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Simultaneous conditioning of valence and arousal

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Evaluative conditioning (EC) refers to the change in the valence of a conditioned stimulus (CS) due to its pairing with a positive or negative unconditioned stimulus (US). To the extent that core affect can be characterised by the two dimensions of valence and arousal, EC has important implications for the origin of affective responses. However, the distinction between valence and arousal is rarely considered in research on EC or conditioned responses more generally. Measuring the subjective feelings elicited by a CS, the results from two experiments showed that (1) repeated pairings of a CS with a positive or negative US of either high or low arousal led to corresponding changes in both CS valence and CS arousal, (2) changes in CS arousal, but not changes in CS valence, were significantly related to recollective memory for CS–US pairings, (3) subsequent presentations of the CS without the US reduced the conditioned valence of the CS, with conditioned arousal being less susceptible to extinction and (4) EC effects were stronger for high arousal than low arousal USs. The results indicate that the conditioning of affective responses can occur simultaneously along two independent dimensions, supporting evidence in related areas that calls for a consideration of both valence and arousal. Implications for research on EC and the acquisition of emotional dispositions are discussed.

Keywords: Associative learning; Arousal; Core affect; Evaluative conditioning; Extinction.

When a stimulus repeatedly cooccurs with a positive or negative event, the stimulus tends to acquire the evaluative connotation of that event. In commercial advertisements, for example, it is commonly assumed that the pairing of a consumer product with emotionally pleasant images leads to a more favourable evaluation of the product (e.g., Gibson, 2008; Sweldens, Van Osselaer, & Janiszewski, 2010). Such changes in valence are most prominently reflected in research on evaluative conditioning (EC), showing that repeated pairings of a neutral conditioned stimulus (CS) with a positive or negative unconditioned stimulus (US) change evaluations of the CS in line with the valence of the US (for reviews, see De Houwer, Thomas, & Baeyens, 2001; Jones, Olson, & Fazio,

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2010). Conceptually, EC can be defined as the change in the evaluation of a CS due to its pairing with a valenced US (De Houwer, 2007). Although the functional properties of EC are still the subject of ongoing debate, the effect itself has received considerable empirical support and is now well established in the literature on human evaluative learning (for a meta-analysis, see Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010).

Because EC involves a change of valence, it has important implications for understanding not only the formation and change of attitudes (Walther, Nagengast, & Trasselli, 2005) but also the acquisition of emotional dispositions. For example, although measures of evaluation are usually absent in studies on fear conditioning, it is often assumed that fear conditioning involves a change in the evaluative appraisal of the CS. Thus, based on the definition of EC as a change in the evaluation of a CS due to its pairing with a valenced US, fear conditioning may be described as a particular instance of EC (see De Houwer, 2007). However, conditioned fear responses are characterised by more than just a negative evaluation, and indeed, are often operationalised by objective measures of increased physiological arousal in response to the CS (Delgado, Olsson, & Phelps, 2006). Similarly, some appraisal theories of emotion argue that valence and arousal constitute two fundamental dimensions of core affective states (Russell, 2003; Smith & Neumann, 2005). These states are further assumed to provide the basis for more complex emotional episodes (e.g., fear and anger) when they are attributed to some cause (e.g., Neumann, 2000). Thus, although conditioned changes in the valence of a CS might be insufficient to produce an emotional response to the CS, they can contribute to the formation of emotional dispositions when they are combined with conditioned changes of CS arousal.[1]

Despite the significance of valence and arousal for the emergence of complex emotional dispositions, most studies on conditioned responding typically consider only one of the two dimensions (for a notable exception, see Dawson, Rissling, Schell, & Wilcox, 2007). Whereas EC studies mainly focus on valence without considering arousal, research on fear conditioning primarily focuses on arousal responses without considering valence. Yet, although valence and arousal tend to be confounded in many real-life situations, the two dimensions are not only conceptually and psychologically distinct (Osgood, Suci, & Tannenbaum, 1957), but they are also dissociable on a neurocognitive and physiological level (e.g., Anders, Lotze, Erb, Grodd, & Birbaumer, 2004; Gerber et al., 2008; Greenwald et al., 1989; Lang et al., 1993).

The main goal of the current research was to investigate whether a CS that is repeatedly paired with a US simultaneously acquires multiple features of the US, in particular its valence and arousal. The former type of effect is captured by the term *evaluative conditioning* (EC), which refers to the change in the evaluation of a CS due to its pairing with a valenced US (De Houwer, 2007). Correspondingly, the latter type of effect may be labelled *arousal conditioning* (AC), which can be defined as the change in the arousal response to a CS due to its pairing with an arousing US. Drawing on conceptualisations that define affective states in terms of valence and arousal (Russell, 2003), the two kinds of conditioning effects may jointly contribute to changes in the affective response to a CS due to its pairing with a positive or negative US of either high or low arousal. In the current research, we were particularly interested in whether the subjectively experienced feelings elicited by a CS provide evidence for simultaneous conditioning effects of valence and arousal.

[1] It is important to note that the concept of arousal may refer to either (1) characteristics of physiological states or (2) attributes of stimuli. In the current work, we use the term *arousal* to describe the capacity of a stimulus to elicit changes in physiological states, which we measured with subjective reports of the feelings elicited by a given stimulus (for a discussion of how physiological states and subjective experiences are related, see Greenwald, Cook, & Lang, 1989; Lang, Greenwald, Bradley, & Hamm, 1993).

To the extent that CS–US pairings cause simultaneous changes in both subjective valence and subjective arousal, research on EC would provide important insights into the underpinnings of core affective states, which may serve as the basis for more complex emotional episodes (Russell, 2003). Conversely, evidence for simultaneous effects of US valence and US arousal would have important implications for EC, considering that arousal is rarely controlled in research on EC. For example, in studies using valenced pictures as USs, the negative USs (e.g., picture of a snake) are often characterised by higher levels of arousal than their positive counterparts (e.g., picture of a sunset). Such confounds between valence and arousal are particularly problematic in studies using psychophysiological responses as dependent measures (e.g., skin conductance), given that such measures reflect changes in CS arousal rather than CS valence (Hofmann et al., 2010). These concerns become even more important in light of research, showing that many phenomena that have traditionally been attributed to valence are in fact linked to arousal. For example, there is evidence that the neural regions implicated in encoding stimulus valence are at least partially dissociable from those involved in encoding stimulus arousal (e.g., Colibazzi et al., 2010; Cunningham, Raye, & Johnson, 2004). Similarly, research on attentional biases to emotional stimuli has shown that some instances of biased attention allocation are driven by high levels of stimulus arousal rather than negative stimulus valence (Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008; see also Mitchell, Luo, Vythilingham, Finger, & Blair, 2008). Taken together, these results call for a consideration of both valence and arousal in the conditioning of affective responses.

