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Cue competition in evaluative conditioning as a function of the learning process

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ABSTRACT

Evaluative conditioning (EC) is the change in the valence of a stimulus resulting from pairings with an affective (unconditioned) stimulus (US). With some exceptions, previous work has indicated that this form of conditioning might be insensitive to cue competition effects such as blocking and overshadowing. Here we assessed whether the extent of cue competition in EC depends upon the type of contingency learning during conditioning. Specifically, we contrasted a learning task that biased participants toward cognitive/inferential learning (i.e., predicting the US) with a learning task that prevented prolonged introspection (i.e., a rapid response made to the US). In all cases, standard EC effects were observed, with the subjective liking of stimuli changed in the direction of the valence of the US. More importantly, when inferential learning was likely, larger EC effects occurred for isolated stimuli than for compounds (indicating overshadowing). No blocking effects on explicit evaluations were observed for either learning task. Contingency judgments and implicit evaluations, however, were sensitive to blocking, indicating that the absence of a blocking effect on explicit evaluations might be due to inferences that occur during testing.

1. Introduction

The subjective evaluation of an object tends to change when it is repeatedly presented together with an affect-laden stimulus. For instance, the extent to which an individual reports liking an arbitrary product (e.g., a car) may increase if it is consistently shown together with a stimulus that produces a positive emotional response (e.g., an image of an attractive woman). Conversely, pairings of the same object with a negative stimulus (e.g., graphic videos of mutilation) may result in a decrease in the degree to which an individual likes the product. These affective transfer effects have been referred to as 'evaluative conditioning' (EC; for reviews see De Houwer, Thomas, & Baeyens, 2001; De Houwer, 2007; Gast, Gawronski, & De Houwer, 2012; Walther, Nagengast, & Trasselli, 2005). Specifically, EC is defined as a change in the valence of a conditioned stimulus (CS) that results from temporal or spatial pairings with a positive or negative unconditioned stimulus (US). While there are numerous studies demonstrating EC as a robust and reliable effect that can be obtained with very different types of CSs and USs ('medium' effect size; see Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010, for a meta-analysis), there is still an ongoing debate as to the specific processes underlying the effect. In particular, simple association-formation accounts, which assume that EC depends on the strengthening of pathways between the representations of the CS and the US (e.g., the referential account, Baeyens, Vansteenwegen, Hermans, & Eelen, 2001), stand in opposition to propositional accounts, which expect EC to be the result of inferential reasoning processes about the CS–US relationship (e.g., De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009).

It has been argued that EC may differ from other forms of associative learning in several ways. For instance, in contrast to most other forms of Pavlovian conditioning, there are studies indicating that EC may be insensitive to CS–US contingency (Baeyens, Hermans, & Eelen, 1993; Kattner, 2014) and resistant to extinction (e.g., Baeyens, Crombez, Van den Bergh, & Eelen, 1988; Dwyer, Jarratt, & Dick, 2007). In other words, unpaired CS (or US) presentations during or after conditioning do not seem to affect the acquired valence of a stimulus (i.e. the conditioned response).

Another crucial feature found in most forms of associative learning is cue competition, that is, the observation that learning about a CS depends on the concurrent presence of other CSs that may or may not be associated with the US. *Overshadowing* is one example of cue competition and it refers to lower levels of conditioned responding that are typically observed when two co-occurring CSs are paired with the US (AB → US), as compared to when an isolated CS is paired with the US (C → US). While overshadowing constitutes a very common observation in classical conditioning (Mackintosh, 1975; Pavlov, 1927), there are very few studies on overshadowing in EC. Dwyer et al. (2007) paired either single food images (control condition) or pairs of food images (overshadowing condition) with either liked (normal) or disliked (obese) body shapes and found that the resulting EC effects did not

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differ significantly between the control and overshadowing conditions, indicating that EC may not be subject to overshadowing. In contrast, Walther, Ebert, and Meinerling (2011) found EC effects only when either a brand name or a product image was paired with the US, but not when both name and image co-occurred as a compound. However, in contrast to typical overshadowing procedures, participants in this study did not rate the two CSs of a compound separately. Additional evidence for overshadowing in EC may thus be required.

