When orienting and anticipation dissociate – a case for scoring electrodermal responses in multiple latency windows in studies of human fear conditioning

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Abstract

Electrodermal activity in studies of human fear conditioning is often scored by distinguishing two electrodermal responses occurring during the conditional stimulus-unconditional stimulus interval. These responses, known as first interval responding (FIR) and second interval responding (SIR), are reported to be differentially sensitive to the effects of orienting and anticipation. Recently, the FIR/SIR scoring convention has been questioned, with some arguing in favor of scoring a single response within the entire conditional stimulus-unconditional stimulus interval (entire interval responding, EIR). EIR can be advantageous in practical terms but may fail to capture experimental effects when manipulations produce dissociations between orienting and anticipation. As an illustration, we rescored the data reported by Luck and Lipp (2015b) using both FIR/SIR and EIR scoring techniques and provide evidence that the EIR scoring technique fails to detect the effects of instructed extinction, an experimental manipulation which produces a dissociation between orienting and anticipation. Thus, using a technique that scores electrodermal response indices of fear conditioning in multiple latency windows is recommended.

Key words: electrodermal responses, methodology, first interval responding, second interval responding, entire interval responding, conditioning, instructed extinction, differential fear conditioning.

Electrodermal activity has been a popular and widely reported autonomic index of conditional responding since the early studies of human fear conditioning. Since the 1960s, with the advent of using long conditional stimulus-unconditional stimulus intervals (CS-US interval) of six seconds or more, most researchers have agreed that separate response components can be observed during the CS-US interval, leading to the development of scoring techniques aimed at identifying and separating these components (Boucsein, 2012). The existence of multiple electrodermal responses is well accepted, but there is less agreement as to whether these responses reflect distinct psychological processes and whether information is lost if they are combined during scoring (Öhman, 1983; Pineles, Orr, & Orr, 2009).

Following calls to standardize the reporting of electrodermal activity in psychological research, Prokasy and Kumpfer (1973) reviewed the then extant literature on electrodermal activity as a measure of conditioning and argued in favor of distinguishing multiple responses during a CS-US interval of sufficient duration (usually 6 s or more). A first component (first interval response, FIR) was said to emerge within 1-4 s of CS onset and a second component (second interval response, SIR) shortly after this depending on the duration of the CS-US interval (within 4-7 s for a 6 s CS-US interval and 4-9 s for an 8 s CS-US interval). The FIR, was argued to be more sensitive to orienting elicited by CS onset whilst the SIR was said to be more sensitive to anticipation of the US (Öhman, 1983). A response to the US (third interval response, TIR) is scored within 1-4 s after the onset of the US, regardless of whether the US onset coincides with the CS or the CS offset (delay conditioning) or whether there is a time interval between the CS offset and the US onset (trace conditioning). Prokasy and Kumpfer maintained that both first and second interval responses were sensitive to associative learning, but that their separation was justified on the basis that experimental manipulations did not always affect both components in the same manner (Prokasy & Ebel, 1967), and that first and second interval responding were statistically independent (Prokasy & Ebel, 1967; Prokasy, Williams, Kumpfer, Lee & Jenson, 1973).

The use of separate latency windows when scoring electrodermal responses can be questioned on pragmatic and theoretical grounds. Scoring in multiple latency windows is time consuming and not easily automatized, and reporting results for two response components may be cumbersome and lengthen a report without adding additional information. Moreover, the separation of the response components can be difficult in the case of overlapping responses rendering the scoring method subjective and potentially open to bias. On theoretical grounds, studies have frequently failed to support the notion that the two response components reflect dissociable psychological processes, yielding parallel results for FIR and SIR.

Pineles et al. (2009) examined a selection of fear conditioning experiments which scored electrodermal responses in multiple latency windows and argued that, almost always, evidence for conditioning is found in both response components. They argued that separating response components may not be justified and provided evidence for this by rescoring the electrodermal responses obtained from a large study on differential fear conditioning (N = 287) using both a FIR/SIR component approach and an approach that scored a single response component, the entire interval response (EIR). The EIR was defined as the difference between skin conductance baseline (defined as the average skin conductance level 2 seconds before CS onset) and the peak skin conductance value observed anywhere within the CS-US interval of eight seconds (but before the onset of the unconditional response). The results were largely comparable across FIR, SIR, and EIR, however, although the FIR and EIR had similar effect sizes, SIR effect sizes were smaller. Indices of differential conditioning, difference scores between CS+ (CS paired with the

US) and CS- (CS presented alone), between EIR and FIR were highly correlated, but correlations with SIR were not so robust.

There may be situations, however, in which experimental manipulations do produce meaningful dissociations between first and second interval responding, to which an EIR approach may be insensitive. One such case with significant empirical support is observed in studies of instructed extinction. During instructed extinction, one group of participants is informed after the completion of acquisition training that US presentations will cease, whilst the control group is interrupted in a similar manner but not informed about the changes to the CS-US contingency. Instructed extinction has been reliably shown to eliminate differential responding to CS+ and CS- at the very beginning of extinction. This conclusion, however, is often based solely on evidence from the SIR, as for the FIR instructed extinction effects are often masked by sensitization of the orienting reflex in the control group. Luck and Lipp (2015a, 2015b) and Rowles, Lipp, and Mallan (2012) report the immediate elimination of differential SIR following instructed extinction in the instruction group, whilst differential SIR remains intact at the beginning of extinction in the control group. In contrast, differential FIR was eliminated in both groups at the beginning of extinction. Closer inspection suggests that in the instruction group differential responding is eliminated due to a decrease in responding to CS+, but in the control group differential responding is eliminated due to an increase in responding to the CS-. This latter finding is interpreted to reflect sensitization of the orienting reflex caused by the interruption by the experimenter in the control group, an effect which is not seen in the instruction group as this group is provided with additional safety information.

