NIH Public Access
Author Manuscript
Behav Neurosci. Author manuscript; available in PMC 2014 June 01.

Published in final edited form as:
Behav Neurosci. 2013 June ; 127(3): 357–368. doi:10.1037/a0032742.

Dissociation between implicit and explicit responses in postconditioning UCS revaluation after fear conditioning in humans

Douglas H. Schultz, **Nicholas L. Balderston**, **Jennifer A. Geiger**, and **Fred J. Helmstetter**
University of Wisconsin-Milwaukee

Abstract

The nature of the relationship between explicit and implicit learning is a topic of considerable debate. In order to investigate this relationship we conducted two experiments on postconditioning revaluation of the unconditional stimulus (UCS) in human fear conditioning. In Experiment 1, the intensity of the UCS was decreased following acquisition for one group (devaluation) and held constant for another group (control). A subsequent test revealed that even though both groups exhibited similar levels of UCS expectancy, the devaluation group had significantly smaller conditional skin conductance responses. The devaluation effect was not explained by differences in the explicit estimates of UCS probability or explicit knowledge that the UCS intensity had changed. In Experiment 2, the value of the UCS was increased following acquisition for one group (inflation) and held constant for another group (control). Test performance revealed that UCS inflation did not alter expectancy ratings, but the inflation group exhibited larger learned skin conductance responses than the control group. The inflation effect was not explained by differences in the explicit estimates of UCS probability or explicit knowledge that the UCS intensity had changed. The SCR revaluation effect was not dependent on explicit memory processes in either experiment. In both experiments we found differences on an implicit measure of learning in the absence of changes in explicit measures. Together, the differences observed between expectancy measures and skin conductance support the idea that these responses might reflect different types of memory formed during the same training procedure and be supported by separate neural systems.

Keywords

AWARENESS; DEVALUATION; EXPECTANCY; FEAR CONDITIONING; INFLATION; SKIN CONDUCTANCE

In Pavlovian conditioning, a behaviorally neutral conditional stimulus (CS) is paired with an unconditional stimulus (UCS). Through repeated pairings, the CS can come to elicit a conditional response (CR) that is often similar to the response elicited by the UCS (Pavlov, 1927). The procedure is referred to as Pavlovian fear conditioning when the UCS is an aversive or fear-eliciting stimulus (for review see Fanselow & Poulos, 2005; Kim & Jung, 2006). The ability of the CS to elicit a CR after training is evidence that associative learning has occurred. Fear conditioning has been widely used with various organisms to investigate learning, memory and emotion.

Address correspondence to: Fred J. Helmstetter, Ph.D., Department of Psychology, University of Wisconsin-Milwaukee, PO Box 413, Milwaukee, WI 53211, Phone: 414-229-4903, Fax: 414-229-5219.

The nature of what is learned during conditioning has been repeatedly debated in the history of learning theory. Stimulus-response (S-R) theories tend to focus on the importance of associations between the CS and responses emitted by the subject. The S-R approach puts little emphasis on the role of the UCS in acquisition beyond its initial ability to elicit a response. In contrast, stimulus-stimulus (S-S) theories often state that the important association in conditioning is between the CS and a representation of the predicted outcome or UCS (Mackintosh, 1983).

One method to test between the S-R and S-S oriented theories of conditioning is to modify the value of the UCS representation, independent of the CS-UCS association, after acquisition. This experimental approach is referred to as "revaluation". Revaluation can generate different hypotheses from an S-R or S-S theoretical standpoint (Delameter & Lolordo, 1991; Rozeboom, 1958) and can be done in either of two ways. *Devaluation* occurs when the potency of the UCS representation is weakened following acquisition, and inflation occurs when the potency of the UCS representation is strengthened or increased after acquisition. S-R theory predicts that manipulating the UCS representation following conditioning will result in no change to the CR in a test session because the important association is directly between the CS and the response. However, S-S theory predicts that a manipulation of the UCS representation will result in changes to the CR in a test session.

Rescorla (1973) examined devaluation using a conditioned-suppression procedure. In this experiment one group of rats (devaluation) underwent habituation training with the UCS following acquisition in the absence of any CS presentations. Another group (control) did not experience UCS habituation following acquisition. In a subsequent test session, the devaluation group exhibited less conditioned suppression when the CS was presented. These findings suggest that the current value of the UCS representation is an important factor in the production of a CR. Subsequent experiments (Rescorla, 1974) found that an inflation manipulation increased conditioned suppression relative to controls. Together, these findings suggest that conditional responses are dependent upon the current value of the UCS representation and these data support S-S theory. Other work (Holland & Rescorla, 1975) examined the effect of revaluation on first and second order conditional stimuli. These experiments replicated prior findings with a first order CS, but observed that UCS revaluation effects were not evident in the presence of a second order CS. Revaluation effects are also observed under instrumental contingencies. If the value of a reinforcer is changed following the initial acquisition of the instrumental contingency, responses at test change according to the new value of the reinforcer (Adams & Dickinson, 1981; Colwill & Rescorla, 1985a, 1985b). Revaluation effects are seen in a variety of conditioning preparations including flavor preferences (Delamater, Campese, LoLordo & Sclafani, 2006; Dwyer, 2005) and conditioned suppression (Rescorla, 1973, 1974).

Postconditioning changes to the value of the UCS have also been examined with human subjects in "evaluative conditioning". This procedure involves pairing a neutral stimulus with a stimulus that has some affective property and subsequently measuring the affective value of the previously neutral stimulus (for review see De Houwer, Thomas & Baeyens, 2001). Baeyens, Eelen, Van den Bergh & Crombez (1992) paired faces that had been rated by subjects as neutral, with faces that had been rated as either positive or negative. The revaluation phase consisted of presenting the positive or negative faces along with verbal information concerning the person in the picture. This verbal information was either positive or negative in nature. A test session revealed that this postconditioning UCS modification was successful in affecting the evaluative response to the CS that predicted a UCS whose value had been manipulated relative to a control group. Evaluative conditioning studies also find evidence of changes in responses evoked by a CS after a revaluation of the UCS.

Several studies have examined postconditioning UCS revaluation in human subjects using fear conditioning. White and Davey (1989) used a mild 65 dB tone as a UCS in a differential conditioning experiment. Following acquisition the value of the UCS was increased to an aversive level for the inflation group and it was held constant for the control group. The inflation group received several presentations of the UCS alone after acquisition. Each UCS presentation increased in intensity incrementally with a 115 dB final tone. Neither group demonstrated differential skin conductance responses in the acquisition phase, but in the test session the inflation group exhibited differential responses while the control group did not. These data suggest that postconditioning UCS revaluation occurs in human subjects.

De Jong, Murris, and Merckelbach (1996) used concurrent measures of both an explicit and implicit response system during an inflation experiment in classical conditioning. This study aimed to replicate the skin conductance response (SCR) results of White and Davey (1989) using a similar procedure. This study added an explicit measure of conditioning, UCS expectancy, in which subjects continuously reported the degree to which they expected the UCS to occur. The results did not show an inflation effect on the SCR measure, but there was an effect on the UCS expectancy measure with the inflation group showing a greater differential expectancy between the CS+ and the CS− relative to the control group. The authors concluded that the inflation effect in humans is neither reliable nor robust.

Another study (Hosoba, Iwanaga & Seiwa, 2001) using the same type of procedure found that devaluation and inflation manipulations both had an impact on conditional responses measured with SCR, which supports the White and Davey (1989) study. However, CS aversiveness ratings that were recorded at several time points throughout the experiment indicate that the revaluation effect was not due to changes in the perceived aversiveness of the CS as White and Davey had suggested. The discrepancy between the observed revaluation effect measured with SCR and the lack of a revaluation effect on the CS aversiveness scores was interpreted as reflecting different learning systems.

A number of studies have identified important dissociations between explicit and implicit response measures in conditioning paradigms (Bechara et al., 1995; Clark & Squire, 1998; Manns, Clark & Squire, 2001). These studies suggest that implicit conditional responses are not dependent upon explicit contingency knowledge. Lovibond and Shanks (2002) questioned these conclusions and postulated that there was not sufficient evidence to support the idea that implicit and explicit memory systems were operating independently of one another. Instead they proposed a model of conditioning in which implicit response systems will demonstrate learning only if the explicit system exhibits learning. However, Lovibond and Shanks based their argument largely on the method of using a post-experimental questionnaire to assess contingency awareness that the previous studies had employed. Forgetting or interference could both occur in the period of time between the conditioning session and the completion of the questionnaire. Lovibond and Shanks concluded that there was not sufficient evidence to support the idea that implicit and explicit memory systems were operating independently of one another.