In addition to demonstrating simultaneous effects of US valence and US arousal, we were also interested in potential differences in the functional properties of the resulting conditioned responses as reflected in measures of subjective valence and subjective arousal. Specifically, we investigated whether conditioning effects of US valence and US arousal are differentially related to recollective memory for CS–US pairings. In addition, we tested potential differences between the two kinds of conditioning effects in their susceptibility to extinction. Evidence for different functional properties would suggest that EC effects and AC effects may be the result of distinct mechanisms that operate simultaneously on the basis of the same stimulus episode.

EXPERIMENT 1

The main goal of Experiment 1 was to test whether subjectively experienced feelings elicited by a CS provide evidence for simultaneous conditioning effects of US valence and US arousal. In addition, we investigated whether EC effects and AC effects are differentially related to recollective memory for CS–US pairings. EC is often regarded as distinct from other forms of conditioning in that it has been claimed to be independent of people's conscious awareness of CS–US pairings during encoding (e.g., Baeyens, Eelen, & Van den Bergh, 1990; Fulcher & Hammerl, 2001; Jones, Fazio, & Olson, 2009; Walther & Nagengast, 2006). Although claims of unconscious EC have been challenged by several recent studies showing that EC effects depend on recollective memory for CS–US pairings (e.g., Bar-Anan, De Houwer, & Nosek, 2010; Dawson et al., 2007; Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Stahl, Unkelbach, & Corneille, 2009), it is important to note that measures of recollective memory remain ambiguous about the role of encoding-related versus retrieval-related processes. In a strict sense, relations between EC effects and recollective memory speak only to the role of recollective memory at the time of measurement, but they fail to provide diagnostic evidence about the role of conscious awareness during encoding (Gawronski & Walther, 2012). This interpretation is consistent with evidence showing that reduced memory for CS–US pairings over time is associated with corresponding reductions of EC effects (e.g., Förderer & Unkelbach, 2013; Gast, De Houwer, & De Schryver, 2012; but see Fulcher & Cocks, 1997). Yet, recent research using advanced data analytic methods to disentangle recollective memory and conditioned responses provided compelling evidence that EC effects can indeed emerge in the absence of recollective memory, such that EC effects remain intact despite reduced memory for CS–US pairings over time (Hütter, Sweldens, Stahl, Unkelbach, & Klauer, 2012; for related evidence, see Balas & Gawronski, 2012; Fulcher & Cocks, 1997).

In the current study, we were less interested in whether EC depends on recollective memory in an absolute sense. Instead, we aimed to investigate whether EC effects and AC effects are characterised by distinct functional properties, such that the two kinds of conditioning effects may show diverging relations to recollective memory for CS-US pairings. Towards this end, participants were presented with repeated pairings of neutral CSs (meaningless drawings) and positive or negative USs of either high or low arousal (standardised photographs). Afterwards, participants were asked to rate the valence and the arousal of their feelings towards the CSs and to complete a measure of recollective memory for the CS–US pairings.

Participants and design

A total of 100 summer students (71 female and 29 male) at the University of Western Ontario in Canada were recruited for a study on visual perception. The sample size was determined on the basis of prior research in our lab using the same EC paradigm. The data were collected in one shot without prior statistical analyses. No data were excluded from analyses, and we report all manipulations and all measures in the study. Participants were paid CDN-$ 10 as compensation. The study included a 2 (US Valence: positive vs. negative) × 2 (US Arousal: low vs. high) within-subjects design.

Procedure

When participants arrived at the lab, they were welcomed by the experimenter who obtained informed consent and seated participants in a cubicle in front of a desktop computer. Written instructions on the screen explained that the study is concerned with visual perception and that participants will be presented with images that will appear sequentially on the screen. Participants were further informed that the images include computer-generated drawings and real-world photographs and that their task was to pay close attention to the images. Participants were then presented with the CS–US pairings, after which they were asked to rate the valence and arousal of their feelings elicited by the CSs. After completion of these ratings, we measured participants' recollective memory for the CS–US pairings. Finally, participants were debriefed and thanked for their participation in the study.

Materials

The CSs were comprised of five meaningless images that were created with the computer software CorelDRAW®. The images depicted five distinct shapes with different patterns and colours.[2] As USs, we used four pictures from the International Affective Picture System (IAPS) that were matched for valence and arousal. The pictures were selected on the basis of Lang, Bradley, and Cuthbert's (2008) normative data, such that they showed comparable ratings of valence and arousal for both men and women (see Appendix). Two of the selected pictures were of positive valence and two were of negative valence. Orthogonal to the manipulation of valence, two of the selected pictures were characterised by high arousal and two by low arousal.

Conditioning procedure

To investigate the simultaneous conditioning of valence and arousal, one of the five CS images was paired with the positive, low-arousal US; one was paired with the positive, high-arousal US; one was paired with the negative, low-arousal US and one was paired with the negative, high-arousal US. The remaining CS image was not paired with

[2] The images are available from the authors upon request.

another stimulus to serve as a baseline. The particular pairings of CSs and USs were counterbalanced by means of a Latin square with five non-overlapping conditions, such that each CS was used once for each of the five pairing conditions (i.e., unpaired, positive-high, positive-low, negative-high, negative-low). Participants were randomly assigned to one of the five pairing conditions. The conditioning procedure included 7 presentations of each CS–US pair and the unpaired CS, resulting in a total of 35 trials. Each trial started with a fixation cross that was displayed for 250 msec in the centre of the screen. The fixation cross was followed by the CS for 1000 msec, which was replaced by the US for 1000 msec. For the unpaired CS, the screen turned blank for 1000 msec after the presentation of the CS. The inter-trial interval was 1500 msec. The images used as CSs were displayed in a size of 2.00 × 1.43 inches; the pictures used as USs were displayed in a size of 14.22 × 10.67 inches.[3]