Even though both differential FIR and SIR are eliminated after instructed extinction in the experimental group, it is crucial that evidence of intact differential responding be present in the control group to attribute the effect to the content of the instructions rather than to the fact that the experimental stimulus sequence was interrupted. Given the amplitude of the FIR tends to be larger than that of the SIR, we would predict that the EIR would reflect a response pattern similar to that seen for the FIR, and therefore would not allow for the detection of instructed extinction effects. If the EIR approach fails to detect instructed extinction effects, it could still be argued that using a FIR/SIR scoring technique is not justified based on the findings of one fear conditioning paradigm, however as it is not possible to predict a-priori when dissociations will occur important information could be missed if an EIR approach is not sensitive to such dissociations. In order to examine this possibility we applied the FIR/SIR and the entire interval scoring technique to the data reported by Luck and Lipp (2015b). This study compared two instruction groups (US electrode attached and US electrode removed) with a non-instructed control group, measuring electrodermal responding and conditional stimulus valence evaluations. As the focus of the current paper is on the electrodermal data, not the effect of instructed extinction, the reader is referred to Luck and Lipp (2015b) for details about the conditional stimulus valence measure, the effect of removal/attachment of the US electrode, and a more comprehensive discussion of instructed extinction.

Method

Participants

Seventy-eight (47 female) undergraduate students, aged between 17 and 50 years (*M* = 22.28 years), volunteered participation. The participants were compensated with course credit or monetary compensation and the procedures were approved by the Curtin University ethics review board. The participants were randomly assigned to either the control (*n* = 24), the instruction (electrode-on) group (n = 30), or the instruction (electrode-off) group (n = 24). One participant's electrodermal responses were lost due to problems with the recording device.

Apparatus/Stimuli

Color pictures of four Caucasian, male adults [NimStim database: images M_NE_C: models 20, 21, 32, 31, Tottenham et al. (2009)] displaying neutral facial expressions were used as the conditional stimuli (CS). The pictures were 506 × 650 pixels in size and were presented on a 24 inch color LCD screen for 6 s. Counter-balancing was conducted across participants, varying three factors – the faces used in the experiment, the face used as CS+/CS-, and the nature of the first trial (CS+/CS-). The trial sequence was arranged in a pseudo-random order, such that a CS+ or CS- was not presented on more than two consecutive trials. The unconditional stimulus (US) was a 200 ms electrotactile stimulus, pulsed at 50 Hz and delivered by a Grass SD9 Stimulator to the participant's preferred forearm.

Electrodermal activity was recorded with two 8 mm Ag/AgCl electrodes filled with an isotonic gel and DC amplified at a gain of 5 μSiemens per Volt. A Biopac MP150 system, using AcqKnowledge Version 3.9.1 at a sampling frequency of 1000 Hz was used to record the electrodermal responding and respiration data, and DMDX 4.0.3.0 software (Forster & Forster, 2003) was used to control the stimulus presentation and timing.

Procedure

After washing their hands and providing informed consent the participants were seated in front of a monitor in a separate cubicle of the laboratory. The electrodermal electrodes were attached to the thenar and hypothenar prominences of their non-dominant hand. The US electrode was attached to their dominant forearm and the participants underwent a shock work up procedure to set the intensity of the electrotactile stimulus to a level they experienced as subjectively unpleasant but not painful. After the work-up procedure, the participants were asked to relax and watch a blank computer screen while a 3 minute baseline of their electrodermal activity was recorded. After this baseline, participants were informed that they would view faces on the screen and that they should pay attention and evaluate the faces as pleasant or unpleasant. The conditioning sequence, which consisted of habituation, acquisition, and extinction phases was started. During habituation, both CS+ and CS- were presented a total of 4 times to allow for the habituation of orienting responses. Acquisition, which followed habituation immediately, involved 8 presentations of the CS+ and the CS-, with the offset of the CS+ coinciding with the onset of the US in a 100% reinforcement schedule, whilst the CS- was presented alone. For example a 6 s CS+ was immediately followed by 200 ms electrotactile stimulus (or a 6 s CS- was presented alone) and then a blank rest screen was presented for either 11, 13 or 15 s before the onset of the next CS.

