specifically, for several EDRs to be regarded as clusters, relatively large initial EDRs have to occur

in order to relate them to any possible common causal factor. We argue that only relatively strong stimuli elicit several electrodermal reactions. Therefore, we propose an amplitude of .4 μS as criterion of evaluation. In the case of two superimposed EDRs, e.g., when there is an incomplete return after the first EDR peak before another ascent, the peaks of the two EDRs are added when (1) the latency of the onset of the second EDR does not exceed one second of the peak of the first and when (2) its amplitude is smaller. Likewise, for any following EDR to be linked to the same cause (3) its amplitude must not exceed that of the first EDR, (4) its onset (rate of ascent) must not be lower than that of the preceding one, and (5) its onset has to be within a specific latency window. As a general rule for the second EDR, we suggest a latency window in seconds derived from multiplying the amplitude of the first EDR with the factor 10 (e.g., 1 μS corresponds to 10 sec.). For any following EDRs, we suggest a latency window (in seconds) of two times the amplitude of the first EDR, with maximum values not being greater than 20 sec. The line of reasoning behind this idea refers to the relationship between strength of electrodermal reaction and recovery rate: the higher the amplitude, the longer the recovery rate and the more likely it is for further causality linked EDRs to occur. Yet, any consecutive EDR must not exceed the amplitude of the preceding one (we suggest a factor of 1.5); otherwise we assume it to be a distinct electrodermal response. Upon identifying several EDRs as one complex, it is then examined whether there is any respiratory irregularity 1–5 seconds before the EDA onset. On confirmation, they are deemed as artifacts and discarded from further evaluation. Yet, we strongly advocate a careful checking of the appropriateness of any alteration in respiration and the extent of EDRs to be discarded.

For changes in breathing to be considered irregular, they, too, have to meet several criteria. In our view, a respiratory irregularity is a sudden alteration in the inhalation rhythm, e.g., breath suspension, or amplitude, e.g., deep inhalation. Likewise, any absence of a to-be-expected pattern or continuation from preceding respiration amplitudes (e.g., irregular wave form) also constitutes an irregularity (see Appendix, p. 920).

Example.—The following example delineates how the set of criteria is to be handled when several related nonspecific SCRs and respiration irregularities covary. Fig. 3 illustrates a typical recording of skin conductance (above) and respiration (below). As can be seen, there are respiration alterations that coincide with several, consecutive nonspecific SCRs. However, the problem is whether and which of the observed nonspecific SCRs should be discarded due to a linkage with the observed changes in respiratory activity.

According to our manual, SCR 1 will not be classified as artifact since its onset (9.38 sec.) precedes the onset of the marked change in breathing activity (10.42 sec.). The next marked change in respiration is to be found in

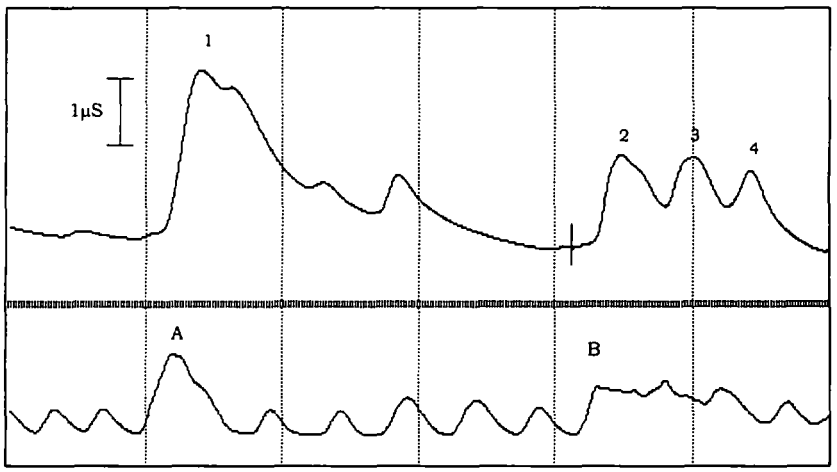

FIG. 3. Example of covarying skin conductance reactions and respiratory alterations. 1: SCR latency = 9.38 sec.; SCR amplitude = 2.82 μS; 2: SCR latency = 41.38 sec.; SCR amplitude = 1.58 μS; 3: SCR latency = 48.00 sec.; SCR amplitude = .85 μS; 4: SCR latency = 52.50 sec.; SCR amplitude = .64 μS; A: Onset of respiration alteration = 10.42 sec.; B: Onset of respiration alteration = 42.86 sec.

the last third of the recording epoch. To check whether the three covarying SCRs comprise a complex, the following points are checked (also see Appendix, p. 920):

(1) *Amplitude and recovery*:—The amplitude of SCR 2 (1.58 μS) clearly exceeds 0.4 μS (step 2) and its recovery is incomplete as indicated by the onset of SCR 3. SCR 3 is smaller in size (0.85 μS) than SCR 2 (step 4).