Several studies have used a continuous UCS expectancy measure in order to eliminate some of the concerns about forgetting and interference when a questionnaire is used to assess awareness. Data from studies that have employed UCS expectancy measures has supported a dual process theory which states that implicit and explicit performance are dissociable from one another (Knight, Nguyen & Bandettini, 2003; Schultz & Helmstetter, 2010). Furthermore, participants demonstrate learning on an implicit measure when contingency awareness is blocked with a masking procedure (Balderston & Helmstetter, 2010).

Another way to test the dual process theory is postconditioning UCS revaluation. We hypothesized this manipulation would result in changes in the skin conductance response independent of any differences in explicit memory processes. The aim of the current study was to assess postconditioning UCS revaluation in human subjects simultaneously on both implicit and explicit response measures. Results from previous studies (De Jong, Murris & Merckelbach, 1996; Hosoba, Iwanaga & Seiwa, 2001; White & Davey, 1989) that have examined postconditiong UCS revaluation have been inconsistent. Here we tested whether or not UCS revaluation effects are observed on SCR. Furthermore, we aimed to identify whether or not any revaluation effect on SCR could be explained by explicit memory processes. We used UCS expectancy and intensity ratings to assess the explicit component of this type of learning. UCS expectancy captures the probabilistic component of an explicit process, but it does not provide any information regarding the sensory qualities of the UCS that are expected. We also measured UCS intensity ratings to capture a qualitative component of subjects' knowledge about the predicted outcome.

Experiment 1

In the first experiment we focused on postconditioning UCS devaluation. SCR and UCS expectancy were measured throughout the experiment. Following differential fear conditioning one group (devaluation) had the value of the UCS decreased while another group (control) had the value of the UCS held constant. Both groups were then tested for CR performance in the absence of the UCS. Based on previous studies that examined revaluation without modifying contingencies (Hosoba, Iwanaga & Seiwa, 2001; White & Davey, 1989) we predicted that skin conductance responses would be lower at test for the devaluation group relative to controls. The experiment was designed to manipulate the value of the UCS independent of the contingencies so we predicted that UCS expectancy ratings would not differ between the groups at test.

Method

Participants—Thirty-four (nineteen females) right-handed, neurologically normal undergraduates ranging from eighteen to twenty-five years old (*M* = 19.5, *SEM* = 0.3) volunteered for this study. Participants received extra-credit in a psychology course. Participants supplied informed consent. All procedures were approved by the Institutional Review Board for human subject research at the University of Wisconsin-Milwaukee.

Apparatus

Electrical stimulus: The UCS was a 500 ms electrical stimulation delivered via a custom made AC (60Hz) source through two aluminum surface electrodes (2 cm diameter) placed over the right tibial nerve above the right medial malleolus consistent with previously published behavioral studies (Balderston & Helmstetter, 2010; Schultz & Helmstetter, 2010). The maximum possible output current was 7.50 mA. Each participant determined the maximum UCS intensity used in the experiment prior to the start of the experiment in a work up procedure. The work up procedure consisted of five or fewer presentations of the electrical stimulation. Each presentation was rated by the participant on a scale from 0–10 (0 = no sensation, 10 = painful but tolerable). The intensity of the electrical stimulus was increased until the participant rated it as a 10. The maximum UCS intensity for the experiment was set at a level that the participant rated as painful but tolerable.

UCS expectancy: Participants manipulated a custom-made rotary dial to report their expectancy of receiving the UCS at all times during the experiment. The dial controlled a cursor that was present at the bottom of the visual display. The cursor was set on a scale (range: 0–100). Real time feedback of the position of the cursor was displayed continually on the visual display. The dial was attached to the subject's right thigh with a Velcro strap. Participants manipulated the dial with their right hand. Participants were given verbal instructions on how to use the dial prior to the experiment. They were instructed to place the cursor at 0 on the scale if they were certain that they would not experience the UCS, at 50 if they were unsure if they would experience the UCS and at 100 if they were certain they would experience the UCS. Participants were instructed to continuously update their ratings throughout the course of the experiment. Subjects were not given any information about potential programmed relationships between the UCS and visual stimuli.

Skin conductance: A Contact Precision Instruments unit (Boston, MA) with a SC5 24 bit digital amplifier from Contact Precision Instruments was used to record skin conductance at a rate of 80 Hz. PSYLAB software (London, UK) was used for skin conductance data analysis. Skin conductance data was collected with electrodes (BIOPAC, Goleta, CA; 8 mm diameter, model EL258-RT) filled with electrolytic gel (Signagel, Parker Laboratories, Fairfield, NJ). Electrodes were attached to the sole of the left foot 2 cm apart consistent with previously published studies (Balderston & Helmstetter, 2010; Schultz & Helmstetter, 2010).

Visual stimuli: The experiment was performed using Presentation® software (Albany, CA). The visual stimuli and the UCS expectancy rating bar were presented on a Dell Inspiron 9300 (Round Rock, TX) laptop computer with a 17″ LCD monitor with a 60 Hz refresh rate. Two white geometric shapes (circle and triangle) with a 75 cm viewing distance served as conditional stimuli. The geometric shapes were 12.7 cm in height.

Procedure—Participants arrived in the laboratory and were randomly assigned to one of two groups (control and devaluation). The experimental room was 2.75 meters by 4.9 meters. The computer was placed on a table and participants sat in front of the table in a chair. The experiment was comprised of three different phases. In the first phase (acquisition) each CS was presented five times on a black background. CS presentations were eight seconds in duration. The CS+ co-terminated with a 500 ms UCS on all trials. The CS− was never paired with the UCS. CS trials were separated by a variable ITI (16, 20 or 24 seconds) with an average ITI of 20 seconds. In the acquisition phase the UCS intensity was set to 100% of the current that participants had rated as "painful but tolerable" (Control group, M = 5.83 mA, SEM = 0.46; Devaluation group, M = 5.00 mA, SEM = 0.57). Two different pseudorandom trial order conditions were created in which there were not more than two consecutive trials of the same type. The geometric shapes that served as conditional stimuli were counterbalanced. The acquisition phase was identical for both groups. Following acquisition participants were asked to give a verbal rating of the UCS intensity on the same scale that had been used in the work up procedure. In the second phase of the experiment (revaluation) all participants received three presentations of the UCS in the absence of either CS. The background of the visual display was blue during the revaluation phase. For the control group (n = 17) the UCS intensity during the revaluation phase was the same as it had been in the acquisition phase (100% of the maximum current, M = 5.84 mA, SEM = 0.46). For the devaluation group (n = 17) the UCS intensity during the revaluation phase was less than it was during the acquisition phase (50% of the maximum current, M = 2.50 mA, SEM = 0.28). Following the revaluation phase participants were again asked to give a verbal rating of the UCS intensity. In order to reduce the probability of ceiling effects on SCR in the test session, participants completed an unrelated task after giving the UCS intensity rating. This task was included so that participants would remain engaged in the experiment while waiting for autonomic activity to return to a stable baseline. The task consisted of the presentation of several non-emotional and non-arousing images from the International Affective Picture System (IAPS) database (Lang, Bradley & Cuthbert, 2005).

Participants were asked to identify whether the image on the screen was the same image they saw two images prior (2-back). After the 2-back task there was a two minute rest period with the screen dark. In the last phase of the experiment (test) each CS was presented five times on a black background in a pseudorandom order with the same constraints as the acquisition phase. The UCS was not presented in the test phase.

Data analysis—UCS expectancy for each participant on each trial was defined as the mean expectancy rating during the last four seconds of the CS period. Skin conductance response was calculated by identifying the peak of the response during the CS period and subtracting the mean of a five second baseline period prior to CS onset for each participant on each trial. A trial by CS type by group repeated measures ANOVA was conducted on the acquisition data for both UCS expectancy and SCR. Independent *t*-tests were conducted on the UCS intensity ratings following both the acquisition and revaluation phases. Visual inspection of the test session data revealed that CRs had extinguished by the third test trial. A CS type by group repeated measures ANOVA conducted on both the UCS expectancy and SCR data on the fourth trial of the test session supported this observation, largest F = 2.1, p = .15. By the fourth trial of the test session participants in both groups no longer displayed differential UCS expectancy ratings or SCRs. For this reason the data analysis of the test session only included the first three trials. A trial by CS type by group repeated measures ANOVA was conducted on the first three trials of the test session.

Results

Acquisition

UCS expectancy: A trial by group by CS type repeated measures ANOVA yielded a significant trial by CS type interaction, $F(4, 128) = 109.8$, $p < .001$, indicating that during the acquisition phase participants learned to expect the UCS on CS+ trials and not to expect the UCS on CS− trials; see Figure 1a. Simple effects tests were then conducted using the error term from the original ANOVA. Simple effects tests identified a significant difference between expectancy on the first CS+ trial relative to the first CS− trial with a higher level of expectancy on the CS− trial, $F(1, 128) = 3.92$, $p < .05$. Simple effects on the remaining trials found a significant difference between expectancy on the CS+ and the CS− trials with higher expectancy ratings on the CS+ trials, smallest $F = 125.44$, $p < .001$. There was also a significant main effect for CS type, $F(1, 128) = 296.5$, $p < .001$. There were no significant effects involving the group factor, largest $F = 1.28$, $p = .27$, indicating that all groups learned to expect the UCS on CS+ trials and not to expect the UCS on CS− trials as acquisition progressed.