Another well-known type of cue competition, *blocking* (Kamin, 1969), refers to the attenuation of learning when a CS co-occurs with another CS which is already known to be a good predictor of the US. More precisely, when stimulus A (which is consistently followed by a US) occurs both alone (A → US) and in combination with another stimulus X (A + X → US), then the conditioned response to X is typically found to be reduced, compared to if there were no A → US trials. Although there are numerous studies showing blocking in Pavlovian conditioning (e.g., Hinchy, Lovibond, & Terhorst, 1995; Martin & Levey, 1991) and contingency learning (e.g., De Houwer & Beckers, 2003; Dickinson, 2001), evidence for blocking effects in evaluative learning is scarce. Several studies in fact failed to find blocking in EC (Beckers, De Viqo, & Baeyens, 2009; Dickinson & Brown, 2007; Laane, Aru, & Dickinson, 2010; Lipp, Neumann & Mason, 2001; Walther et al., 2011). Beckers et al. (2009), for instance, did not find any evidence for blocking in an EC procedure with children, pairing either one or two symbols (CSs) with the gain or loss of a candy reward (the US). Others, however, did find blocking to affect pleasantness ratings in the context of a contingency learning task (Tobler, O'Doherty, Dolan, & Schultz, 2006, see below). These inconsistencies indicate that EC may be affected by blocking under certain yet unexplained conditions.

In principle, both associative association-strengthening and propositional learning models can account for the occurrence of cue competition effects in EC. According to a classical pathway-strengthening account of blocking (e.g., Rescorla & Wagner, 1972), A → US trials will promote the formation of a strong association between A and the US, whereas the link between X and the US will remain weak due to a small prediction error in A + X → US trials. Similarly, in the case of overshadowing, two CSs that are trained as part of a compound are expected to share the associative strength supported by the US (whereas a single CS can acquire the full associative strength). Having said that, it has been argued that EC, unlike other forms of learning, might not actually be based on a reduction of prediction errors, but rather on simple contiguity-based Hebbian learning (cf., referential account of EC; Baeyens & De Houwer, 1995; Baeyens et al., 2001). Since the mere exposure to CS–US pairings should thus be sufficient to produce a change in evaluations, EC is not expected to be affected by cue competition as long as the CS was paired repeatedly with the US (see Beckers et al., 2009).

Propositional accounts – although via a different route than association-strengthening models – are also able to explain cue competition in EC. According to a propositional model, cue competition effects should be contingent on the individual's subjective belief that A and X are independent causes of the US (Lovibond, Been, Mitchell, Bouton, & Frohardt, 2003). Moreover, this model predicts that cue competition effects will be absent for propositional learning when the learner does not have sufficient cognitive resources available to make inferences regarding alternative causes of the US (e.g., due to limited time during conditioning). Consistent with this account, it has been shown, for instance, that distraction may reduce blocking effects for contingency learning (De Houwer & Beckers, 2003). Here, the acquisition of evaluative responses and contingency knowledge is assumed to be based on the same learning mechanism, that is, the formation and evaluation of propositions (De Houwer, 2009). Cue competition might thus be expected to occur in EC whenever it is found in CS–US contingency judgments. And indeed, there is some indication that EC can be modulated by blocking in the context of a contingency learning task (Tobler et al., 2006; so far providing the probably most convincing data for blocking in EC). In this study, participants rapidly responded to the location of complex visual images (while lying in a 1.5 Tesla fMRI scanner) some of which predicted a juice reward. Pre–post pleasantness ratings indicated that the liking of the juice-predicting image increased, whereas the liking of an image that predicted no juice to be delivered decreased (i.e., EC). However, no change in pleasantness was found for an image that, on some trials, co-occurred with the juice-predicting image.