(2) *Latency window*:—The onset of SCR 3 (48 sec.) falls within the maximal latency window of 60.6 sec. (step 6; onset SCR 2 amp = 41.38 sec.; assumed latency window for the consecutive compound SCR = amplitude of SCR 2 multiplied by 10, in seconds = 15.8 sec.; maximal latency windows for compound SCR 3 = 41.38 sec. + 15.8 sec. = 57.18 sec.).

Likewise, criteria (1) and (2) are checked for any successive SCR (steps 7 and 8). The onset of SCR 4 (52.5 sec.) also falls within the critical latency window for SCR 3 (assumed maximal latency window for the consecutive compound SCR 4 = 41.38 + 20 sec. = 61.38), and its amplitude is smaller than that of SCR 3.

(3) *Conclusion*:—SCRs 2–4 are treated as one compound ('one' SCR) and are assumed to be related to the onset of the observed breathing irregularity (step 9). Since the onset of the compound (identical to the onset of SCR 2) clearly precedes the onset of the marked change in respiration (step 10), there is no reason to assume that the change in EDA, as indicated by

SCRs 2–4, stems from the change in respiration. The SCRs in question are therefore not discarded.

Results

Data

Table 1 provides the average number of SCRs and standard deviation for the original and edited data. As can be seen, both the total number and the average of nonspecific SCRs per minute decreased considerably when the data were edited.

TABLE 1
Average Number and Standard Deviations of Nonspecific Skin Conductance Reaction Frequency Per Minute and Participant For Original and Edited Data

	Nonspecific Skin Conductance Reaction		
	Total	Frequency	*SD*
Original Data	1774	2.71	2.53
Edited Data	1482	2.27	2.23

Reliability Coefficients of the Catalogue

To estimate the reliability of editing for the independent raters (RS, SS, & MB), we calculated reliability coefficients separately for the two experiments as well as for both experiments combined. Rather than including the absolute number of artifacts for each rater, we determined their proportion according to the total number of SCRs determined by the parameterization software EDR_PARA. This was done to account for high interindividual differences in the number of spontaneous fluctuations. Thus, for every experiment we obtained one value for the number of SCRs and one value for the sum of their amplitudes for each rater. According to Winer's (1971) suggestions we determined the reliability of the three ratings by calculating within and between subject variances. The reliability estimate for three raters is $3\theta/(1+3\theta)$, $\theta = (MS\ \text{b.subjects} - MS\ \text{w.experiments})/3\ MS\ \text{w.experiments}$, where MS = mean squares of variation, b = between, and w = within subjects.

The results are depicted in Table 2. As can be seen, the reliability coefficients for the judgements of all three raters yielded a satisfactory degree of convergence as indicated by the indices ranging from .82 to .95. Since the editing was performed independently by each rater it can be concluded that the catalogue's criteria for artifact control indeed enhanced the accuracy of the evaluations, thereby making them more homogeneous and reliable. Specifically, it helped to identify respiration peculiarities and answered the question whether and which electrodermal responses were to be related to deviant breathing patterns and thus had to be removed from further evaluation. Note that the higher reliability coefficients found for Exp. 2 were probably

due to chance (nonspecific SCR frequency: $z = .61$, $p = .27$; Sum of nonspecific SCR amplitudes: $z = -.5$, $p = .31$) and, as expected, not affected by any sort of learning effect.

TABLE 2
RELIABILITY COEFFICIENTS FOR THREE INDEPENDENT RATERS

Experiment	n	Nonspecific Skin Conductance Reaction: r_3	
		Frequency	Sum of Amplitudes
1	14	.87	.82
2	12	.94	.95
Total	26	.92	.91

DISCUSSION

In our view, contemporary EDA research suffers from the lack of standardized procedures which control for respiration-related electrodermal reactions. This is especially true for recordings of nonspecific EDRs. Although there is a variety of filtering processes to alleviate the detection of artifacts in respiratory activity or EDA, they lack the capacity to link both parameters on a rule driven, and thus systematic, basis. From our experience with large nonspecific SCR data sets, we can conclude that both the complexity of covariation of respiration and EDA and their interdependence must not be underestimated. For example, after discarding respiration related SCRs from 26 25-min. nonspecific SCR data recordings according to our catalogue's guidelines, the effect sizes derived for nonspecific SCR frequency and Sum of nonspecific SCR amplitude dropped by about 50% of their initial values ($r = .4$, vs $r = .2$) when two experimental conditions were compared (Schmidt, *et al.*, 2001). Hence, EDA and respiration can share a substantial proportion of common variance which needs to be reliably identified.