Skin conductance: A trial by group by CS type ANOVA yielded a significant trial by CS type interaction, $F(4, 128) = 8.05$, $p < .001$, indicating that during the acquisition phase participants began to exhibit larger SCRs on CS+ trials than they did on CS− trials; see Figure 1b. Simple effects tests did not detect any differences between the SCR on the first CS+ trial compared to the first CS− trial, $F(1, 128) < 1$. However, the responses on the remaining CS+ trials of acquisition were significantly larger than the responses on the remaining CS− trials of acquisition, smallest $F = 11.75$, $p < .001$. There was also a main effect for CS type, $F(1, 128) = 29.05$, $p < .001$. The main effect for trial was also significant, $F(4, 128) = 6.41$, $p < .001$. There were no significant effects involving the group factor, largest $F = 1.34$, $p = .26$. The lack of any significant group effects indicates that both groups demonstrated equivalent levels of differential conditioning on the SCR measure.

UCS intensity ratings: We conducted a group by time repeated measures ANOVA on the UCS intensity ratings collected following acquisition and revaluation. We found a significant group by time interaction, $F(1, 32) = 22.08$, $p < .001$. There was not a significant difference between the UCS intensity ratings of the control group and the devaluation group following acquisition, $t(32) = -0.69$, $p = .5$. Further analysis of this interaction is included in the next section. Additionally, there was not a significant difference in the current used for the UCS across groups, $t(32) = 1.16$, p = .26. Both groups were exposed to the same level of UCS intensity in the acquisition phase and they reported similar intensity ratings; see Figure 2.

Revaluation

UCS intensity ratings: There was a significant difference between the UCS intensity ratings of the control and the devaluation groups following the revaluation phase, $t(32) = 3.07$, $p = .004$, with the control group rating the UCS as more intense than the devaluation group; see Figure 2. The control group was exposed to the same UCS intensity as they had in the acquisition phase and the devaluation group was exposed to the UCS intensity at half of the current they had in the acquisition phase. There was a significant difference between groups on the current used for the UCS during the revaluation phase, $t(32) = 6.22$, $p < .001$. The differences between the groups on the UCS intensity ratings signify that the devaluation group perceived the UCS as less intense than the control group in the revaluation phase.

Test

UCS expectancy: A trial by CS type by group repeated measures ANOVA conducted on the first three test trials results in a significant main effect for trial, $F(2, 64) = 68.3$, $p < .001$, characteristic of extinction learning when the CS is presented in the absence of the UCS. There was also a significant main effect for CS type, $F(1, 64) = 68.49$, $p < .001$, characterized by higher expectancy ratings for the CS+ than for the CS− trials. There was also a significant trial by CS type interaction, $F(2,64) = 27.02$, $p < .001$. This interaction was characterized a large difference in UCS expectancy ratings for the CS+ compared to the CS− on the first test trial, $t(66) = 9.88$, p < .001, a smaller difference on the second test trial, $t(66) = 4.73$, p < .001, and a small difference between CS+ and CS− UCS expectancy ratings by the third test trial, $t(66) = 2.51$, p = .015. There were no significant effects with group as a factor, largest $F = 0.24$, $p = .78$. These results suggest that UCS expectancy decreases across test trials, is larger on CS+ trials than CS− trials, and that there are no differences between the groups; see Figure 3a. The devaluation group and the control group showed similar levels of UCS expectancy at test following the revaluation phase.

Skin conductance: A trial by CS type by group repeated measures ANOVA conducted on the first three test trials resulted in a significant main effect for CS type, $F(1, 32) = 28.82$, $p < .001$, with larger responses on CS+ trials than on CS− trials. There was also a significant group by CS type interaction, $F(1, 32) = 7.77$, $p = .009$, and a significant trial by CS type by group interaction, $F(2, 64) = 3.31$, $p = .04$. This interaction was characterized by a significant difference in CS+ responses between groups on the first trial, $t(32) = 2.77$, p = .009, a marginal difference on the second test trial, $t(32) = 1.97$, p = .053, a difference on the third trial, $t(32) = 2.2$, p = .034, and a lack of difference in CS− responses between groups throughout the test session, largest $t = 0.85$, p > .05. These data suggest that there is an effect of the devaluation procedure on SCR and that this is an associative effect as it is specific to the CS+; see Figure 3b.

Explicit awareness of UCS intensity: We observed devaluation on SCR in the absence of UCS expectancy differences at test. However, this dissociation between explicit and implicit measures could also be explained by another explicit process, the expectation of a different UCS intensity. We examined if different UCS intensity ratings could account for the devaluation effect by splitting the devaluation group into different subgroups based on whether or not participants demonstrated explicit knowledge that the intensity of the UCS had changed from acquisition to the revaluation phase. Participants were categorized as UCS intensity aware (n = 10) if they decreased their UCS intensity rating following the revaluation phase by two or more units from their rating following the acquisition phase. Participants were categorized as UCS intensity unaware (n = 6) if they failed to meet this criterion. The UCS intensity aware and unaware groups did not receive significantly different UCS intensities during acquisition (UCS intensity aware M = 4.13 mA, SEM = 0.72; UCS intensity unaware M = 6.04 mA, SEM = 0.84), $t(14) = 1.68$, $p = .12$, nor did they differ in their UCS intensity ratings following acquisition (UCS intensity aware M = 7.8, SEM = 0.63; UCS intensity unaware M = 6.92, SEM = 0.86), $t(14) = 0.82$, $p = .41$.

An independent *t*-test indicated that UCS intensity aware subgroup changed their intensity ratings significantly more than the UCS intensity unaware subgroup, $t(14) = 4.25$, $p = .001$; see Figure 4a. A subgroup by CS type by trial repeated measures ANOVA conducted on the SCR data from the test trials results in no significant effects, largest $F = 2.04$, $p = .17$; see Figure 4b. These results suggest that the devaluation effect on SCR was not dependent on the expectation of a less intense UCS following the revaluation phase. To ensure that UCS expectancy ratings did not differ between the UCS intensity awareness subgroups we conducted a subgroup by CS type by trial repeated measures ANOVA on the UCS expectancy data from the test trials. We did not find a main effect or any significant interactions involving the UCS intensity awareness variable, largest $F = 0.085$, $p = .92$.

Discussion

The results of Experiment 1 are consistent with previous data related to UCS revaluation effects on SCR (Hosoba, Iwanaga & Seiwa, 2001; White & Davey, 1989). However, we found that UCS revaluation did not have an effect on UCS expectancy. This is inconsistent with other work that did not demonstrate a revaluation effect on SCR, but did identify a revaluation effect on UCS expectancy (De Jong, Murris & Merckelbach, 1996). Additionally, the SCR revaluation effect was similar between participants that were aware of the change in UCS intensity and participants that were unaware of the change in UCS intensity.

In the acquisition phase, both groups demonstrated similar levels of performance on both UCS expectancy and SCR suggesting that both groups learned the task in a similar manner. The devaluation group rated the UCS presentations during the revaluation phase as less intense than the control group indicating that the manipulation of UCS value was effective for the devaluation group. The subsequent test session revealed that both groups exhibited similar levels of UCS expectancy, but the devaluation group was characterized by smaller SCRs than the control group. The similar levels of UCS expectancy at test suggest that the revaluation manipulation did not have an effect on the CS-UCS contingency. The goal of a revaluation manipulation is to modify the UCS representation without modifying the CS-UCS contingency. The UCS expectancy effects reported by De Jong, Murris and Merckelbach (1996) appear to be caused by the UCS exposure during the revaluation phase and are interesting in their own right, but the manipulation modified the CS-UCS contingency making it difficult to interpret the data in the terms of UCS revaluation. There were no statistically significant differences in the SCR revaluation effect when the devaluation group was split into two subgroups based on how much participants changed their UCS intensity ratings from the acquisition phase to the revaluation phase. The lack of an effect between these two subgroups in conjunction with the lack of effect on the UCS expectancy measure suggests that the revaluation effect on SCR is not dependent on these explicit processes.

Experiment 2

Postconditioning UCS inflation was examined in a second experiment. SCR and UCS expectancy were measured throughout. Following differential fear conditioning one group (inflation) had the value of the UCS increased while another group (control) had the value of the UCS held constant. Both groups were then tested in the absence of the UCS. We expected similar results as were observed in Experiment 1 with the only difference being that inflation would increase SCR at test relative to the control condition because the value of the UCS was increased in this experiment. We predicted that skin conductance responses would be larger for the inflation group than for the control group at test. We also predicted that UCS expectancy ratings would not differ between the groups at test because we did not modify the CS-UCS contingency.