Recent empirical evidence suggests that EC as an effect (De Houwer, 2007) can be based on very different learning processes (e.g. inferential learning vs. association-strengthening; see Sternberg & McClelland, 2012). The occurrence of cue competition in EC might thus depend on the type of learning processes driving the change in stimulus evaluations. For example, Gawronski, Gast, and De Houwer (2014) recently found that extinction of EC depends on certain procedural characteristics. Specifically, unreinforced CS presentations were shown to attenuate EC effects on self-report measures only if the participants had previously been asked to rate the stimuli, whereas resistance to extinction was found without pre-ratings as well as for implicit measures of CS valence (i.e., affective priming). In the same vein, Hütter and Sweldens (2013) showed that, depending on temporal characteristics of the conditioning procedure, EC may either depend on the conscious recollection of CS–US pairings or not. Results like these indicate that changes in stimulus evaluations can result from different processes (e.g. inferential learning and association-strengthening), depending on procedural properties, with some processes potentially being more sensitive to extinction, conscious recollection and cue competition than others.

Sternberg and McClelland (2012) recently demonstrated a dissociation between inferential learning and association-strengthening processes with regard to the occurrence of cue-competition effects in contingency learning. In particular, cue competition was found to be sensitive to specific framing instructions when participants were required to predict the outcome on each trial during learning (i.e., cue competition was found only with a causal framing of the CS–US relationship). In contrast, cue competition effects occurred regardless of the instruction if the participants were asked to rapidly respond to the outcomes (RT task). This dissociation was explained by surmising that the prediction task provided sufficient cognitive resources for inferential learning, whereas the RT task suppressed inferential learning, leading to quick association-formation.

The present study is an attempt to test overshadowing and blocking effects on acquired stimulus evaluations in the context of a contingency learning task that allows the type of learning process to be manipulated. Specifically, we tested whether cue competition affects EC when either inferential learning or association strengthening is the most likely source of learning. If EC does occur solely as a result of propositional learning, then blocking should occur only in situations where sufficient cognitive resources are available during conditioning. However, if association-strengthening processes are the cause of EC effects, then cue competition should be observable even with limited cognitive resources available during conditioning. To test these alternatives, we utilized a procedure that was adopted from Sternberg and McClelland (2012). In Experiment 1, participants were required to deliberately predict the USs based on the CS presentations in order to facilitate inferential learning. Experiment 2 investigated whether constraining the cognitive resources available for inferential learning affected cue competition. Here, the task was identical to that utilized in Experiment 1, but the cognitive load was increased by introducing a response deadline during the prediction task. In Experiment 3, participants rapidly responded to the occurrence of the USs (which was also predicted by the CSs). As inferential learning is supposed to be a slow, resource-consuming process, the CS–US associations in Experiment 3 were expected to be learned through association-strengthening processes rather than through inferential learning (see Sternberg & McClelland, 2012, p. 60).

In addition, the experiments were designed to assess the relation between EC and the acquisition of contingency knowledge. Since contingency knowledge is known to reflect both the current predictive value of a CS as well as an integration of contingencies across several trials (e.g., Lipp & Purkis, 2006; Vadillo, Miller, & Matute, 2005), contingency knowledge was tested (a) during the conditioning phase (by means of either US-prediction responses in Experiments 1 and 2, or RTs to the US in Experiment 3) and (b) after the conditioning phase (by means of CS–US contingency ratings). Specifically, previous research has shown that US predictions are based on the conditional probability of the US given the CS, while contingency ratings reflect the CS–US contingency (i.e., the conditional probability of the US in the absence of the CS subtracted from the conditional probability of the US in the presence of the CS; see Vadillo & Matute, 2007; Vadillo et al., 2005). In order to allow concurrent US prediction responses during the conditioning phase,[1] CS and US were presented sequentially (without a trace interval), rather than simultaneously, in the present study. There is evidence suggesting that EC is closely related to (explicit) contingency knowledge with sequential CS–US presentations, whereas EC effects may occur in the absence of contingency awareness with simultaneous CS–US presentations (Hütter & Sweldens, 2013).