After the last trial of the acquisition, the experimenter entered the participants' room and informed them that the half-way point of the experiment had been reached and that the electrodes needed to be checked, before visually inspecting the electrodermal electrodes. For participants in the control group, the experimenter removed and reattached the shock electrode. For participants in the instruction/electrode-on group, the shock electrode was removed and reattached, and the participants were informed they would not receive the electrotactile stimulus anymore. For participants in the instruction/electrode-off group, the shock electrode was removed and the participants were informed they would no longer receive the electrotactile stimulus. After the interruption, all participants were informed that the experiment would continue and the extinction phase, consisting of 8 unreinforced presentations of both the CS+ and the CS- was started. A blank rest screen, presented randomly for either 11, 13, or 15 seconds was used as the inter-trial intervals during the conditioning phases. Following extinction, the electrodes were removed and the participants were led into a separate room to complete a post-experimental questionnaire, in which they were asked to identify (from a set of 4) which faces they had viewed during the experiment and which face had been followed by the electrotactile stimulus, as a measure of contingency awareness. As a manipulation check, participants were asked to indicate whether or not they had believed the instructions (yes or no question; instruction groups only).

Scoring and Response Definition

First and second interval scoring. As recommended by Prokasy and Kumpfer (1973), first interval responding (FIR) was defined as responses starting within 1-4 seconds of CS onset, second interval responding (SIR) was defined as responses starting within 4-7 seconds of CS onset. The largest response starting within the latency response window was scored and the magnitude was calculated as the difference between response onset and peak (Prokasy & Kumpfer, 1973). First and second interval responses were square root transformed to reduce the positive skew of the distribution (Dawson et al., 2007), and range corrected to reduce the effect of individual differences in response size (Boucsein et al., 2012; Dawson et al., 2007). The largest response displayed by the participant, most often the response to the first or second presentation of the US, was used as the reference for the range correction. To avoid bias in the scoring, the scorer was blind to participant group and the nature of the CS trial (CS+ or CS-). To reduce the influence of trial by trial variability, FIR and SIR were averaged into blocks of 2 consecutive trials.

Entire interval scoring. The entire interval response (EIR) was scored as described in Pineles et al. (2009). The mean skin conductance level recorded during the two seconds immediately preceding the CS was subtracted from the highest skin conductance level recorded during the 6 s CS presentation. Subtraction of the baseline mean often resulted in a negative value for the EIR for which a zero response was substituted (40% of all responses). An additional measure of EIR was obtained by scoring the largest response starting within the 6 s CS presentation as the difference between response onset and response peak. This additional scoring methodology was included to ensure that any difference between the first and second interval scoring technique and the entire interval scoring technique was not due to differences in the way a 'response' was defined, i.e. highest skin conductance level in CS-US interval - pre-CS baseline vs. actual identification of the largest response during the CS-US interval. The two EIR scoring methods yielded largely comparable results and therefore only responses based on Pineles et al. (2009) are reported, however the additional results are available on request. A square root transformation and range correction was conducted on the EIR in the same manner as the FIR and SIR and the EIR was averaged into blocks of two consecutive trials.

Statistical Analyses

FIR, SIR, and EIR were subjected to separate 3 × 2 × n (Group [control, electrode-on, electrode-off] × CS [CS+, CS-] × Block [habituation = 2, acquisition = 4, extinction = 4]) factorial ANOVAs for habituation, acquisition, and extinction. As the influence of the instructional manipulation is expected between the last trial of acquisition and the first trial of extinction, additional 3 × 2 × 2 (Group [control, electrode-on, electrode-off] × CS [CS+, CS-] × Phase [last trial of acquisition, first trial of extinction]) factorial ANOVAs were performed. Bonferroni adjustments were used on all main and simple effect comparisons to protect against the accumulation of α –error and adjusted *p* values have been reported for these follow-up analyses. All analyses were conducted with IBM SPSS Statistics 22 with a significance level of .05, and Pillai's trace statistics have been reported.

Results

Preliminary Checks. The male to female sex ratio between groups did not differ (control: 8:16, electrode on: 14:16, electrode off: 9:15), $\chi^2(2) = 1.06$, $p = .588$, however the groups did differ in age, $F(2, 77) = 3.70$, $p = .029$, $\eta p^2 = .090$. The control group ($M = 21.71$ years, $SD = 6.68$ years) did not differ from the electrode on group, $p > .999$, or the electrode off group, $p = .224$, however the electrode off group ($M = 25.50$ years, $SD = 10.93$ years) was older than the electrode on group ($M = 20.17$ years, $SD = 2.53$ years), $p = .027$. Six participants aged over 34 years (control = 2, electrode off = 4) were considered outliers using Tukey's outlier identification method (Hoaglin, Iglewicz, & Tukey, 1986; Hoaglin & Iglewicz, 1987). When they were excluded from the analyses no differences between the groups were detected, $F(2, 71) = 0.96$, $p = .390$, $\eta p^2 = .027$ (control: $M = 19.91$ years, $SD = 2.29$ years; electrode on: $M = 20.17$ years, $SD = 2.53$ years; electrode off: $M = 21.25$ years, $SD = 5.00$ years), and when the analyses were run excluding these participants the pattern of results did not change.

Habituation

First Interval Responding. The FIR recorded during habituation is presented in the left panel of Figure 1. A main effect of block, $F(1, 74) = 61.11$, $p < .001$, $\eta p^2 = .452$, and a Block × Group interaction, $F(2, 74) = 3.82$, $p = .026$, $\eta p^2 = .094$, were detected. Responding significantly declined from block 1 to block 2 in the control, $F(1, 74) = 36.47$, $p < .001$, $\eta p^2 = .330$, electrode-on, $F(1, 74) = 28.01$, $p < .001$, $\eta p^2 = .275$, and electrode-off groups, $F(1, 74) = 5.19$, $p = .026$,

$\eta p^2 = .066$, however this decline was smaller in the electrode-off group resulting in the Block × Group interaction. The remaining main effects and interactions did not reach significance, largest (CS × Block), $F(1, 74) = 0.91$, $p = .342$, $\eta p^2 = .012$.