Method

Participants and apparatus—Twenty-five (thirteen females) right-handed, neurologically normal undergraduates ranging from eighteen to twenty-five years old (M = 19, SEM = 0.34) volunteered for this study. Participants received extra-credit in a psychology course. Participants supplied informed consent. All procedures were approved by the Institutional Review Board for human research at the University of Wisconsin-Milwaukee. The apparatus was the same as that used in Experiment 1.

Procedure and data analysis—The procedure was similar to that used in Experiment 1. The acquisition phase was identical for both groups. The same UCS intensity work up procedure was used to determine the maximum shock current that each participant rated as "painful but tolerable". The UCS intensity in the acquisition phase was set to 50% of the current participants had identified as "painful but tolerable" (Control group, M = 2.68 mA, SEM = 0.32; Inflation group, M = 2.78 mA, SEM = 0.24). Following acquisition participants were asked to give a verbal rating of the UCS intensity on the same scale that had been used in the work up procedure. In the second phase of the experiment (revaluation) all participants received three presentations of the UCS in the absence of either CS. The background of the visual display was blue during the revaluation phase. For the control group (n = 12) the UCS intensity during the revaluation phase was the same as it had been in the acquisition phase (50% of the maximum current, M = 2.78 mA, SEM = 0.24). For the inflation group (n = 13) the UCS intensity during the revaluation phase was higher than it was during the acquisition phase (100% of the maximum current, M = 5.56 mA, SEM = 0.49). Following the revaluation phase participants were again asked to give a verbal rating of the UCS intensity. In order to reduce the probability of ceiling effects on SCR in the test session, participants completed a 2-back task immediately after giving the UCS intensity rating. After the 2-back task there was a two minute rest period with the screen dark. In the last phase of the experiment (test) each CS was presented five times on a black background in a pseudorandom order with the same constraints as the acquisition phase. The UCS was not presented in the test phase. The data analysis procedure was the same as that used in Experiment 1. Consistent with the first experiment s CS type by group repeated measures ANOVA conducted on both the UCS expectancy and SCR data on the fourth trial of the test session to ensure that both groups had extinguished and that there were no differences between CS+ and CS− responses on either measure in either group, largest F = 3.5, p = .07. By the fourth trial of the test session participants in both groups no longer displayed differential UCS expectancy ratings or SCRs. For this reason the data analysis of the test session only included the first three trials.

Results

Acquisition

UCS expectancy: A trial by group by CS type repeated measures ANOVA yielded a significant CS type by trial interaction, $F(4, 92) = 52.49$, $p < .001$, indicating that participants learned to expect the UCS on CS+ trials and not to expect the UCS on CS− trials during the acquisition session; see Figure 5a. Simple effects tests did not identify a difference between expectancy on the first CS+ trial relative to the first CS− trial, $F(1, 92) = 1.27$, $p = .26$. Simple effects on the remaining acquisition trials found a significant difference between expectancy on the CS+ and the CS− trials with higher expectancy ratings on the CS+ trials, smallest $F = 78.32$, $p < .001$. There was also a significant main effect for CS type, $F(1, 92) = 129.06$, $p < .001$. There were no significant effects involving the group factor, largest $F = 1.59$, $p = .18$, indicating that all groups learned to expect the UCS on CS+ trials and not to expect the UCS on CS− trials as acquisition progressed.

Skin conductance: A trial by group by CS type ANOVA yielded a significant main effect for CS type, $F(1, 92) = 14.22$, $p = .001$, with larger responses on CS+ trials relative to CS− trials; see Figure 5b. The main effect for CS type was the only significant effect. There were no significant effects involving the group factor, largest $F = 1.26$, $p = .27$. The lack of any significant group effects indicates that both groups demonstrated equivalent levels of differential conditioning on the SCR measure.

UCS intensity ratings: We conducted a group by time repeated measures ANOVA on the UCS intensity ratings collected following acquisition and revaluation. We found a significant group by time interaction, $F(1, 32) = 15.32$, $p =.001$. There was no significant difference between the UCS intensity ratings of the control group and the devaluation group following acquisition, $t(23) = 0.215$, $p = .83$. Further analysis of this interaction is included in the next section. Additionally, there was no significant difference between groups on the current used for the UCS during the acquisition session, $t(23) = 0.26$, $p = .8$. Both groups were exposed to the same level of UCS intensity in the acquisition phase and they reported similar intensity ratings; see Figure 6.

Revaluation

UCS intensity ratings: There was a significant difference between the UCS intensity ratings of the control and the inflation groups following the revaluation phase, $t(23) = 2.54$, $p = .02$, with the control group rating the UCS intensity lower than the inflation group; see Figure 6. The control group was exposed to the same UCS intensity as they had in the acquisition phase and the inflation group was exposed to the UCS intensity at twice the current they had in the acquisition phase. There was a significant difference between the groups on the current used for the UCS during the revaluation phase, $t(23) = 4.87$, $p < .001$. The differences between the groups on the UCS intensity ratings signify that the inflation group perceived the UCS as more intense than the control group in the revaluation phase.

Test

UCS expectancy: A group by trial repeated measures ANOVA conducted on the first three trials of the test session results in a significant main effect for trial, $F(2, 46) = 18.2$, $p < .001$, characteristic of extinction learning when the CS is presented in the absence of the UCS. There was also a significant main effect for CS type, $F(1, 23) = 21.05$, $p < .001$, characterized by larger UCS expectancy ratings on CS+ trials compared to CS− trials. There was also a significant trial by CS type interaction, $F(2, 46) = 8.84$, $p = .001$. This interaction was characterized a large difference in UCS expectancy ratings for the CS+ compared to the CS− on the first test trial, $t(48) = 6.43$, p < .001, a smaller difference on the second test trial,

$t(48) = 2.5$, $p = .016$, that diminished by the third test trial, $t(48) = 1.5$, p = .14. There were no significant effects with group as a factor, largest $F < 1$. These results suggest that UCS expectancy decreases across test trials and that there are no differences between the groups; see Figure 7a. The inflation group and the control group showed similar levels of UCS expectancy at test following the revaluation phase.

Skin conductance: A trial by CS type by group repeated measures ANOVA conducted on the first three test trials resulted in a significant main effect for trial, $F(2, 46) = 16.46$, $p < .001$, consistent with extinction learning when the CS is presented in the absence of the UCS There was also a significant trial by CS type by group interaction. This interaction was characterized by a difference in CS+ responses between groups on the first trial, $t(23) = 2.63$, $p = .015$, that diminished by the second and third test trials, largest $t = 0.7$, $p = .94$. Furthermore, there were no differences between the groups on CS− responses throughout the test session, largest $t = 0.93$, $p = .36$. These data suggest that there was an effect of inflation on SCR and that this effect was largest on the first test trial and group differences diminish by the third test trial; see Figure 7b. The inflation effect on SCR was also associative in nature as it was specific to the CS+.

Explicit awareness of UCS intensity: We observed inflation on SCR in the absence of UCS expectancy differences at test. However, this dissociation between explicit and implicit measures could also be explained by the expectation of a different UCS intensity. In order to assess the influence of UCS intensity expectations on inflation we performed a similar analysis as was described in the devaluation experiment. Participants were categorized as UCS intensity aware (n = 6) if they increased their UCS intensity rating following the revaluation phase by two or more units from their rating following the acquisition phase. Participants were categorized as UCS intensity unaware (n = 7) if they failed to meet this criterion. The UCS intensity aware and unaware groups did not receive significantly different UCS intensities during acquisition (UCS intensity aware $M = 2.82$ mA, $SEM = 0.41$; UCS intensity unaware $M = 2.74$ mA, $SEM = 0.31$), $t(11) = 0.15$, $p = .87$. The groups did differ in their UCS intensity ratings following acquisition (UCS intensity aware $M = 5.75$, $SEM = 0.72$; UCS intensity unaware $M = 8.07$, $SEM = 0.37$), $t(11) = 2.98$, $p = .013$. However, this difference in UCS intensity rating across groups would bias the analysis in the direction of finding a UCS intensity awareness effect on revaluation. The intensity aware group rated the UCS as less aversive during acquisition which would lead to the prediction that the inflation effect would be greater for this group.