2. Experiment 1

Experiment 1 was developed to test whether blocking and overshadowing can be found in EC when the CS–US pairings were presented in the context of an inferential contingency learning task. Participants were instructed to explicitly learn the CS–US contingencies by predicting the US on each trial without any temporal constraints (similar to Sternberg & McClelland, 2012).

2.1. Method

2.1.1. Participants

Thirty undergraduate students at the University of Wisconsin-Madison (23 women) participated in Experiment 1. Ages ranged between 18 and 32 years ($M = 18.8$; $SD = 2.6$). The duration of the experiment was about 30 min. All participants were compensated with extra course credit. One female participant was removed from the data set as her performance indicated that she was not following task instructions.

2.1.2. Apparatus and stimuli

Stimulus presentation and response registrations were programmed in MATLAB (on a Windows computer) using the Psychophysics toolbox extensions (Brainard, 1997; Pelli, 1997). Stimuli and text instructions were presented on a 22″ wide-screen TFT monitor with a resolution of 1680×1050 pixels. The monitor was placed approximately 57 cm in front of the participant and covered approximately $24.5° \times 15.9°$ of visual angle. A standard keyboard was used as the response device. A set of twenty presumed 'Maya' drawings served as the CSs. Each drawing was presented in black within a white square subtending $2° \times 2°$ (see Fig. 1 for some examples). For each participant, ten of these drawings were randomly selected and used as the different types of stimuli (see below). All stimuli were presented on gray background.

2.1.3. Procedure

Prior to the learning stage, participants were told that the task was to predict whether a smiling or frowning character would be presented on the screen following certain 'Maya' drawings. Each trial of the learning stage started with the presentation of a fixation cross for 250 ms (approximately $0.6° \times 0.6°$) at an eccentricity of 4.3° left of the center of the screen. Then, either one or two drawings were presented as CSs on the left side of the screen (a single drawing was presented at an eccentricity of 3.8° left of the center, and two drawings were presented side by side in counterbalanced order, covering a rectangle of $4° \times 2°$ at 4.8° eccentricity left of center). The participants' task was to predict the outcome character by pressing either the up ('positive') or down ('negative') arrow key. After each response, the drawing disappeared, and either a smiling [☺] or frowning [☹] character (the US) was presented on the right side of the screen for 1500 ms ($2° \times 2°$ at an eccentricity of 4.3° right of the center). Simultaneously, verbal feedback ('CORRECT' or 'WRONG', depending on whether the participants' prediction corresponded to the valence of the US or not) was shown in the top center of the screen. The next trial started after an intertrial interval of 1250 ms.

The different types of CSs or pairs of CSs that were presented during the learning task are shown in Table 1. Half of the CSs or compounds were associated with a positive US (smiling face), and half were associated with a negative US (frowning face). Overshadowing effects were tested by comparing CSs that were exclusively trained alone (I and J) with CSs that were exclusively trained as part of a compound (E and G). Blocking effects were tested by comparing 'blocked' CSs (B and D) which co-occurred with CSs that were also trained alone on different trials to 'control' CSs (E and F) which co-occurred with CSs that were never presented alone.

Each type of trial was repeated 20 times, resulting in a total of 160 learning trials. The order of the eight different types of trials was randomized within each repeated block.

In order to measure the evaluative responses to the CSs, all ten 'Maya' drawings were subsequently presented in random order, and participants were asked to rate each drawing on a horizontal nonverbal visual analog scale ranging from 'dislike' (0) to 'like' (1). Note that a horizontal scale was used to avoid direct response mappings from the conditioning phase (up/down) to the rating phase (left/right). Participants were instructed to rate the subjective pleasantness spontaneously, and to rely on their immediate personal feelings toward the drawings.