Measures

To measure conditioned responses to the CSs, participants were shown each of the five CSs and asked to rate how pleasant or unpleasant each image makes them feel on a 7-point scale ranging from 1 (*very unpleasant*) to 7 (*very pleasant*). In addition, participants were asked to rate how aroused or calm each image makes them feel on a 7-point scale ranging from 1 (*very calm*) to 7 (*very aroused*). Order of the CSs in the two measures was randomly determined by the computer for each individual participant. To avoid potential confusion about the difference between the two dimensions, we adapted Lang et al.'s (2008) instructions for the normative IAPS ratings of valence and arousal. Specifically, for the valence ratings participants were told: *In this part of the study, we are interested in your global feelings towards each of the computer-generated drawings of the visual perception task. For this purpose, you will be presented with all of the drawings one more time, and your task is to indicate how pleasant or unpleasant the presented image makes you feel right now.* For the arousal ratings participants were told: *In this part of the study, we are interested in how aroused versus calm the drawings make you feel. With "aroused" we mean feelings of being stimulated, frenzied, jittery, wide-awake, and excited. With "calm" we mean feelings of being relaxed, sluggish, dull, sleepy, and unaroused. Please note that, in this particular sense, one can feel either aroused or calm about positive things. At the same time, one can feel either aroused or calm about negative things. Please indicate how aroused or calm the presented image makes you feel right now.* To measure participants' recollective memory for CS–US pairings, we used a variant of the four-picture recognition task in which participants were asked to identify which of the four USs was paired with which CS (see Walther & Nagengast, 2006). For this purpose, participants were presented with the four USs at the top of the screen and one of the CSs at the bottom of the screen. Each US was marked with a number from 1 to 4, and the participants were asked to make their response by pressing the corresponding key on the keyboard. For the CS that was not paired with a US, participants were asked to press the 9 key. The position of the four USs was determined by a random procedure and kept constant for all participants.

Results

CS valence

Ratings of CS valence were submitted to a 2 (US Valence: positive vs. negative) × 2 (US Arousal: low vs. high) ANOVA for repeated measures. Supporting the occurrence of EC, the analysis revealed a significant main effect of US Valence, indicating that CSs that had been paired with a positive US were rated more favourably than CSs that had been paired with a negative US, $F(1,99) = 59.41$, $p < .001$, $\eta_p^2 = .375$ (see Figure 1). In addition, there was a significant main effect of US Arousal, indicating that CSs that had been paired

[3] The USs were presented in a larger size to ensure that they elicit a sufficiently strong arousal response.

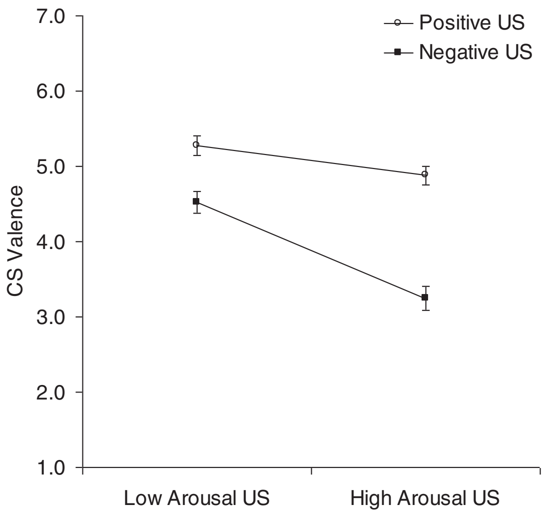

Figure 1. *Ratings of CS valence as a function of US Valence (Positive vs. Negative) and US Arousal (High vs. Low), Experiment 1. Higher values indicate more favourable evaluations. Error bars depict standard errors.*

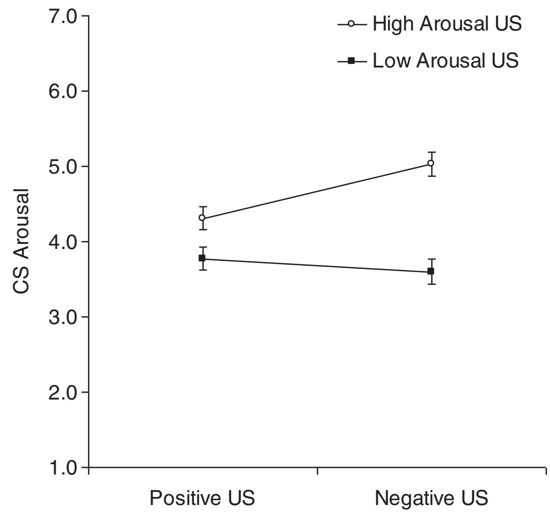

Figure 2. *Ratings of CS arousal as a function of US Valence (Positive vs. Negative) and US Arousal (High vs. Low), Experiment 1. Higher values indicate higher levels of subjective arousal. Error bars depict standard errors.*

with a low-arousal US were rated more favourably than CSs that had been paired with a high-arousal US, $F(1,99) = 44.24$, $p < .001$, $\eta_p^2 = .309$. A significant two-way interaction between US Valence and US Arousal, $F(1,99) = 11.30$, $p = .001$, $\eta_p^2 = .102$, further revealed that the effect of US Valence was stronger for CSs that had been paired with a high-arousal US, $F(1,99) = 54.88$, $p < .001$, $\eta_p^2 = .357$, than for CSs that had been paired with a low-arousal US, $F(1,99) = 17.42$, $p < .001$, $\eta_p^2 = .150$. Although this interaction was not anticipated, it suggests that conditioning EC effects may increase as a function of US arousal. Valence ratings of the four CSs that had been paired with a US significantly differed from the valence ratings of the unpaired baseline CS ($M = 4.04$; all $|t|$s > 2.97, all ps < .004).

CS Arousal

Ratings of CS arousal were submitted to the same 2 (US Valence: positive vs. negative) × 2 (US Arousal: low vs. high) ANOVA for repeated measures. Supporting the occurrence of AC, the analysis revealed a significant main effect of US Arousal, indicating that CSs that had been paired with a high-arousal US elicited higher levels of subjective arousal than CSs that had been paired with a low-arousal US, $F(1,99) = 26.48$, $p < .001$, $\eta_p^2 = .211$ (see Figure 2). A significant two-way interaction between US Valence and US Arousal, $F(1,99) = 12.03$, $p = .001$, $\eta_p^2 = .108$, further revealed that the effect of US Arousal was stronger for CSs that had been paired with a negative US, $F(1,99) = 32.31$, $p < .001$, $\eta_p^2 = .246$, than for CSs that had been paired with a positive US, $F(1,99) = 6.80$, $p = .01$, $\eta_p^2 = .064$. Arousal ratings of the CSs that had been paired with a US significantly differed from the arousal ratings of the unpaired baseline CS ($M = 3.79$) for the two CSs that had been paired with a high-arousal US (all ts > 2.63, all ps < .01), but not for the two CSs that had been paired with a low-arousal US (all $|t|$s < 1.00, all ps > .32).