An independent *t*-test indicated that UCS intensity aware subgroup changed their intensity ratings significantly more than the UCS intensity unaware subgroup, $t(11) = 4.75$, $p = .001$; see Figure 8a. A subgroup by CS type by trial repeated measures ANOVA conducted on the test trials resulted in a significant effect of trial, $F(1,11) = 36.08$, $p < .001$. There was not a statistically significant effect of subgroup or a subgroup by trial interaction, largest $F = 1.4$, $p = .263$; see Figure 8b. These results suggest that the inflation effect on SCR was not dependent on the expectation of a more intense UCS following the revaluation phase. To ensure that UCS expectancy ratings did not differ between the UCS intensity awareness subgroups we conducted a subgroup by CS type by trial repeated measures ANOVA on the UCS expectancy data from the test trials. We did not find a main effect or any significant interactions involving the UCS intensity awareness variable, largest $F = 2.8$, $p = .08$.

Discussion

The results of Experiment 2 demonstrate a postconditioning UCS inflation effect on SCR. We did not observe an inflation effect on UCS expectancy. The data from the acquisition phase indicates that both groups acquired similar differential responses on both UCS expectancy and SCR. There were no differences between the groups on UCS intensity ratings following the acquisition phase. In the revaluation phase the inflation group experienced the UCS at a higher intensity than the control group. Following the revaluation phase the inflation group rated the UCS as more intense than the control group. In the test phase the inflation group initially exhibited larger SCRs than the control group with the group differences diminishing by the third test trial. UCS expectancy during the test session did not reveal any differences between the inflation and the control group. These data are consistent with previous studies that have indentified postconditioning UCS revaluation effects on SCR (Hosoba, Iwanaga & Seiwa, 2001; White & Davey, 1989). Furthermore, the inflation effect was independent of explicit knowledge that the intensity of the UCS had been increased from the acquisition phase to the revaluation phase.

General Results

We found a revaluation effect on SCR in both experiments that occurred independent of contingency or UCS intensity awareness. However, splitting the experimental group into UCS intensity aware and UCS intensity unaware groups in both experiments left us with small groups and less power to detect the possible influence of awareness. The criteria we used to determine whether or not subjects were aware or unaware that the intensity of the UCS had changed resulted in groups that showed statistically significant differences on their UCS intensity ratings, but it was based on subjective ratings. In order to more closely examine the issue of the role of awareness on revaluation we combined the devaluation group from Experiment 1 and the inflation group from Experiment 2 and explored the relationship between these two factors.

Rather than dividing these groups categorically into an aware and an unaware group we choose to look at awareness as a continuous variable. In order to create a metric of UCS intensity awareness across the two experiments we calculated a difference score between each subjects UCS intensity rating following acquisition and revaluation. We then took the absolute value of this difference because in Experiment 1 the values decreased and in Experiment 2 the values increased. Thus we were left with a UCS intensity awareness score for each subject where a value of zero indicated that they rated the UCS at the same intensity at both time points and larger values indicate that they changed their ratings to a greater degree. We also calculated a revaluation metric for each subject on both UCS expectancy and SCR. In order to create the revaluation metric we calculated terminal performance from the acquisition session. We calculated the mean CS+ and CS− response over the last two acquisition trials and created a difference score. We also calculated a difference score between the first CS+ and the first CS− trial of the test session. A ratio between those two difference scores was calculated. Because the revaluation effect for the devaluation group from experiment 1 was a decrease, we changed the sign so that larger values on the revaluation metric indicated a larger overall revaluation effect independent of direction. All of these metrics were then standardized before correlation coefficients were calculated.

There was not a significant correlation between UCS intensity awareness and revaluation performance on the SCR measure, $r = -.09$, $p = .62$; See Figure 9. These results indicate that the magnitude of the revaluation effect on SCR across experiments was not related to explicit awareness that the intensity of the UCS had changed from acquisition to revaluation. There was also not a significant correlation between UCS intensity awareness and revaluation performance on the UCS expectancy measure, $r = .28$, $p = .13$. This analysis included the revaluation group from both experiments. We also defined UCS intensity awareness on a continuous scale. We failed to find a relationship between awareness and revaluation despite the increased power and sensitivity of this type of analysis.

General Discussion

The results of both of these experiments identified an effect of postconditioning UCS revaluation on SCR. These effects appeared to be independent of any differences in UCS expectancy. Experiment 1 investigated postconditioning UCS devaluation and Experiment 2 investigated postconditioning UCS inflation. In both cases revaluation effects were observed on SCR without any corresponding change in UCS expectancy. Both experiments also found that revaluation was not dependent on differential expectations regarding the intensity of the UCS at test. Furthermore, there was no correlation between the magnitude of the revaluation effect on SCR and UCS intensity awareness.

The revaluation effects observed in these studies are consistent with a number of similar experiments in non-human animals (Holland & Straub, 1979; Rescorla, 1973, 1974). Postconditioning UCS revaluation procedures are intended to modify the value of the UCS representation. Modification of the UCS representation leads to a change in behavioral output suggesting that as organisms acquire the association the CS gains the ability to activate a representation of the UCS. These studies add support to the idea that the association between the CS and the UCS representation is critical for the acquisition of this type of conditioning in humans as well as non-human animals.

Previous studies examining postconditioning UCS revaluation in human subjects have had mixed results. Some have observed a revaluation effect on SCR (Hosoba, Iwanaga & Seiwa, 2001; White & Davey, 1989). One study observed an inflation effect on a reaction time measure (Gottfried, O'Doherty & Dolan, 2003). Another study (De Jong, Murris & Merckelbach, 1996) did not observe a revaluation effect on SCR, but did detect group differences on a UCS expectancy measure. The current studies provide further support for conditioning in human subjects being susceptible to revaluation manipulations. Our lack of a revaluation effect on UCS expectancy indicates that we were able to modify the subjects' representation of the UCS without changing their knowledge of the CS-UCS contingency. This is an important aspect of a postconditioning UCS revaluation manipulation. The UCS expectancy effect observed by De Jong and colleagues (1996) could be due to differences in the revaluation procedure. De Jong and colleagues increased the UCS intensity incrementally over twelve UCS presentations and we used three UCS presentations of the same intensity. An important aspect of this study is that the revaluation manipulation did not impact the CS-UCS contingency.

Both of the present experiments showed a revaluation effect on SCR, but no revaluation effect on UCS expectancy. Dissociations between two different measures of learning have been reported in a number of paradigms including eye blink conditioning (Clark & Squire, 1998; Smith, Clark, Manns & Squire, 2005), backward masking with fear relevant (Esteves, Parra, Dimberg & Ohman, 1994; Soares & Ohman, 1993) and fear irrelevant stimuli (Balderston & Helmstetter, 2010), and in fear conditioning (Knight, Nguyen & Bandettini, 2003; Schultz & Helmstetter, 2010). Dissociations between explicit and implicit measures of memory are predicted by a dual process model of memory. The strongest version of the single process model of memory predicts that any implicit memory effect would have to be accompanied by an explicit memory effect. The present studies demonstrate a revaluation effect on an implicit measure of memory, SCR, without any effect on an explicit measure of memory, UCS expectancy. UCS intensity ratings, another measure of explicit memory, demonstrate a revaluation effect. However, when participants were split into groups that were aware that the UCS intensity had changed and groups that were unaware that the UCS intensity had changed we did not observe any significant differences on the SCR revaluation effect between them. This suggests that the SCR revaluation effect was not entirely due to the explicit nature of expecting an UCS of a different intensity at test. The revaluation effect on SCR was obtained without modifying the CS-UCS association and it also occurred regardless of whether or not the participants were explicitly aware that the UCS intensity had changed. This pattern of data is inconsistent with a single process model of learning.

Revaluation is an important topic of study. It is a paradigm that can be used to examine the interaction of different types of memory. Because the intensity of the UCS changes we can examine the role of the different components of explicit memory including the memory for the sensory components of the UCS and the probabilistic component of UCS expectancy on implicit measures. From a therapeutic perspective, it is interesting to consider that the magnitude of a CR can be reduced by simply exposing the subject to the same UCS at a lower intensity. This type of approach may be useful in the treatment of anxiety disorders. Future studies should examine how revaluation affects subsequent extinction and the retention of this extinction memory.

One limitation of the current experiments is that we divided the experimental group in each experiment into a UCS intensity aware and unaware group. These subgroups were left with a relatively small number of subjects which would make it more difficult to observe an effect of awareness on SCR. However, we combined the experimental groups across the experiments and still failed to find a relationship between UCS intensity awareness and SCR revaluation. Another limitation is that during the revaluation phase of the experiments a different background color appeared on the monitor, but the physical environment was the same as it was during training and testing. Ideally, the revaluation phase would take place in a different context entirely. We observed a revaluation effect on SCR in both experiments, but it is difficult to parse out how effective our different color background on the monitor was at serving as a different context.

The present results demonstrate postconditioning UCS revaluation effects on SCR. These effects cannot be attributed to group differences in the acquisition phase. The revaluation manipulation did not have a significant effect on UCS expectancy ratings. This means that the revaluation manipulation was successful because it changed the value of the UCS without affecting the CS-UCS contingency. This effect was not dependent on the ability of participants to explicitly detect that the intensity of the UCS had been changed. Together, these data provide further evidence to support a dual process model of learning.