Second Interval Responding. The SIR recorded during habituation is presented in the left panel of Figure 2. No main effects or interactions reached significance, largest (Block), $F(1, 74) = 1.88$, $p = .175$, $\eta p^2 = .025$.

Entire Interval Responding. The EIR recorded during habituation is presented in the left panel of Figure 3. A main effect of block was detected, $F(1, 74) = 52.53$, $p < .001$, $\eta p^2 = .415$, which confirmed that responding declined from block 1 to block 2. The remaining main effects and interactions did not reach significance, largest (CS), $F(1, 74) = 1.76$, $p = .189$, $\eta p^2 = .023$.

Acquisition

First Interval Responding. The FIR recorded during acquisition is presented in the middle panel of Figure 1. Main effects of CS, $F(1, 74) = 50.08$, $p < .001$, $\eta p^2 = .404$, and block, $F(3, 72) = 10.12$, $p < .001$, $\eta p^2 = .297$, were qualified by a CS × Block interaction, $F(3, 72) = 13.41$, $p < .001$, $\eta p^2 = .359$. During block 1, responding to CS+ and CS- did not differ $F(1, 74) = 0.01$, $p = .918$, $\eta p^2 < .001$, however during blocks 2, $F(1, 74) = 37.20$, $p < .001$, $\eta p^2 = .335$, 3, $F(1, 74) = 62.50$, $p < .001$, $\eta p^2 = .458$, and 4, $F(1, 74) = 37.44$, $p < .001$, $\eta p^2 = .336$, responding to CS+ was larger than responding to CS-. The remaining main effects and interactions did not attain significance, largest (Block × Group), $F(6, 146) = 0.82$, $p = .556$, $\eta p^2 = .033$.

Second Interval Responding. The SIR recorded during acquisition is presented in the middle panel of Figure 2. Main effects of CS, $F(1, 74) = 62.35$, $p < .001$, $\eta p^2 = .457$, and block, *F*(3, 72) = 3.64, *p* = .017, ηp^2 = .132, were qualified by a CS × Block interaction, *F*(3, 72) = 13.67, *p* < .001, ηp^2 = .363. During block 1, responding between CS+ and CS- did not differ, *F*(1, 74) = 0.16, *p* = .689, ηp^2 = .002, but during blocks 2, *F*(1, 74) = 22.12, *p* < .001, ηp^2 = .230, 3, *F*(1, 74) = 41.00, *p* < .001, ηp^2 = .357, and 4, *F*(1, 74) = 64.08, *p* < .001, ηp^2 = .464, CS+ elicited larger responses than CS-. The remaining main effects and interactions did not attain significance, largest (Block × Group), *F*(6, 146) = 1.46, *p* = .196, ηp^2 = .057.

Entire Interval Responding. The EIR recorded during acquisition is presented in the middle panel of Figure 3. A main effect of CS, *F*(1, 74) = 80.61, *p* < .001, ηp^2 = .521, and a main effect of block, *F*(3, 72) = 8.97, *p* < .001, ηp^2 = .272, were qualified by a CS × Block interaction, *F*(3, 72) = 14.54, *p* < .001, ηp^2 = .377. During block 1, responding between CS+ and CS- did not differ, *F*(1, 74) = 0.15, *p* = .702, ηp^2 = .002, but during blocks 2, *F*(1, 74) = 41.63, *p* < .001, ηp^2 = .360, 3, *F*(1, 74) = 78.73, *p* < .001, ηp^2 = .515, and 4, *F*(1, 74) = 53.23, *p* < .001, ηp^2 = .418, CS+ elicited larger responses than CS-. The remaining main effects and interactions did not attain significance, largest (Block × Group), *F*(6, 146) = 1.61, *p* = .149, ηp^2 = .062.

Instructed Extinction Manipulation – Trial Based Analysis

First Interval Electrodermal Responding. The FIR recorded during the last trial of acquisition and the first trial of extinction is presented in the top section of Figure 4. A main effect of CS, *F*(1, 74) = 13.75, *p* < .001, ηp^2 = .157, and a main effect of phase, *F*(1, 74) = 8.87, *p* = .004, ηp^2 = .107, were qualified by a CS × Phase interaction, *F*(1, 74) = 18.84, *p* < .001, ηp^2 = .203. On the last trial of acquisition, differential responding between CS+ and CS- was present, *F*(1, 74) = 30.15, *p* < .001, ηp^2 = .289, however, this differential responding was not present on the first trial of extinction, *F*(1, 74) = 0.01, *p* = .925, ηp^2 < .001. The critical CS × Phase ×

Group interaction did not reach significance, $F(2, 74) = 0.51$, $p = .602$, $\eta p^2 = .014$, and follow-up analyses confirm that differential responding was not present in any group at the beginning of extinction, all p's > .642. The remaining main effects and interactions did not attain significance, largest (Phase × Group), $F(2, 74) = 1.78$, $p = .176$, $\eta p^2 = .046$.