Recollective memory

An index of recollective memory for CS–US pairings was derived from calculating the proportion of correct responses on the recognition task. Overall, memory performance was significantly above the chance-level of 20% with an average of 87%, $t(99) = 25.77$, $p < .001$. However, memory performance varied considerably with a minimum value of 0% and a maximum value of 100% (*SD* = .26). To investigate the relation of the two kinds of conditioning effects to recollective memory for CS–US pairings, we calculated two indices reflecting the overall magnitude of EC effects (independent of arousal) and the overall magnitude of AC effects (independent of valence), respectively. An index of EC was calculated by subtracting the mean valence ratings of the two CSs that had been paired with a negative US from the mean valence ratings of the two CSs that had been paired with a positive US. Thus, higher values indicate larger EC effects. A corresponding index was calculated for AC by subtracting the mean arousal ratings of the two CSs that had been paired with a low-arousal US from the mean arousal ratings of the two CSs that had been paired with high-arousal US. Thus, higher values indicate larger AC effects. The two indices showed a significant positive correlation, $r(99) = .30$, $p = .003$, suggesting that participants who showed stronger EC effects also showed stronger AC effects, and vice versa. More importantly, whereas AC effects showed a significant positive correlation with recollective memory for CS-US pairings, $r(99) = .37$, $p < .001$, the correlation between EC effects and recollective memory was not statistically significant, $r(99) = .13$, $p = .20$. The difference between the two correlations was statistically significant, $z = 2.54$, $p = .01$.[4]

Relation between EC and AC

Although the current study used matched images to orthogonally manipulate US valence and US arousal, either manipulation showed significant effects on the measure of the other respective dimension. Moreover, the two indices reflecting the overall magnitude of EC and AC were positively correlated, suggesting that the effect of one dimension may potentially depend on the other (e.g., Glaser & Walther, 2013). Thus, to further explore the relation between the EC and the AC, we regressed EC scores onto AC scores, and vice versa. In addition to replicating the significant zero-order relation between the two scores, $\beta = .30$, $t(99) = 3.07$, $p = .003$, both regressions revealed statistically significant intercepts, indicating that EC effects were still significant after controlling for their relation to AC effects, $t(99) = 5.72$, $p < .001$, and AC effects were still significant after controlling for their relation to EC effects, $t(99) = 2.36$, $p = .02$. In other words, even when one of the two conditioning scores showed a value of zero, the respective other one showed a statistically significant conditioning effect. Thus, although EC effects and AC effects were positively correlated, our data suggest that the occurrence of one effect does not depend on the occurrence of the other.

Discussion

The results of Experiment 1 provide evidence that a CS that is repeatedly paired with a US simultaneously acquires multiple features of the US. In the current study, subjective feelings elicited by a given CS reflected both the valence and the arousal of the US it had been paired with. Moreover, whereas AC effects showed a significant positive relation to recollective memory for CS–US pairings, EC effects were unrelated to recollective memory. These results confirm our hypothesis of simultaneous conditioning effects of valence and arousal. In addition, the current findings provide evidence that the two kinds of conditioning effects are characterised by different functional properties, as suggested by their differential relation to recollective memory for CS–US pairings.

Another interesting finding is that EC effects were stronger for high-arousal USs as compared to low-arousal USs. This pattern seems particularly remarkable considering that low-arousal USs and high-arousal USs had been matched for their valence on the basis of normative data (Lang et al., 2008). If anything, the difference between the

[4] Inspection of the raw data revealed one potential outlier at the upper end of recollective memory that might have unduly enhanced the relation between recollective memory and AC effects. Exclusion of this outlier did not qualify the relation of recollective memory to EC effects, $r(98) = .02$, $p = .86$, and AC effects, $r(98) = .30$, $p = .003$.

normative valence data of positive and negative USs was somewhat larger for low-arousal USs than high-arousal USs (see Appendix). Thus, in addition to providing evidence for simultaneous conditioning effects of valence and arousal, the current results suggest that US arousal may modulate conditioning effects of US valence. That is, EC effects may be larger for high-arousal USs than low-arousal USs. Although valence-by-arousal interactions were not the primary focus of the current research, a secondary goal of Experiment 2 was to replicate the obtained asymmetry, using a different set of stimuli as USs.

EXPERIMENT 2

The main goal of Experiment 2 was to replicate the simultaneous occurrence of EC and AC using a different set of stimuli as USs. In addition, we aimed at providing further evidence for differences in the functional properties of the two kinds of conditioning effects. An important feature that has been claimed to distinguish EC from other forms of conditioning is its resistance to extinction (De Houwer et al., 2001; Walther et al., 2005). Specifically, it has been argued that subsequent individual presentations of a CS without the US leave the conditioned valence of the CS unaffected. This assumption is consistent with the results of several studies, showing that unreinforced presentations of the CS do not reduce conditioned evaluative responses to the CS (e.g., Baeyens, Crombez, Van den Bergh, & Eelen, 1988; De Houwer, Baeyens, Vansteenwegen, & Eelen, 2000; Dwyer, Jarratt, & Dick, 2007; Kerkhof, Vansteenwegen, Baeyens, & Hermans, 2011; Vansteenwegen, Francken, Vervliet, De Clercq, & Eelen, 2006). On the basis of these findings, we expected subjective indices of conditioned valence to be unaffected by unreinforced presentations of the CS without the US. In contrast, subjective indices of conditioned arousal were expected to show a pattern of gradual extinction, such that individual presentations of the CS without the US would incrementally reduce subjective feelings of arousal elicited by the CS. The latter hypothesis was based on research showing that conditioned physiological arousal is typically reduced by unreinforced presentations of the CS without the US (for a review, see Myers & Davis, 2007). To test these hypotheses, the participants were presented with repeated pairings of neutral CSs and positive or negative USs of either high or low arousal. In a second block, half of the participants were presented with the same CS–US pairings a second time. For the remaining half, the CSs were presented individually without the USs. After each of the two learning blocks, the participants were asked to rate the valence and the arousal of their feelings towards the CSs.

Method

Participants and design

A total of 156 undergraduate students (108 female and 48 male) at the University of Western Ontario in Canada were recruited for a study on visual perception. One-hundred-and-one participants were paid CDN-$ 10 as compensation; the remaining 55 participants received research credit for an introductory psychology course.[5] The study included a 2 (US Valence: positive vs. negative) × 2

[5] Experiment 2 combined the samples of two identical replications that were conducted independently: one including the 101 participants who were paid $10 as compensation and the other one including the 55 participants who received research credit. Although the two studies were combined to streamline the presentation of our findings, it is worth noting that all of the reported effects are statistically significant within each of the two subsamples. The two identical replications were conducted to rule out the possibility of false-positives for the unexpected pattern of results in this study (see LeBel & Peters, 2011; Simmons, Nelson, & Simonsohn, 2011). The sample size of the first study (n = 101) was determined on the basis of prior research in our lab using the same EC paradigm; the sample size of the second study (n = 55) was determined on the basis of the effect sizes obtained in the first study. The data for both studies were collected in one shot without prior statistical analyses. No data were excluded from analyses and we report all manipulations and all measures in the study.