References

Adams C, Dickinson A. Instrumental responding following reinforcer devaluation. The Quarterly Journal of Experimental Psychology B: Comparative and Physiological Psychology. 1981; 33B: 109–121.

Baeyens F, Eelen P, Van den Bergh O, Crombez G. The content of learning in human evaluative conditioning: Acquired valence is sensitive to US-revaluation. Learning and Motivation. 1992; 23:200–224.

Balderston N, Helmstetter F. Conditioning with masked stimuli affects the timecourse of skin conductance responses. Behavioral Neuroscience. 2010; 124:478–489. [PubMed: 20695647]

Bechara A, Tranel D, Damasio H, Adolphs R, Rockland C, Damasio A. Double dissociation of conditioning and declarative knowledge relative to the amygdala and hippocampus in humans. Science. 1995; 269:1115–1118. [PubMed: 7652558]

Clark R, Squire L. Classical conditioning and brain systems: the role of awareness. Science. 1998; 280:77–81. [PubMed: 9525860]

Colwill R, Rescorla R. Postconditioning devaluation of a reinforcer affects instrumental responding. Journal of Experimental Psychology: Animal Behavior Processes. 1985; 11:120–132.

Colwill R, Rescorla R. Instrumental responding remains sensitive to reinforcer devaluation after extensive training. Journal of Experimental Psychology: Animal Behavior Processes. 1985; 11:520–536.

De Houwer J, Thomas S, Baeyens F. Association learning of likes and dislikes: A review of 25 years of research on human evaluative conditioning. Psychological Bulletin. 2001; 127:853–869. [PubMed: 11726074]

De Jong P, Murris P, Merckelbach H. UCS inflation and human aversive autonomic conditioning. Biological Psychology. 1996; 43:227–239. [PubMed: 8831956]

Delamater A, Campese V, LoLordo V, Sclafani A. Unconditioned stimulus devaluation effects in nutrient-conditioned flavor preferences. Journal of Experimental Psychology: Animal Behavior Processes. 2006; 32:295–306. [PubMed: 16834496]

Delamater, A.; LoLordo, V. Event revaluation procedures and associative structures in Pavlovian conditioning. In: Dachoswki, L.; Flaherty, C., editors. Current topics in animal learning: Brain, emotion, and cognition. Hillsdale, N.J: Erlbaum; 1991. p. 55-93.

Dwyer D. Reinforcer devaluation in palatability-based learned flavor preferences. Journal of Experimental Psychology: Animal Behavior Processes. 2005; 31:487–492. [PubMed: 16248735]

Esteves F, Parra C, Dimberg U, Ohman A. Nonconscious associative learning: Pavlovian conditioning of skin conductance responses to masked fear-relevant facial stimuli. Psychophysiology. 1994; 31:375–385. [PubMed: 10690918]

Fanselow M, Poulos A. The neuroscience of mammalian associative learning. Annual Review of Psychology. 2005; 56:207–234.

Gottfried J, O'Doherty J, Dolan R. Encoding predictive reward value in human amygdala and orbitofrontal cortex. Science. 2003; 301:1104–1107. [PubMed: 12934011]

Holland P, Rescorla R. The effect of two ways of devaluing the unconditioned stimulus after first and second-order appetitive conditioning. Journal of Experimental Psychology: Animal Behavior Processes. 1975; 1:355–363. [PubMed: 1202141]

Holland P, Straub J. Differential effects of two ways of devaluing the unconditioned stimulus after Pavlovian appetitive conditioning. Journal of Experimental Psychology: Animal Behavior Processes. 1979; 5:65–78. [PubMed: 528879]

Hosoba T, Iwanaga M, Seiwa H. The effect of UCS inflation and deflation procedures on 'fear' conditioning. Behaviour Research and Therapy. 2001; 39:465–475. [PubMed: 11280344]

Kim J, Jung M. Neural circuits and mechanisms involved in Pavlovian fear conditioning: A critical review. Neuroscience and Biobehavioral Reviews. 2006; 30:188–202. [PubMed: 16120461]

Knight D, Nguyen H, Bandettini P. Expression of conditional fear with and without awareness. Proceedings of the National Academy of Sciences of the United States of America. 2003; 100:15280–15283. [PubMed: 14657356]

Lang, P.; Bradley, M.; Cuthbert, B. International Affective Picture System (IAPS): Digitized Photographs, Instruction Manual and Affective Ratings. University of Florida; Gainesville, FL: 2005.

Lovibond P, Shanks D. The role of awareness in Pavlovian conditioning: empirical evidence and theoretical implications. Journal of Experimental Psychology: Animal Behavioral Processes. 2002; 28:3–26.

Mackintosh, N. Conditioning and Associative Learning. New York: Oxford University Press; 1983.

Manns J, Clark R, Squire L. Single-cue delay eyeblink conditioning is unrelated to awareness. Cognitive, Affective & Behavioral Neuroscience. 2001; 1:192–198.

Pavlov, I. Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex. London: Oxford University Press; 1927.

Rescorla R. Effects of US habituation following conditioning. Journal of Comparative and Physiological Psychology. 1973; 82:137–143. [PubMed: 4684968]

Rescorla R. Effect of inflation of the unconditioned stimulus value following conditioning. Journal of Comparative and Physiological Psychology. 1974; 86:101–106.

Rozeboom W. What is learned? An empirical enigma. Psychological Review. 1958; 65:22–33. [PubMed: 13505979]

Schultz D, Helmstetter F. Classical conditioning of autonomic fear responses is independent of contingency awareness. Journal of Experimental Psychology: Animal Behavior Processes. 2010; 36:495–500. [PubMed: 20973611]

Smith C, Clark R, Manns J, Squire L. Acquisition of differential delay eyeblink conditioning is independent of awareness. Behavioral Neuroscience. 2005; 119:78–86. [PubMed: 15727514]

Soares J, Ohman A. Backward masking and skin conductance responses after conditioning to nonfeared but fear-relevent stimuli in fearful subjects. Psychophysiology. 1993; 30:460–466. [PubMed: 8416072]

White K, Davey G. Sensory preconditioning and UCS inflation in human ‘fear’ conditioning. Behaviour Research and Therapy. 1989; 27:161–166. [PubMed: 2930441]

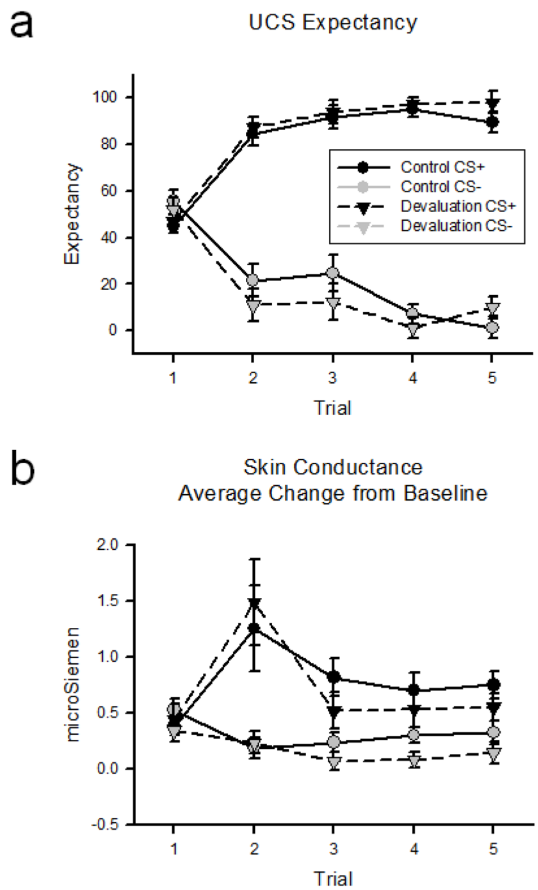

Figure 1.
a) UCS expectancy data for CS+ and CS− trials for each group in the acquisition phase. b) Skin conductance responses for CS+ and CS− trials for each group in the acquisition phase. Error bars show SEM.