Second Interval Electrodermal Responding. The SIR recorded during the last trial of acquisition and the first trial of extinction is presented in the middle section of Figure 4. Main effects of CS, $F(1, 74) = 22.86$, $p < .001$, $\eta p^2 = .236$, and phase, $F(1, 74) = 7.51$, $p = .008$, $\eta p^2 = .092$, and a CS × Phase interaction, $F(1, 74) = 23.19$, $p < .001$, $\eta p^2 = .239$, were qualified by a CS × Phase × Group interaction, $F(2, 74) = 3.44$, $p = .037$, $\eta p^2 = .085$. On the last trial of acquisition, responding to CS+ was larger than responding to CS- in all groups (control: $F(1, 74) = 9.23$, $p = .003$, $\eta p^2 = .111$; electrode-on: $F(1, 74) = 25.03$, $p <.001$, $\eta p^2 = .253$; electrode-off: $F(1, 74) = 11.54$, $p = .001$, $\eta p^2 = .135$). Following instructed extinction, differential responding to CS+ and CS- was present in the control group, $F(1, 74) = 4.20$, $p = .044$, $\eta p^2 = .054$, but not in the electrode-on, $F(1, 74) = 1.53$, $p = .220$, $\eta p^2 = .020$, or electrode-off groups, $F(1, 74) = 0.02$, $p = .887$, $\eta p^2 < .001$. The remaining main effects and interactions did not attain significance, largest (group), $F(2, 74) = 3.00$, $p = .056$, $\eta p^2 = .075$.

Entire Interval Electrodermal Responding. The EIR recorded during the last trial of acquisition and the first trial of extinction is presented in the bottom section of Figure 4. Main effects of CS, $F(1, 74) = 35.03$, $p < .001$, $\eta p^2 = .321$, and phase, $F(1, 74) = 5.29$, $p = .024$, $\eta p^2 = .067$, were qualified by a CS × Phase interaction, $F(1, 74) = 37.31$, $p < .001$, $\eta p^2 = .335$. On the last trial of acquisition, differential responding between CS+ and CS- was present, $F(1, 74) = 73.06$, $p < .001$, $\eta p^2 = .497$, however, this differential responding was no longer present on the first trial of extinction, $F(1, 74) = 0.08$, $p = .777$, $\eta p^2 = .001$. The critical CS × Phase × Group interaction did not reach significance, $F(2, 74) = 0.44$, $p = .645$, $\eta p^2 = .012$, and follow-up analyses confirm that differential responding was not present in any group at the beginning of extinction, all p's > .472. The remaining main effects and interactions did not attain significance, largest (Phase × Group), $F(2, 74) = 1.63$, $p = .203$, $\eta p^2 = .042$.

Extinction

First Interval Electrodermal Responding. The FIR recorded during extinction is presented in the right panel of Figure 1. A marginal main effect of CS, $F(1, 74) = 3.84$, $p = .054$, $\eta p^2 = .049$, revealed that electrodermal responding to CS+ was marginally larger than to CS-. A main effect of block, $F(3, 72) = 5.93$, $p = .001$, $\eta p^2 = .198$, revealed that responding was larger in block 1 in comparison with block 3, $p = .002$, and block 4, $p = .002$. The remaining omnibus effects failed to reach significance, largest (Block × Group), $F(6, 146) = 1.52$, $p = .176$, $\eta p^2 = .059$.

Second Interval Electrodermal Responding. The SIR recorded during extinction is presented in the right section of Figure 2. A main effect of block, $F(3, 72) = 2.94$, $p = .039$, $\eta p^2 = .109$, revealed that responses in block 1 were larger than responses in block 4, $p = .042$. A main effect of group, $F(2, 74) = 3.68$, $p = .030$, $\eta p^2 = .090$, and a CS × Group interaction, $F(2, 74) = 4.90$, $p = .010$, $\eta p^2 = .117$, were detected. In the control group, CS+ elicited larger responses than CS-, $F(1, 74) = 8.65$, $p = .004$, $\eta p^2 = .105$, however, in the electrode on group, $F(1, 74) = 1.43$, $p = .236$, $\eta p^2 = .019$, and the electrode off group, $F(1, 74) = 0.14$, $p = .709$, $\eta p^2 = .002$, responses to CS+ and CS- did not differ. The remaining main effects and interactions did not attain significance, largest (Block × Group), $F(6, 146) = 1.19$, $p = .313$, $\eta p^2 = .047$.

Entire Interval Responding. The EIR recorded during extinction is presented in the right panel of Figure 3. A main effect of CS, revealed that responding to CS+ was larger than responding to CS-, $F(1, 74) = 4.40$, $p = .039$, $\eta p^2 = .056$. A main effect of block was detected, $F(3, 72) = 2.82$, $p = .045$, $\eta p^2 = .105$, revealing that responding was larger in block 1 in comparison with block 3, $p = .002$, and block 4, $p = .002$. The remaining omnibus effects failed to reach significance, largest (Block × Group), $F(6, 146) = 1.63$, $p = .143$, $\eta p^2 = .063$.