(US Arousal: low vs. high) × 2 (Time of Measurement: Time 1 vs. Time 2) × 2 (Learning Group: reinforcement vs. extinction) mixed-model design with the first three variables as within-subjects factors and the last one as a between-subjects factor. Participants were randomly assigned to one of the two learning group conditions.

Procedure

The instructions and main procedures were identical to Experiment 1. Participants were initially presented with a first set of CS–US pairings, after which they were asked to rate the valence and arousal of their feelings elicited by the CSs (Time 1). After completion of these ratings, half of the participants were presented with the same CS–US pairings a second time (*reinforcement group*); the remaining half was presented with the CSs alone (*extinction group*). All participants were then asked to complete the measures of valence and arousal a second time (Time 2). Finally, participants were debriefed and thanked for their participation in the study.

Conditioning procedure

The conditioning procedure was identical to the one in Experiment 1, the only difference being the use of a different set of IAPS images as USs (see Appendix). All participants initially underwent a conditioning manipulation. Subsequently, half of the participants were presented with the same pairings a second time using the same procedural parameters (*reinforcement group*). The remaining half was presented with the CSs alone, such that the screen remained blank for the 1000 msec interval that was initially used for the presentation of the USs (*extinction group*). All other procedural parameters were identical across the two groups.[6]

Measures

The measures of subjective valence and subjective arousal were identical to the ones in Experiment 1. Ratings of valence and arousal were administered twice: once after the initial conditioning phase (Time 1) and once after the manipulation of reinforcement versus extinction (Time 2).

Results

CS valence

Ratings of CS valence were submitted to a 2 (US Valence: positive vs. negative) × 2 (US Arousal: low vs. high) × 2 (Time of Measurement: Time 1 vs. Time 2) × 2 (Learning Group: reinforcement vs. extinction) mixed-model ANOVA. Replicating the occurrence of EC, the analysis revealed a significant main effect of US Valence, indicating that CSs that had been paired with a positive US were rated more favourably than CSs that had been paired with a negative US, $F(1,154) = 105.34$, $p < .001$, $\eta_p^2 = .406$. In addition, there was a significant two-way interaction of US Valence and Time of Measurement, $F(1,154) = 9.23$, $p = .003$, $\eta_p^2 = .057$, indicating that EC effects were larger at Time 1, $F(1,154) = 113.69$, $p < .001$, $\eta_p^2 = .425$, compared with Time 2, $F(1,154) = 64.05$, $p < .001$, $\eta_p^2 = .294$. Moreover, a significant three-way interaction between US Valence, US Arousal and Time of Measurement, $F(1,154) = 8.72$, $p = .004$, $\eta_p^2 = .054$, indicated that the effect of US Valence at Time 1 was stronger for high-arousal USs (*M*s = 3.01 vs. 4.83, respectively) than for low-arousal USs (*M*s = 3.41 vs. 4.80, respectively), $F(1,154) = 4.67$, $p = .03$, $\eta_p^2 = .029$, replicating the moderating influence of arousal on EC effects in Experiment 1. However, the effect of US Valence did not differ as a function

[6] When we planned the basic design of Experiment 2, we also considered the possibility of a control group, seeing no further pairings instead of using reinforcement as a control group. We eventually decided that a pre-post design comparing conditioning effects after reinforcement versus extinction would provide the most diagnostic data. Such a design controls for multiple confounds, the most important being differential fatigue and differential exposure to the CSs. Moreover, because measurement after no further pairing is conceptually equivalent to post-acquisition measurement in our pre-post design, the current design allowed us to test potential effects of reinforcement, which did not further increase conditioning effects for EC and AC (see below).

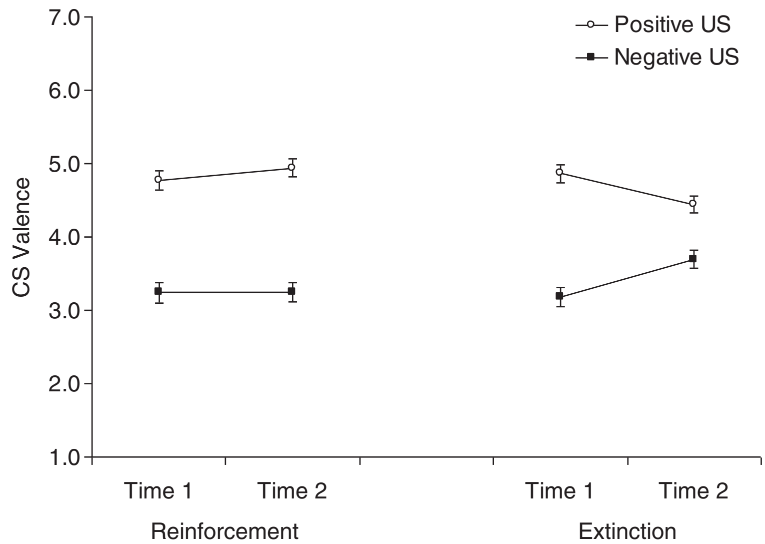

Figure 3. *Ratings of CS valence as a function of US Valence (Positive vs. Negative), Time of Measurement (Time 1 vs. Time 2), and Learning Group (Reinforcement vs. Extinction), Experiment 2. Measurements at Time 1 reflect CS valence ratings after initial conditioning; measurements at Time 2 reflect CS valence ratings after reinforcement versus extinction, respectively. Higher values indicate more favourable evaluations. Error bars depict standard errors.*

of high arousal (*M*s = 3.44 vs. 4.55, respectively) versus low arousal (*M*s = 3.51 vs. 4.84, respectively) at Time 2, $F(1,154) = 1.33$, $p = .25$, $\eta_p^2 = .009$.

More important for the current question, the ANOVA also revealed a significant three-way interaction of US Valence, Time of Measurement and Learning Group, $F(1,154) = 18.69$, $p < .001$, $\eta_p^2 = .108$ (see Figure 3). To specify the particular pattern of this interaction, we aggregated the valence ratings of the two CSs that had been paired with a US of the same valence separately for Time 1 and Time 2. These scores were then submitted to separate 2 (US Valence: positive vs. negative) × 2 (Time of Measurement: Time 1 vs. Time 2) ANOVAs for each of the two learning groups.