Finally, contingency knowledge was tested for each individual CS. Participants were asked to rate how likely it was that the drawing actually caused either the smiling or the frowning character to appear on the screen. Therefore, all CSs were presented again in random order together with a horizontal visual analog ranging from 'certainly frowning character' (1) through 'don't know' (0.5) to 'certainly smiling character' (0). Note that the scale was reversed, compared to the evaluative rating scale, to prevent participants from simply copying their evaluative responses.

2.2. Results

2.2.1. Contingency learning

The accuracy of outcome predictions during the conditioning phase indicated successful contingency learning (see Fig. 2). On average, accuracy increased from 53.4% correct ($SD = 50.0\%$) on the first presentation of a CS type (block 1) to 98.3% correct ($SD = 13.0\%$) on the last presentation of a CS type (block 20). Overshadowing effects were assessed by comparing the accuracy of predictions on trials with isolated (I and J) and compound CSs (EF and GH). A 2 (presentation mode: isolated vs. compound) × 20 (block) repeated-measures ANOVA revealed a significant main effect of block, $F(19, 532) = 34.20$; $p < .001$; $\eta^2_G = 0.38$ (confirming contingency learning), and a significant main effect of presentation mode, $F(1, 28) = 10.02$; $p = .004$; $\eta^2_G = 0.02$, indicating that the mean accuracy of predictions (collapsed across trials) was higher on trials with isolated CSs (94% correct for I and J) than on trials with compound CSs (90% correct for EF and GH). There was no interaction between block and presentation mode, $F(19, 532) = 0.90$; $p = .58$.

Moreover, the final contingency judgments of specific drawings that were paired with frowning characters ($M = 0.70$; $SD = 0.22$) differed

[1] Note that we considered US prediction responses on separate trials (which would keep the temporal contiguity of CS–US presentations constant; e.g., Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002; Vadillo & Matute, 2007) as inappropriate for our purpose because (a) these additional trials would have acted as intermittent conditioning and (b) the predictions would most likely reflect an integration of the predictive values of an individual CS across several trials in which the CS occurred either alone or together with competing stimulus. Both issues could potentially have adversely interacted with the intended cue-competition effects.

Fig. 1. Examples for the CSs used in Experiments 1, 2, and 3.

Table 1
Experimental design of the conditioning stages in Experiments 1, 2, and 3. On each trial, either one or two 'Maya' drawings (indicated by capital letters) were presented prior to a positive (smiling) or negative (frowning) outcome character.

Drawing(s)	Outcome character
AB	Smiling
A	Smiling
CD	Frowning
C	Frowning
EF	Smiling
I	Smiling
GH	Frowning
J	Frowning

significantly from drawings that were paired with smiling characters ($M = 0.32$; $SD = 0.26$), $t(28) = 7.05$; $p < .001$, indicating that participants acquired knowledge of the individual CS–US contingencies.

To test for overshadowing effects in contingency judgments, a 2 (US type: smiling vs. frowning) × 2 (presentation mode: isolated vs. overshadowed) repeated-measures ANOVA was conducted on the contingency ratings of the CSs E, F, G, H, I, and J. The analysis revealed a significant main effect of US type, $F(1, 28) = 45.41$; $p < .001$; $\eta^2_G = 0.47$, as well as a significant interaction between US type and presentation mode, $F(1, 28) = 6.16$; $p = .019$; $\eta^2_G = 0.05$, indicating that differential contingency knowledge was weaker for overshadowed CSs ($M_{EF} = 0.35$; $SD_{EF} = 0.27$ vs. $M_{GH} = 0.65$; $SD_{GH} = 0.24$)[2] than for isolated CSs ($M_I = 0.25$; $SD_I = 0.20$ vs. $M_J = 0.72$; $SD_J = 0.20$). This result indicates that contingency learning was affected by cue-competition through overshadowing. There was no main effect of presentation mode, $F(1, 28) = 0.37$; $p = .55$.