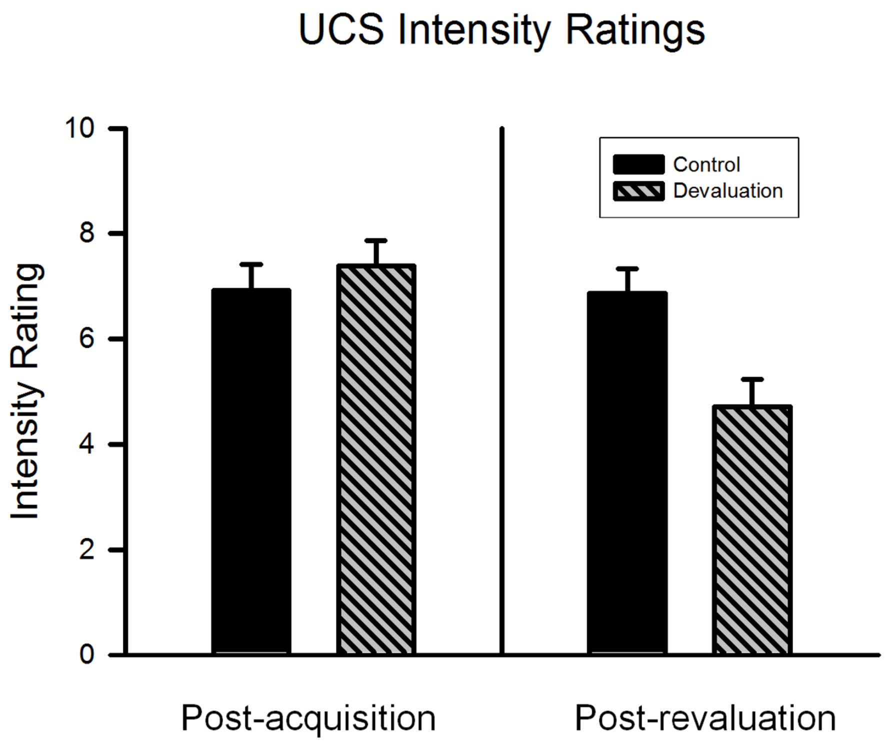

Figure 2.
Verbal ratings of the UCS intensity following the acquisition phase (left panel) and the revaluation phase (right panel).

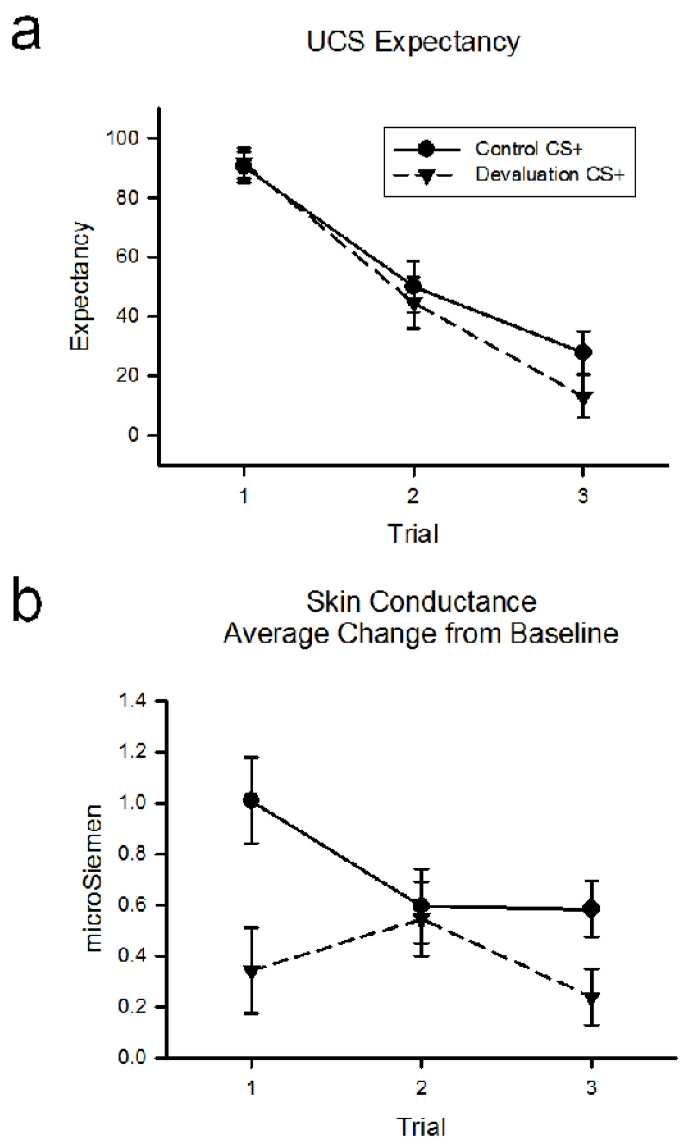

Figure 3.
a) UCS expectancy data for the first three CS+ trials in the test session. b) Skin conductance data for the first three CS+ trials in the test session.

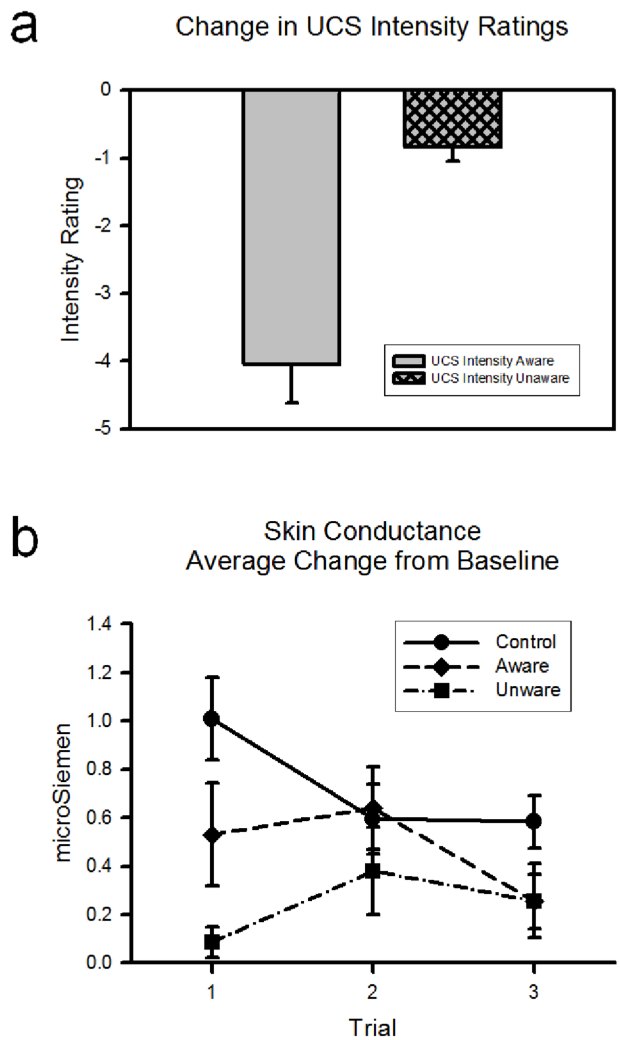

Figure 4.

a) Change in UCS intensity ratings from acquisition to revaluation for subgroups of the devaluation group that were classified as being aware and unaware of this change. b) SCR for the UCS intensity aware and UCS intensity unaware subgroups at test (the control group is depicted for reference).

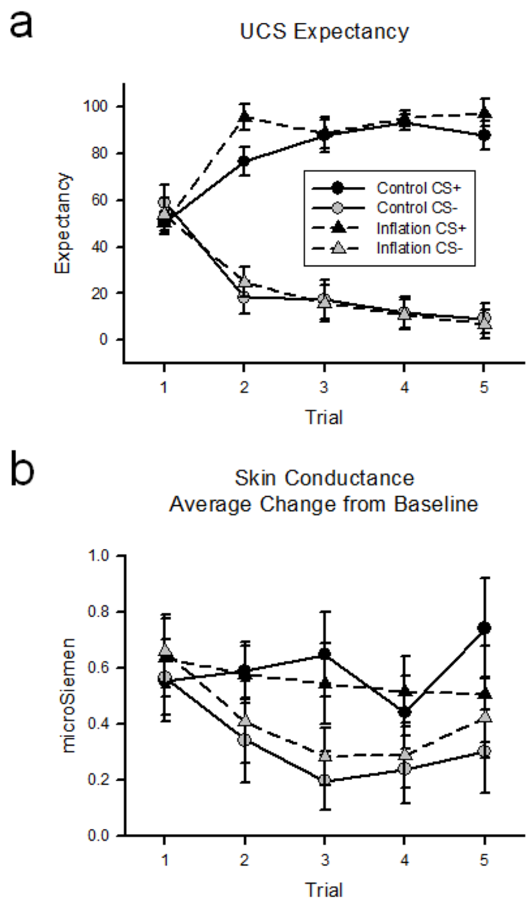

Figure 5.
a) UCS expectancy data for CS+ and CS− trials for each group in the acquisition phase. b) Skin conductance responses for CS+ and CS− trials for each group in the acquisition phase.