In the reinforcement group (see Figure 3, left panel), the ANOVA revealed a significant main effect of US Valence, indicating that CSs that had been paired with a positive US were rated more favourably than CSs that had been paired with a negative US, $F(1,76) = 53.83$, $p < .001$, $\eta_p^2 = .415$. The interaction of US Valence and Time of Measurement was not statistically significant, $F(1,76) = .81$, $p = .37$, $\eta_p^2 = .011$, indicating that EC effects did not change from Time 1 to Time 2 as a result of reinforcement. In the extinction group (see Figure 3, right panel), the ANOVA revealed a significant main effect of US Valence, $F(1,78) = 52.55$, $p < .001$, $\eta_p^2 = .403$, which was qualified by a significant two-way interaction between US Valence and Time of Measurement, $F(1,78) = 27.51$, $p < .001$, $\eta_p^2 = .261$. Although the effect of US Valence was statistically significant at both measurement times, this effect was much larger at Time 1, $F(1,78) = 70.03$, $p < .001$, $\eta_p^2 = .473$, compared with Time 2, $F(1,78) = 17.72$, $p < .001$, $\eta_p^2 = .185$. Thus, counter to our prediction, the current results indicate that EC effects were significantly reduced by unreinforced presentations of the CS without the US. Valence ratings of the CSs that had been paired with a US significantly differed from the valence ratings of the unpaired baseline CS at both measurement times (*M*s = 3.97 and 4.03, respectively; all $|t|$s > 3.44, all *p*s < .001).

CS arousal

Ratings of CS arousal were submitted to a 2 (US Valence: positive vs. negative) × 2 (US Arousal: low vs. high) × 2 (Time of Measurement: Time 1 vs. Time 2) × 2 (Learning Group: reinforcement vs. extinction) mixed-model ANOVA. Replicating the occurrence of AC, this analysis revealed a significant main effect of US Arousal, indicating that CSs that had been paired with a high-arousal US elicited higher levels of subjective arousal than CSs that had been paired with a low-arousal US, $F(1,154) = 59.59$, $p < .001$, $\eta_p^2 = .279$. In addition, there was a significant main effect of US Valence, indicating that CSs that had been paired with a positive US were rated as less arousing than CSs that had been paired with a negative US, $F(1,154) = 10.14$, $p = .002$, $\eta_p^2 = .062$. A significant main effect of Time of Measurement further indicated that CS arousal ratings were generally higher at Time 1 compared with Time 2, $F(1,154) = 5.30$, $p = .02$, $\eta_p^2 = .033$. More important for the current question, both the two-way interaction of US Arousal and Time of Measurement, $F(1,156) = 1.18$, $p = .28$, $\eta_p^2 = .008$, and the three-way interaction of US Arousal, Time of Measurement and Learning Group, $F(1,154) = .70$, $p = .40$, $\eta_p^2 = .005$, failed to reach statistical significance (see Figure 4). There was no significant interaction of US Arousal and Time of Measurement for the reinforcement group, $F(1,76) = .04$, $p = .85$, $\eta_p^2 = .001$ (see Figure 4, left panel), and the extinction group, $F(1,78) = 1.60$, $p = .21$, $\eta_p^2 = .020$ (see Figure 4, right panel). Thus, counter to our predictions, these results indicate that AC effects remained unaffected by unreinforced presentations of the CS without the US. Arousal ratings for the CSs that had been paired with a high-arousal US were significantly higher than arousal ratings of the unpaired baseline CS at both measurement times (Ms = 4.02 and 4.04, respectively; all ts > 2.82, all ps < .006). Somewhat surprisingly, CSs that had been paired with a low-arousal, positive US showed arousal ratings that were significantly below baseline at both measurement times (all $|t|$s > 2.55, all ps < .02). Arousal ratings for CSs that had been paired with a low-arousal, negative US did not significantly differ from arousal ratings of the unpaired baseline CS (all $|t|$s < 1.52, all ps > .13).

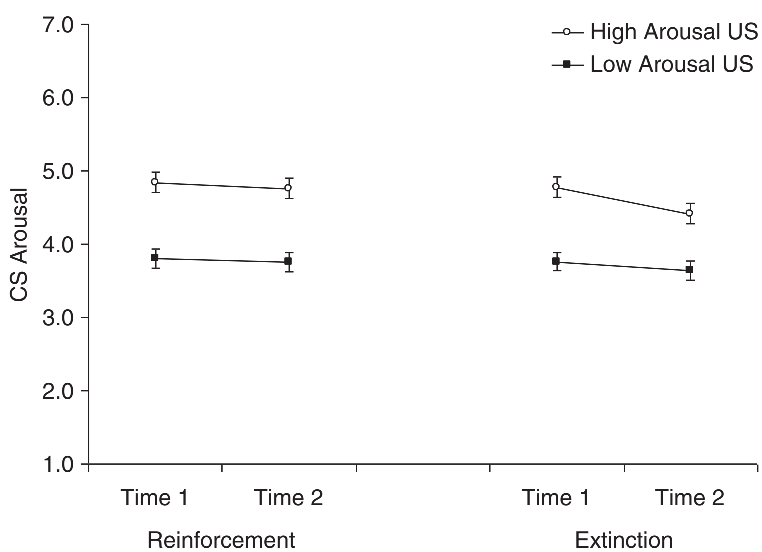

Figure 4. *Ratings of CS arousal as a function of US Arousal (High vs. Low), Time of Measurement (Time 1 vs. Time 2), and Learning Group (Reinforcement vs. Extinction), Experiment 2. Measurements at Time 1 reflect CS arousal ratings after initial conditioning; measurements at Time 2 reflect CS arousal ratings after reinforcement versus extinction, respectively. Higher values indicate higher levels of subjective arousal. Error bars depict standard errors.*

Differential susceptibility to extinction

To determine whether extinction effects were significantly different for EC and AC, we calculated indices reflecting the overall magnitude of EC and AC effects at the two measurement points. Towards this end, we again subtracted the mean valence ratings of the two CSs that had been paired with a negative US from the mean valence ratings of the two CSs that had been paired with a positive US at Time 1 and Time 2, respectively. Thus, higher values indicate larger EC effects (independent of arousal). A corresponding index was calculated for CS arousal by subtracting the mean arousal ratings of the two CSs that had been paired with a low-arousal US from the mean arousal ratings of the two CSs that had been paired with a high-arousal US at Time 1 and Time 2, respectively. Thus, higher values indicate larger AC effects (independent of valence). Confirming the differential influence of unreinforced CS presentations on EC and AC, a 2 (Conditioning Effect: EC vs. AC) × 2 (Time of Measurement: Time 1 vs. Time 2) × 2 (Learning Group: reinforcement vs. extinction) mixed-model ANOVA revealed a significant three-way interaction, $F(1,154) = 6.92$, $p = .009$, $\eta_p^2 = .043$. This interaction corroborates the conclusion that EC effects, but not AC effects, were reduced from Time 1 to Time 2 in extinction group (see Figures 3 and 4, right panels), whereas neither EC effects nor AC effects changed over time in the reinforcement group (see Figures 3 and 4, left panels).