Blocking effects on contingency knowledge were assessed by comparing the contingency ratings of blocked CSs (B and D) and control CSs (F and H) that were presented as part of a compound. A 2 (US type) × 2 (compound type: blocked vs. control) repeated-measures ANOVA revealed a significant main effect of US type $F(1, 28) = 20.11$; $p < .001$; $\eta^2_G = 0.28$, but no interaction with compound type, $F(1, 28) = 0.02$; $p = .89$ ($M_B = 0.39$; $SD_B = 0.33$ vs. $M_D = 0.69$; $SD_D = 0.20$; the 'overshadowed' CSs E, F and G, H served as control CSs for blocking, see above). The contingency judgments thus did not show any evidence of blocking. There was no main effect of compound type, $F(1, 28) = 1.30$; $p = .26$.

2.2.2. Evaluative conditioning

Fig. 3 depicts the evaluative ratings of CSs that were contrasted to test for possible cue-competition effects. Overshadowing effects were evaluated by conducting a 2 (US type) × 2 (presentation mode: isolated vs. overshadowed) repeated-measures ANOVA on the evaluative ratings of CSs that were presented alone (I and J) and CSs that were presented as part of a compound (F and H). The analysis revealed a significant main effect of US type, $F(1, 28) = 29.97$; $p < .001$; $\eta^2_G = 0.33$, indicating an overall EC effect, as well as a significant interaction, $F(1, 28) = 5.52$; $p = .026$; $\eta^2_G = 0.05$. Specifically, the interaction indicates that the acquisition of evaluations was mediated by overshadowing with weaker EC effects for compound CSs than for isolated CSs (see left side of Fig. 3). A Bayesian analysis (see Rouder, Speckman, Sun, Morey, & Iverson, 2009) further showed that the alternative hypothesis (i.e. a difference in EC effects between isolated and overshadowed CSs) was about 54.2 times more likely than the null hypothesis. There was no main effect of presentation mode on evaluative ratings, $F(1, 28) = 0.25$; $p = .62$.

An additional 2 (US type) × 2 (presentation mode) × 2 (rating: evaluative vs. contingency) repeated-measures ANOVA was conducted to investigate whether the observed overshadowing effects differed between contingency judgments and evaluative ratings. The analysis revealed only a significant main effect of US type, $F(1, 28) = 35.47$; $p < .001$; $\eta^2_G = 0.33$, as well as an interaction with presentation mode, $F(1, 28) = 9.22$; $p = .005$; $\eta^2_G = 0.05$, but no 3-way interaction, $F(1, 28) = 0.22$; $p = .64$, indicating that the overshadowing effect did not significantly differ in magnitude between evaluative and contingency ratings.

A 2 (US type) × 2 (compound type) repeated-measure ANOVA on the ratings of blocked (B and D) and control CSs (F and H) also revealed a significant main effect of US type, $F(1, 28) = 13.04$; $p = .001$; $\eta^2_G = 0.21$, but no interaction with compound type, $F(1, 28) = 0.18$; $p =$