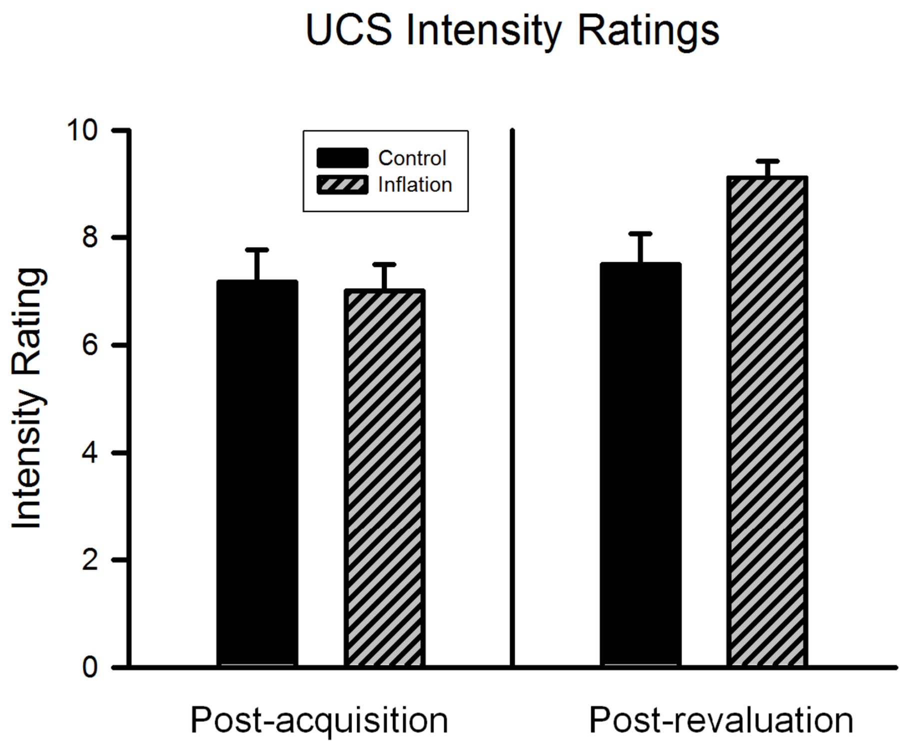

Figure 6.

Verbal ratings of the UCS intensity following the acquisition phase (left panel) and the revaluation phase (right panel).

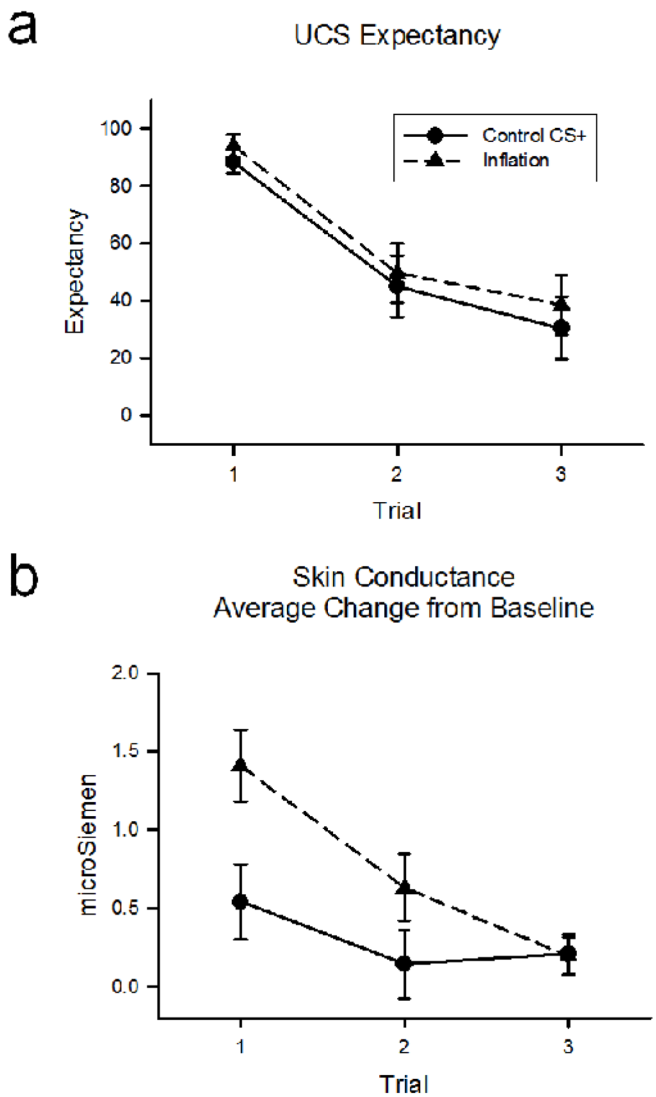

Figure 7.
a) UCS expectancy data for the first three CS+ trials in the test session. b) Skin conductance data for the first three CS+ trials in the test session.

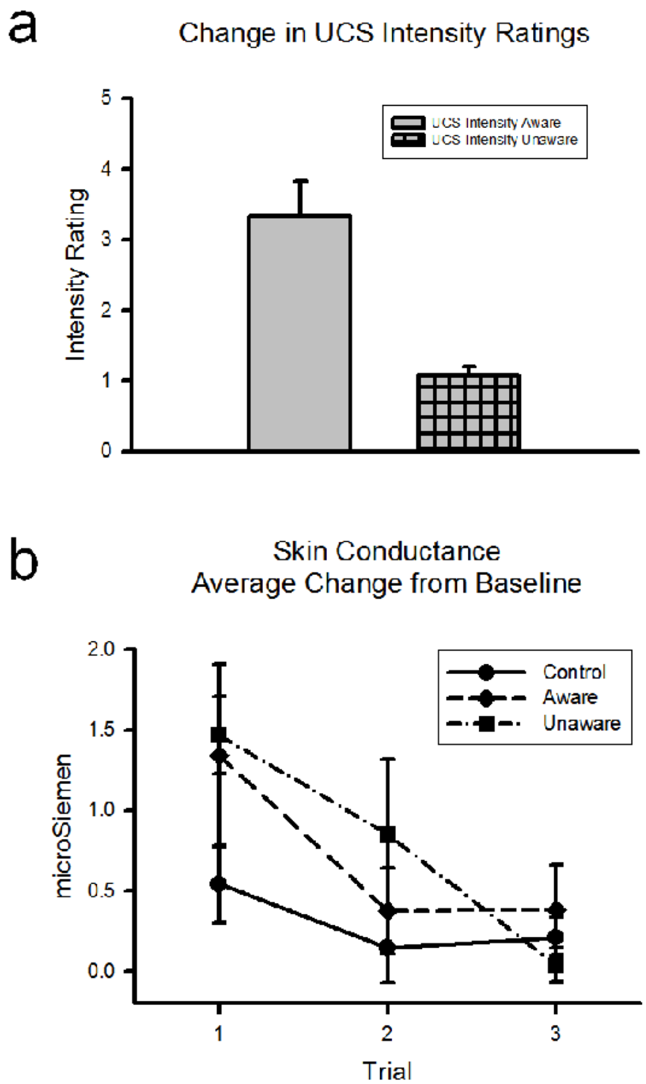

Figure 8.

a) Change in UCS intensity ratings from acquisition to revaluation for subgroups of the inflation group that were classified as being aware and unaware of this change. b) SCR for the UCS intensity aware and UCS intensity unaware subgroups at test (the control group is depicted for reference).

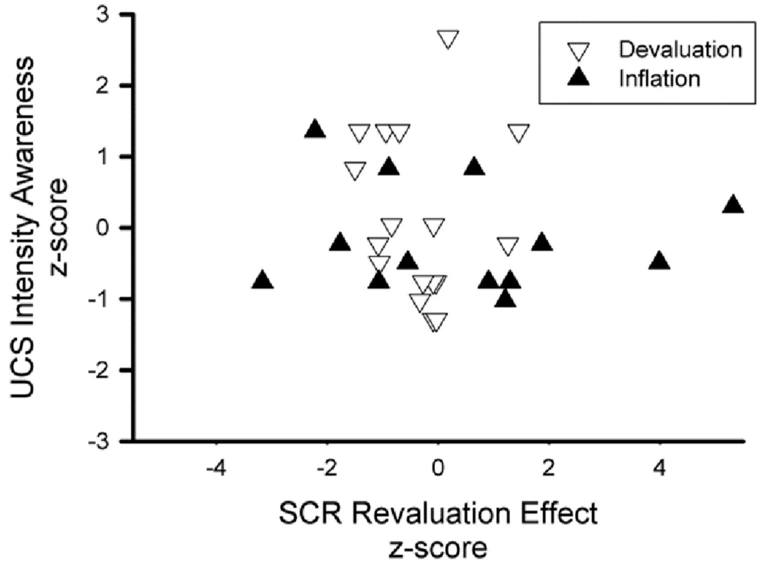

Figure 9.
Correlation between UCS intensity awareness and SCR revaluation effect when the experimental groups from Experiment 1 and 2 are combined.