Discussion

The current paper aimed to investigate the sensitivity of three different electrodermal responses indices, first interval responding (FIR), second interval responding (SIR), and entire interval responding (EIR), to reflect the effects of an instructed extinction manipulation. Instructed extinction is known to produce robust, and meaningful, dissociations between FIR and SIR (see Luck & Lipp, 2015a; 2015b; Rowles, Lipp, & Mallan, 2012). We aimed to examine whether instructed extinction effects would be reflected in EIR by rescoring the data of Luck and Lipp (2015b).

Throughout the habituation phase, a main effect of block confirmed that both FIR and EIR showed evidence for habituation, however, no evidence for habituation was detected in SIR. This finding is consistent with the view that SIR is less sensitive to orienting, and supports the decision to only report FIR during the habituation phase. It should be noted that prior studies have reported changes in SIR during habituation (Pineles et al., 2009), but these changes were considerably smaller than those seen in FIR or EIR (effect sizes [η^2] of .01, .20 and .14, respectively) and may reflect on the larger sample size used in that study. During acquisition, evidence for conditioning was apparent in all electrodermal responses indices and as reported before, results of FIR, SIR, and EIR were comparable. The instructed extinction/control manipulation eliminated differential FIR and EIR in all groups when assessed either on the initial trial of extinction or across the entire extinction training. As described elsewhere (Luck & Lipp, 2015a, 2015b; Rowles, Lipp & Mallan, 2012), elimination of differential responding at the beginning of extinction as a result of the control manipulation is likely to reflect sensitization of the orienting reflex, resulting in increased responding to the CS-. Consistent with the proposal that SIR is less sensitive to the effects of orienting, the control group shows intact differential SIR at the beginning of extinction and across the entire extinction training. It is this intact differential SIR in the control group which allows the conclusion that the current results reflect on the content of the instructions provided rather than a general effect of interrupting the experimental procedure. The entire interval response is not sensitive to the apparent dissociation of orienting and anticipation, and cannot reflect the effects of instructed extinction as it was largely affected by the more prominent effects of orienting. Thus, the effects of instructed extinction would be lost if an EIR measure was used to reflect electrodermal responses in the current study.

To ensure that the current findings were not specific to a particular method of calculating the EIR, we also calculated EIR as the difference between response onset and response peak observed within the entire CS-US interval. As in the majority of differential conditioning designs (including that used by Pineles et al., 2009) a pseudorandom trial sequence (CS+/CS- is not presented more than twice consecutively) is used the presentation of a CS+ is more likely to precede the presentation of a CS- . During acquisition, the response elicited by the US will elevate the skin conductance baseline before the next trial leading to the well-established finding that CS- presentations have higher electrodermal baselines than CS+ presentations (see for instance, Luck & Lipp, 2015b). This baseline difference potentially underestimates the response to CS- which would artificially inflate the size of differential conditioning effects and if a CS fails to elicit a response, the slightly downward trajectory of the skin conductance trace should render the largest skin conductance value during the CS-US interval smaller than a pre-stimulus baseline yielding a nonsensical negative response value. In the current investigation, we found a similar pattern of results emerged for the EIR regardless of whether the response base was defined as the mean of a pre-CS baseline or the response onset within the CS-US interval. This is reassuring, but may reflect on the strong experimental manipulations (100% CS-US contingency) and large sample size in the current study.

The results of the current investigation support Prokasy and Kumpfer's (1973) recommendation that conditioning experiments should be designed and scored in such a way as to allow a distinction between first and second interval responding. We agree, and would expect, that in procedures where orienting and anticipation processes overlap, FIR, SIR, and EIR will yield largely comparable results, and that an entire interval scoring technique, which uses the skin conductance level at response onset as a reference, could accurately capture the experimental outcomes. Based on this it could be argued that the current examination is paradigm specific and not applicable to broader fear conditioning studies, however it is not always possible to predict a-priori when dissociations between different processes might occur and limiting the scoring to EIRs could lead to the loss of important information. Based on the current analysis, a strategy that scores electrodermal response indices of Pavlovian conditioning in distinct latency windows following the recommendations of Prokasy and Kumpfer (1973) seems advisable.