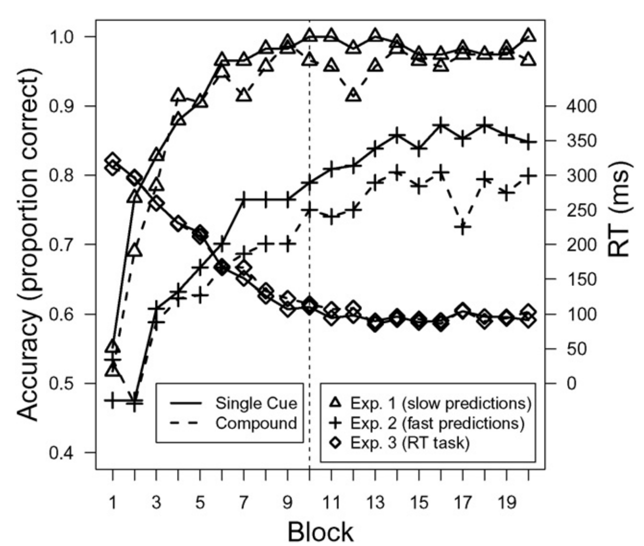

Fig. 2. Learning curves: average accuracy of the predictions in Experiments 1 and 2 (right ordinate), and average RTs of the US categorization responses in Experiment 3 (left ordinate). Each block comprises eight trials (one presentation of each trial type) of the prediction tasks Experiments 1 and 2, and 20 trials of the RT task in Experiment 3. The dashed vertical line indicates the asymptote of the response deadline (200 ms) in Experiment 3.

[2] Note that for CSs that were only presented as a compound (i.e., EF and GH) we averaged both the contingency judgments and the evaluative ratings of the individual cues E, F, and G, H, respectively.

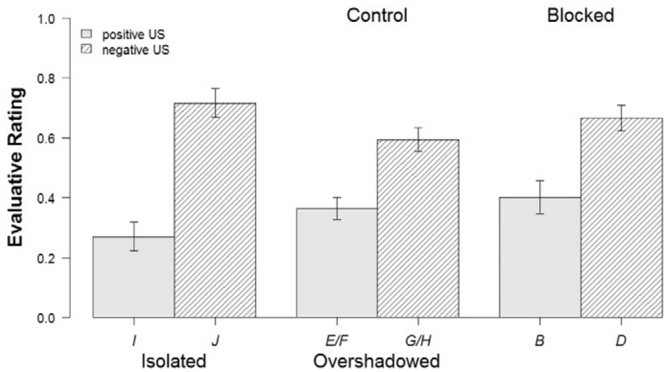

Fig. 3. Overshadowing and blocking effects on the evaluative ratings of individual CSs presented in Experiment 1 (0 = dislike, 1 = like).

.67, suggesting that the magnitude of EC was not affected by blocking (compare bars on the right side of Fig. 3). Calculation of a Bayes factor indicated that the null hypothesis (no difference in EC between blocked and control CSs) was 4.8 times more likely than the alternative hypothesis. There was no significant main effect of compound type on evaluative ratings, $F(1, 28) = 3.31$; $p = .08$.

2.3. Discussion

Using an explicit contingency-learning task, Experiment 1 revealed that cue competition can have an effect on EC. Specifically, co-occurring CSs resulted in weaker EC effects than CSs that were trained alone. An analog overshadowing effect was found in the contingency judgments, suggesting that both measures might be the outcome of inferential learning during the US prediction task that takes into account whether CSs co-occur or not. However, both the evaluative and the contingency ratings of CSs did not provide any indication of blocking. Thus, the evaluation of a CS was not affected by the additional isolated presentations of a co-occurring CS.

Of course, it is not possible to draw any firm conclusions from the null-result regarding blocking. The absence of blocking in both rating measures might suggest that learning was inferential (as expected) and thus depended on the specific framing of the task. Using a similar prediction task, Sternberg and McClelland (2012) found that cue-competition vanished when the instructions did not imply a causal relation between the cues and the outcomes. In Experiment 1, participants were given instructions that implied an attributional relationship between the drawings and their affective meaning rather than a causal relationship. Participants might also have assumed that the meanings of the individual drawings were not independent from each other, which is known to interfere with the occurrence of cue competition effects in an explicit contingency-learning task with unlimited time (again assuming inferential learning; Lovibond, 2003).

Experiment 1 thus confirmed previous findings of blocking being absent in EC (e.g., Beckers et al., 2009; Laane et al., 2010; Walther et al., 2011), while providing some initial evidence for overshadowing in EC. This latter finding contradicts some previous findings in the literature (e.g., Dwyer et al., 2007). We therefore considered it crucial to replicate an evaluative overshadowing effect in a second experiment.