Relation between EC and AC

Indices of the overall magnitude of EC and AC were again positively correlated at Time 1, $r(155) = .34$, $p < .001$, and Time 2, $r(155) = .33$, $p < .001$. Thus, to further explore the potential dependence of the two kinds of conditioning effects, we again regressed EC scores onto AC scores, and vice versa, for each of the two measurement times. Replicating the pattern obtained in Experiment 1, the two regression analyses for conditioning effects at Time 1 revealed statistically significant intercepts, indicating that EC effects were still significant after controlling for AC effects, $t(155) = 7.48$, $p < .001$, and AC effects were still significant after controlling for EC effects, $t(155) = 3.01$, $p = .003$. The same pattern emerged for conditioning effects at Time 2, such that EC effects were still significant after controlling for AC effects, $t(155) = 5.31$, $p < .001$, and AC effects were still significant after controlling for EC effects, $t(155) = 3.40$, $p = .001$. These results suggest that, although EC effects and AC effects were again positively correlated, the occurrence of one effect does not depend on the occurrence of the other.

Discussion

The results of Experiment 2 replicate the simultaneous conditioning of valence and arousal. As with Experiment 1, subjective feelings elicited by a given CS reflected both the valence and the arousal of the US it had been paired with. Moreover, whereas subsequent presentations of the CSs without reinforcement reduced conditioned valence ratings of the CSs, subjective ratings of conditioned arousal were less susceptible to extinction. This finding stands in contrast to our prediction that EC, but not AC, should be resistant to extinction. It also stands in contrast to earlier findings, suggesting that EC effects are resistant to extinction (e.g., Baeyens et al., 1988; De Houwer et al., 2000; Dwyer et al., 2007; Kerkhof et al., 2011; Vansteenwegen et al., 2006). However, it is in line with the results of a recent meta-analysis showing that EC effects tend to be larger for post-acquisition measurements than post-extinction measurements (Hofmann et al., 2010). Importantly, this pattern of results emerged in two identical replications (see Footnote 5), suggesting that the obtained extinction of EC is reliable and not due to sampling error. Thus, although the obtained dissociation corroborates our assumption that EC and AC are characterised by different functional properties, the current findings suggest that EC effects may be more susceptible, not less susceptible, to extinction than AC effects. This finding has important implications for research on EC because it challenges the widespread view that EC effects are resistant to extinction (e.g., De Houwer et al., 2001; Walther et al., 2005; but see Hofmann et al., 2010).

Another noteworthy finding is that Experiment 2 replicated the obtained asymmetry of EC effects as a function of arousal, such that EC effects after the initial acquisition of conditioned responses were stronger for high-arousal USs compared with low-arousal USs. As with Experiment 1, low-arousal USs and high-arousal USs had been matched for their valence on the basis of normative data and, if anything, the valence difference between positive and negative USs in the normative data was somewhat larger for low-arousal USs than high-arousal USs (see Appendix). These results support the conclusion that EC effects are modulated by the arousal that is elicited by the US, such that EC effects may be larger for high-arousal USs than low-arousal USs.

GENERAL DISCUSSION

The main goal of the current research was to test whether repeated CS–US pairings lead to simultaneous conditioning effects of valence and arousal. Results from two experiments supported this assumption, showing that subjective feelings elicited by a given CS reflected both the valence and the arousal of the US it had been paired with. Moreover, the two kinds of conditioning effects were characterised by different functional properties in that (1) AC effects, but not EC effects, were significantly related to recollective memory for CS–US pairings, and (2) subsequent unreinforced presentations of the CS without the US reduced EC effects, with AC effects being less susceptible to extinction. Considering that valence and arousal represent two fundamental dimensions of core affect (Russell, 2003), these findings call for a consideration of both valence and arousal in the conditioning of affective responses.

Although the main goal of the current studies was to investigate independent effects of valence and arousal, our findings also provide preliminary evidence for valence-by-arousal interactions. In both experiments, EC effects were stronger for high-arousal USs than low-arousal USs, and this difference emerged despite the matching of the USs in terms of valence and arousal on the basis of normative data (Lang et al., 2008). If anything, the valence difference between positive and negative USs was somewhat larger for low arousal than high-arousal USs. A potential explanation for this finding is that high levels of arousal elicited by the US increased attention to the stimulus pairings, which may enhance EC effects by virtue of attentional processes during encoding (see Field & Moore, 2005). Yet, an alternative interpretation is that high levels of conditioned CS arousal enhanced the expression of a conditioned evaluative response to the CS (Hull, 1943). Whereas the former mechanism implies a modulating effect of US arousal during the acquisition of an evaluative response, the latter mechanism implies a modulating effect of conditioned CS arousal during the expression of an evaluative response (see Gast, Gawronski, & De Houwer, 2012). Future research may help to clarify the role of arousal during the acquisition versus expression of conditioned evaluative responses.

By demonstrating simultaneous conditioning effects of valence and arousal, the current findings expand on earlier research investigating conditioning effects of non-evaluative features. In one of the earliest studies on this topic, Stevenson and colleagues found conditioning effects of sweet and sour tastes using neutral odours as CSs (Stevenson, Boakes, & Prescott, 1998; Stevenson, Boakes, & Wilson, 2000). These effects were independent of recollective memory for CS–US pairings (Stevenson et al., 1998) and resistant to extinction (Stevenson et al., 2000). Moreover, Meersmans, De Houwer, Baeyens, Randell, and Eelen (2005) found evidence for conditioning effects of gender when images of gender-ambiguous infants were repeatedly paired with images of gender-unambiguous children. However, in contrast to Stevenson et al.'s (1998) findings, conditioning effects of gender occurred only when participants were able to recall the CS–US pairings. Investigating the effects of speed and size perceptions, Olson, Kendrick, and Fazio (2009) obtained evidence for conditioning effects of these non-evaluative attributes, but only when participants were subliminally primed to the relevant dimension before the presentation of the CS–US pairings. Expanding on these findings, Glaser and Walther (2013) found that conditioned perceptions of size and softness were associated with corresponding changes in valence, such that conditioned perceptions of the two semantic dimensions mediated valence-congruent changes in CS evaluations. Finally, Förderer and Unkelbach (2011) showed that initially neutral individuals were perceived as more athletic when they were repeatedly paired with athletic people. The current results expand on these findings showing that (1) arousal represents another non-evaluative feature that can be conditioned through repeated CS–US pairings, (2) EC and AC can occur simultaneously as a result of the same CS–US pairings, (3) AC effects, but not EC effects, are related to recollective memory for CS–US pairings, and (4) subsequent unreinforced presentations of the CS without the US reduce EC effects, with AC effects being less susceptible to extinction.