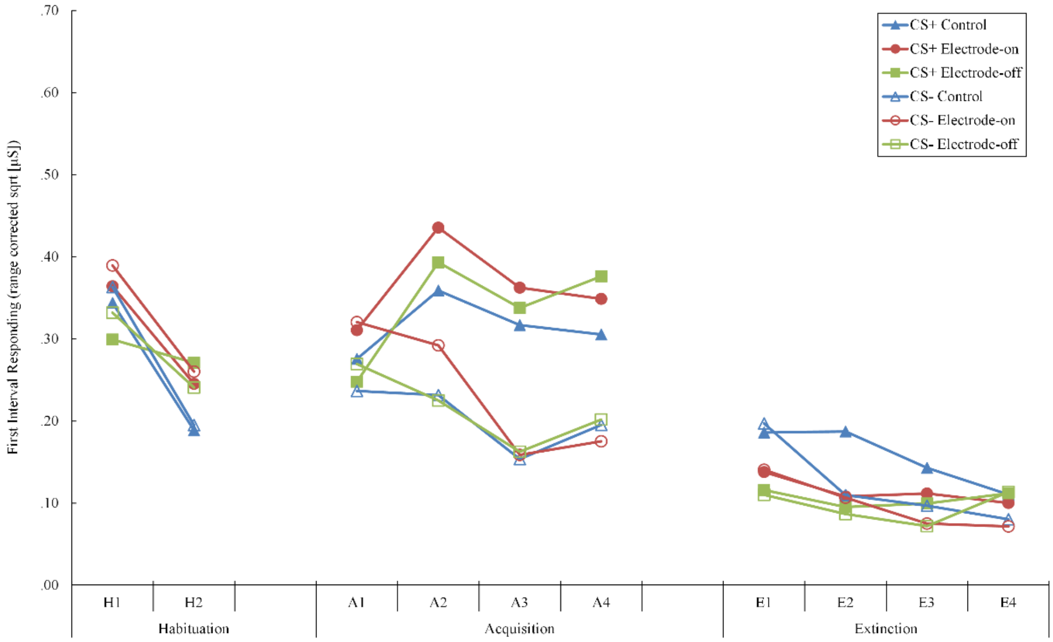

Figure 1. Mean first interval electrodermal responses during habituation, acquisition, and extinction phases.

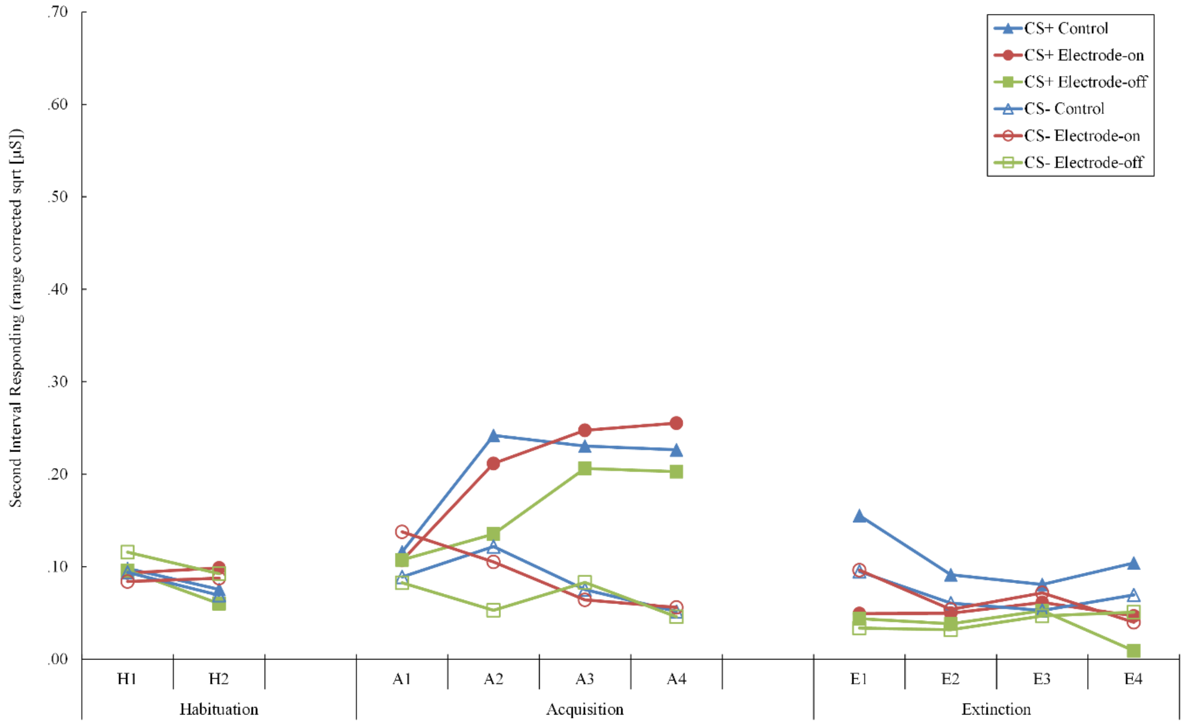

Figure 2. Mean second interval electrodermal responses during habituation, acquisition, and extinction phases.