Obviously, the majority of EDA paradigms favor EDR over nonspecific EDR recordings because the former are of interest when subjects are physically stimulated. Nonetheless, many paradigms (if not all) include sequences of complete or relative stimulus absence which serve as control or baseline measures (for example in habituation research). Hence, a reliable identification of artifacts would be beneficial for both types of recordings.

Our line of reasoning addresses the bidirectional relationship of EDA and respiration. For example, covarying changes in both parameters almost inevitably lead to infinite causality loops because alterations in EDA can occur prior to changes in respiration, and vice versa. This renders artifact control difficult. To circumvent this problem we propose criteria-based solutions which treat several consecutive EDRs as one single EDR. In so doing, we reduce multiple inferences to unicausal ones. It goes without saying that

subjective biases in evaluation cannot completely be excluded. In fact, our manual requires a careful checking of the appropriateness of respiratory irregularities and the related EDR complexes. This has proven valuable because individuals can vastly differ in respiration characteristics. Rather than trying to implement rigid criteria, we favor a flexible approach by considering individual physiological patterns. This flexible approach, however, does not undermine the effectiveness of evaluation. Rather, the high rate of accuracy obtained shows the criteria's usefulness. Most importantly, the reproducibility of rating results for three independent raters is not affected by any learning transfer or familiarity with the catalogue.

Obviously, the usefulness of our approach to standardize the editing process of EDA needs to be confirmed and validated by further research. For example, some of the suggested parameters (e.g., the amplitude of the initial EDR) were typical values we observed from extensive data screenings. Nonetheless, as an initial tool this instrument proves to circumvent a fundamental problem EDA research has not addressed so far.

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Accepted September 29, 2003.

APPENDIX

Manual for the Edition of Nonspecific Electrodermal Reactions

I. Set of Criteria

Multiple EDRs are treated as *one* reaction upon checking the following steps:

Step 1: Within the latency of 1 sec., two successive EDRs are obtained, with the peak amplitude of the second exceeding that of the first (latency being defined as peak of the first EDR to onset of the second EDR).
- yes: Sum both amplitudes, proceed with Step 3.
- no: Proceed with Step 2.

Step 2: The peak amplitude of the first EDR equals/is larger than 0.4 μS.
- yes: Proceed with Step 4.
- no: There is no complex of EDRs.

Step 3: The summed peak amplitude is larger than 0.4 μS.
- yes: Proceed with Step 4.
- no: There is no complex of EDRs.

Step 4: Compared to the first peak amplitude, the consecutive EDR is
- smaller: Proceed with Step 5.
- larger: There is no complex of EDRs.

Step 5: The onset of this EDR is below the onset of the proceeding EDR (baseline drift).
- yes: There is no complex of EDRs.
- no: Proceed with Step 6.

Step 6: The onset of this EDR is within the latency window X, with the latency being defined as onset of the preceding EDR to peak of the consecutive EDR (latency window X being calculated as amplitude of the preceding EDR [e.g., in μS] times ten in seconds, with X maximally assuming 20 sec.
- yes: EDR belongs to the complex, proceed with Step 7.
- no: There is no complex of EDRs.

Step 7: There are further onsets of EDRs within the latency window of 2X (see Step 6) maximally assuming 20 sec. (latency window being defined as peak of the first EDR to peak of the EDR in question).
- yes: Proceed with Step 8.
- no: The complex is defined. Proceed with Step 9.

Step 8: The peak amplitude of one of the consecutive EDRs is larger than one of the preceding EDRs by a factor of more than 1.5.
- yes: This EDR does not belong to the complex. Proceed with Step 9.
- no: This EDR belongs to the complex. Proceed with Step 9.

Step 9: There is a respiration irregularity within the latency window of 1–5 sec. before the onset of the first EDR.
- yes: Proceed with Step 10.
- no: All EDRs comprising the complex are valid, i.e., no artifacts.

Step 10: The dimension of the EDRs of the complex compares to the respiration irregularities.
- yes: Discard the EDRs of the complex.
- no: All EDRs comprising the complex are valid, i.e., no artifacts.

II. Definition of Respiration Irregularity/Set of Criteria

1. Respiration will not be interpreted with regard to possible causal factors.
2. The type of irregularity is inconsiderable (see 3, 4, and 5).
3. An irregularity is—by definition—a sudden change in the respiration rhythm.
4. Any discontinuity in respiration rhythm is—by definition—a marked change in amplitude.
5. Interceptions of a to-be-expected respiration morphology (derived from preceding amplitudes) also qualify for alterations of respiration rhythm.
6. The evaluation of respiration irregularities is based on preceding (not subsequent) amplitudes.
7. To evaluate whether alterations in respiration compare to changes in EDA, only EDRs with a peak amplitude of at least 0.4 μS qualify.