Although the current findings indicate that EC and AC are characterised by different functional properties, an open question concerns the mechanisms underlying the two kinds of conditioning effects. EC effects are often explained in terms of associative processes of automatic link formation (e.g., Gawronski & Bodenhausen, 2006; Rydell & McConnell, 2006) in which the mental representation of the CS becomes automatically associated with the representation of the US (stimulus–stimulus learning; e.g., Walther, Gawronski, Blank, & Langer, 2009) or the evaluative response elicited by the US (stimulus–response learning; e.g., Sweldens et al., 2010). More recently, some researchers have questioned the notion of automatic link formation, arguing that EC effects are due to the non-automatic acquisition and validation of propositional knowledge about CS–US relations (e.g., De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009). The conflicting evidence regarding these competing accounts has led some researchers to speculate that EC effects can be the result of either associative or propositional processes, with the operation of the two processes depending on specific aspects of the stimulus pairings (e.g., De Houwer, 2007; Gawronski & Bodenhausen, 2011; Jones et al., 2010; Sweldens et al., 2010). Although the current findings remain ambiguous with regard to the mechanisms underlying EC and AC, they provide clear evidence that the mechanisms that are responsible for the two kinds of conditioning effects are characterised by different functional properties. Whereas EC effects were independent of recollective memory for CS–US pairings and reduced by unreinforced presentations of the CS, AC effects showed a significant positive relation to recollective memory and lower susceptibility to extinction. These dissociations suggest that the two kinds of conditioning effects are the result of distinct mechanisms that operate simultaneously on the basis of the same stimulus episode.[7] Although speculative, one possibility is that the differential involvement of recollective memory in the two kinds of conditioning effects also plays a role for their differential susceptibility to extinction. However, more research is needed to identify the exact mechanisms underlying EC and AC, and what role these processes play in their susceptibility to extinction.

A potential objection against the current findings is the exclusive use of self-report measures to assess conditioned valence and conditioned arousal. We agree that self-report measures are suboptimal because of their susceptibility to reporting biases. Nevertheless, we believe that the current findings provide an interesting starting point for follow-up studies, using less reactive measures of valence and arousal. However, in designing such studies, it is important to avoid confounds

[7] An important aspect in this context is that arousal represents a unipolar construct that does not include a neutral reference point, whereas valence is characterised by a bipolar dimension that does have a neutral reference point. Although positivity and negativity seem to be represented independently in memory (Cacioppo & Berntson, 1994), it is possible that the obtained differences in the functional properties of EC and AC are at least partly due to their differing dimensionality.

between type of response and procedural details of the measurement instruments. For example, studies using sequential priming tasks to assess evaluative responses (see Wentura & Degner, 2010) and psychophysiological measures to assess arousal responses (see Winkielman, Berntson, & Cacioppo, 2001) would confound the to-be-assessed construct with several procedural differences between the two kinds of measures (cf. Payne, Burkley, & Stokes, 2008; Roediger, 1990). Such confounds were deliberately avoided in the current research by assessing both CS valence and CS arousal by means of procedurally identical measures. In doing so, the present studies raise interesting questions about the relationship between subjective and objective measures of conditioning that should be addressed in future work (cf. Greenwald et al., 1989; Lang et al., 1993; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005).

Another important issue in this context concerns the possibility of demand awareness, which refers to participants' ability to report the experimental hypothesis (De Houwer et al., 2001). Demand awareness can pose a challenge to theoretical conclusions in research using self-report measures to the extent that conditioning effects may be driven by participants' compliance in reporting CS features that are in line with the presumed experimental hypothesis. Although the current studies did not include a measure of demand awareness, the recollective memory task in Experiment 1 provides data that can help to address this concern. Previous research has shown that participants' ability to strategically influence the magnitude of EC effects on self-report measures depends on whether they are able to recall the valence of the US that had been paired with a given CS (Balas & Gawronski, 2012). Because EC effects were unrelated to recollective memory in the current research, demand awareness can be ruled out as an alternative explanation for the obtained effects of US valence. Yet, demand awareness is more difficult to rule out for the effects of US arousal, which showed a significant positive relation to recollective memory. Although the obtained resistance to extinction of AC seems difficult to reconcile with an interpretation in terms of demand awareness, future research using non-reactive measures of arousal would help to rule out potential concerns about demand awareness.

Although more research is needed to corroborate the simultaneous conditioning of valence and arousal, the current results have significant implications for EC and the acquisition of emotional dispositions. Specifically, our findings indicate that it is important to distinguish between valence and arousal as two independent dimensions in the conditioning of affective responses. As we noted in the introduction, studies on EC rarely control for arousal in the selection of the stimulus materials. Because negative USs are often more arousing than positive USs, such confounds can lead to incorrect conclusions in studies using psychophysiological indicators that may reflect changes in arousal rather than valence. This concern also applies to research on fear conditioning (e.g., Knight, Nguyen, & Bandettini, 2003; Schultz & Helmstetter, 2010), given that conditioned fear responses involve a natural confound between negative valence and high arousal. In fact, the current findings indicate that a conceptual and methodological distinction between valence and arousal may provide deeper insights into the functional properties of fear responses and perhaps even their clinical treatment. For example, one possibility is that in therapeutic interventions geared towards alleviating the effects of stimuli that trigger anxiety, improvements in evaluative appraisals may actually precede changes in arousal responses triggered by the same stimuli. Given that many phenomena that have traditionally been attributed to valence have recently been linked to arousal (e.g., Colibazzi et al., 2010; Cunningham et al., 2004; Vogt et al., 2008), the conditioning of arousal should be regarded as an important outcome over and above the well-documented conditioning of valence.

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APPENDIX

Normative ratings of valence and arousal of the IAPS images used as USs (Lang et al., 2008).

			All subjects		Men		Women	
US valence	US arousal	Image	Valence	Arousal	Valence	Arousal	Valence	Arousal
Experiment 1								
Positive	Low	Girl (2035)	7.52	3.69	7.07	3.34	7.79	3.90
Positive	High	Sky Divers (5621)	7.57	6.99	7.28	6.96	7.80	7.00
Negative	Low	Elderly Woman (2590)	3.26	3.93	3.04	4.00	3.46	3.86
Negative	High	Snake (1050)	3.46	6.87	3.90	6.84	3.02	6.90
Experiment 2								
Positive	Low	Nature (5760)	8.05	3.22	7.69	2.77	8.41	3.67
Positive	High	Rollercoaster (8492)	7.21	7.31	7.36	7.07	7.11	7.48
Negative	Low	Cemetery (9001)	3.10	3.67	3.41	3.74	2.82	3.60
Negative	High	Aimed Gun (6230)	2.37	7.35	2.73	7.10	2.06	7.56