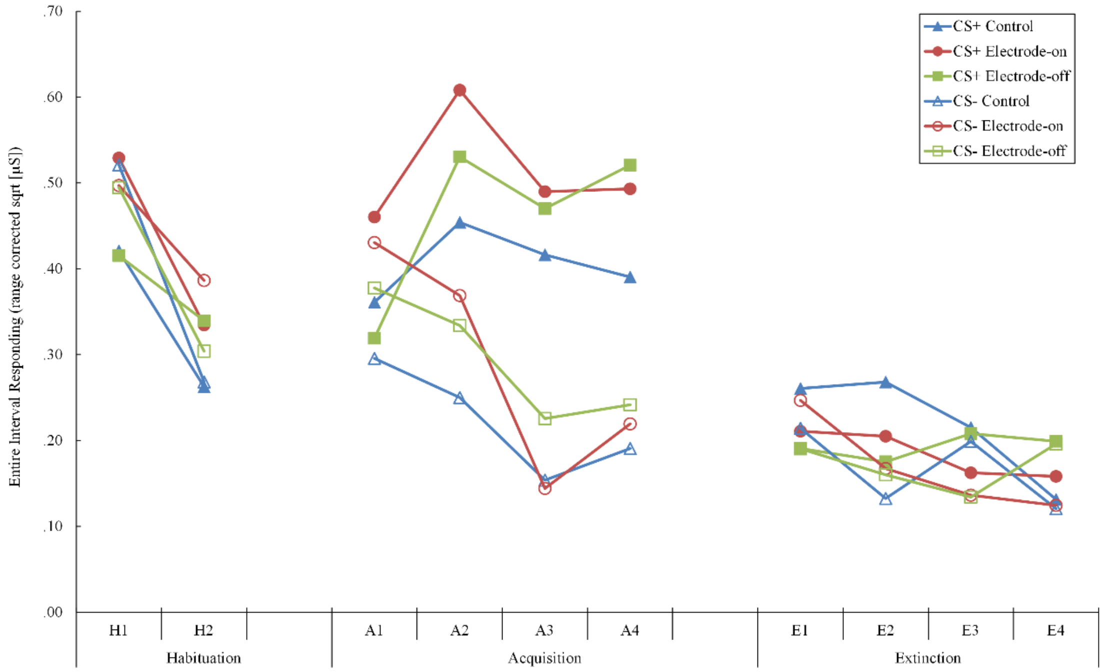

Figure 3. Mean entire interval electrodermal responses during habituation, acquisition, and extinction phases.

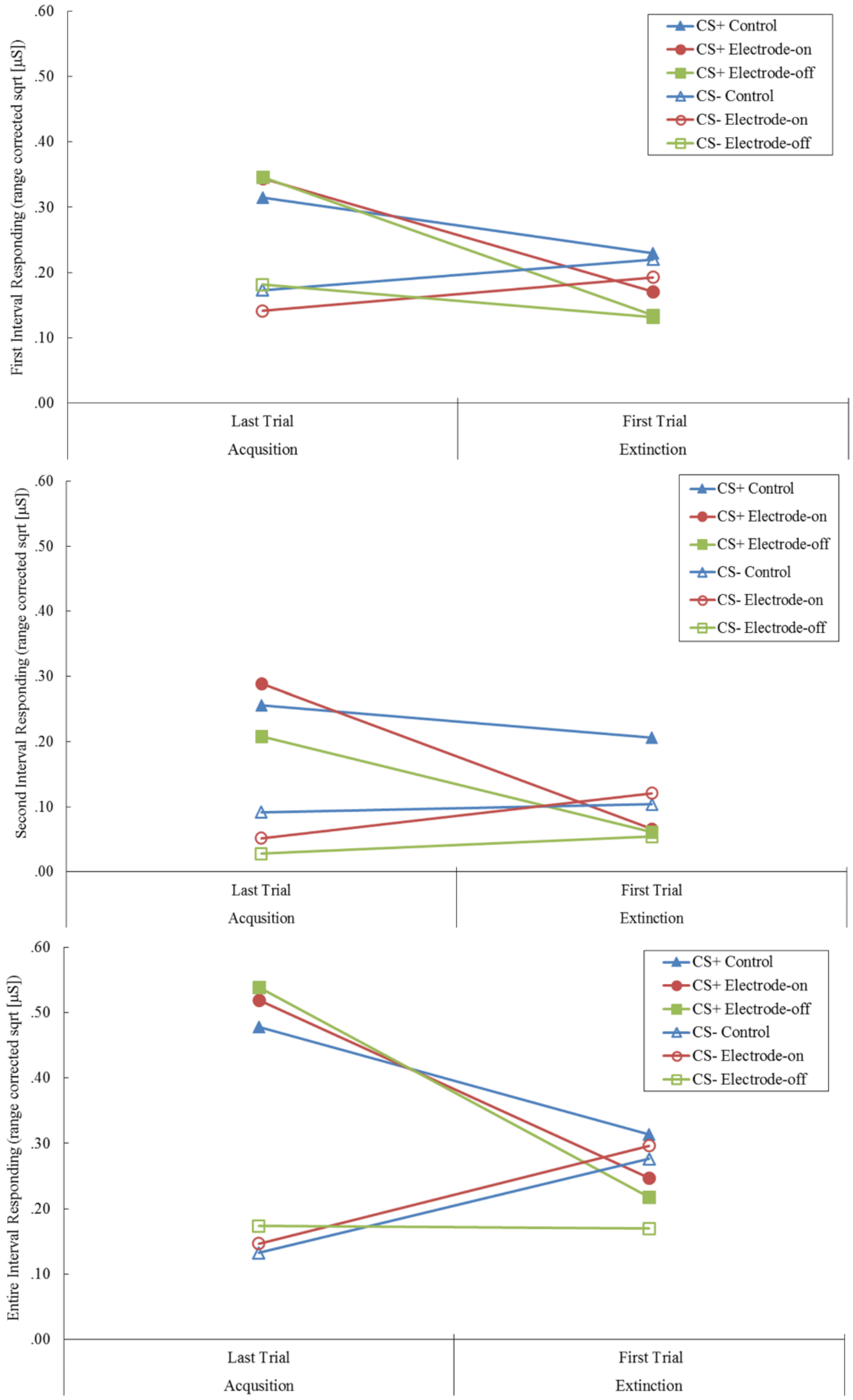

Figure 4. First interval (top), second interval (middle), and entire interval (bottom) electrodermal responses during the last trial of acquisition and the first trial of extinction.

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