3. Experiment 2

Experiment 2 was designed to replicate and extend the cue competition effects seen in Experiment 1. The learning task was the same as in Experiment 1, with the exception of a moderate response deadline (650 ms) that was introduced to limit the cognitive resources available during learning. In particular, the deadline was meant to constrain the specific inferences participants would draw about the CS–US relationship during the learning stage. If the absence of blocking in Experiment 1 was due to certain elaborate inferences about a non-causal relationship between the CS and US, then an increased cognitive load might be sufficient to elicit blocking, assuming that participants would then stick to a default causal propositional assumption concerning the CS–US relationship (e.g. 'certain drawings cause the outcomes').

Furthermore, in addition to explicit evaluative ratings, implicit CS valence measures were obtained using an affective priming task (Fazio, Sanbonmatsu, Powell, & Kardes, 1986) at the end of the experiment. Comparing cue competition effects on explicit and implicit evaluations provides an additional means to assess the role of inferences that might occur during explicit ratings.

3.1. Method

3.1.1. Participants

Fifty-one undergraduate students were recruited from the campus of the University of Wisconsin-Madison (27 women) to participate in Experiment 2. Ages ranged between 18 and 47 years ($M = 19.6$; $SD = 4.2$). The experiment took about 45 min, and all participants were compensated with course credit.

3.1.2. Materials and procedure

The apparatus, stimuli and the experimental design (see Table 1) were the same as in Experiment 1. However, in Experiment 2, participants did not have unlimited time to make predictions during the learning phase. As in Experiment 1, each trial started with a fixation cross for 250 ms (4.3° eccentricity left of center). Then either one or two drawings (CSs) were presented for 650 ms on the left side of the screen (3.8° or 4.8° eccentricity, respectively). The participants were instructed to predict as fast as possible whether the particular configuration of drawings would predict the smiling or the frowning character. After 650 ms, the CS images disappeared, and the US was presented for 1500 ms on the right side of the screen (eccentricity: 4.3°). Text feedback ('CORRECT' or 'WRONG') was presented immediately in the center of the screen if the participant gave a response within 650 ms. If no response was given, the prompt 'BE FASTER!' was shown in the center of the screen. The next trial started after an intertrial interval of 1250 ms.

After the learning phase an affective priming task was conducted. In this task, ten positive and ten negative English adjectives (*pleasant*, *good*, *outstanding*, *beautiful*, *magnificent*, *marvelous*, *excellent*, *appealing*, *delightful*, *nice*, *unpleasant*, *bad*, *horrible*, *miserable*, *hideous*, *dreadful*, *painful*, *repulsive*, *awful*, and *ugly*) were presented as targets, and four CSs (B, D, F, and H) were presented as task-irrelevant primes. Each trial started with a central fixation cross that was displayed for 500 ms. After the fixation cross, a prime was presented. Then, after 200 ms, the prime was replaced by a target word. The participants' task was to respond with the right arrow key as quickly as possible if the word was positive, and with the left arrow key if the word was negative. The target disappeared after the participants' response. The word

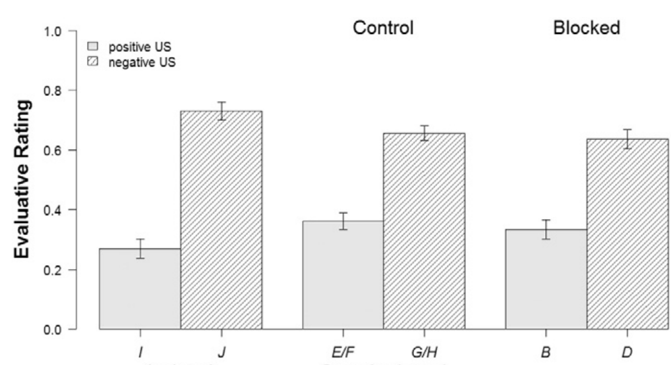

Fig. 4. Overshadowing and blocking effects on the evaluative ratings of individual CSs presented in Experiment 2 (0 = dislike, 1 = like).

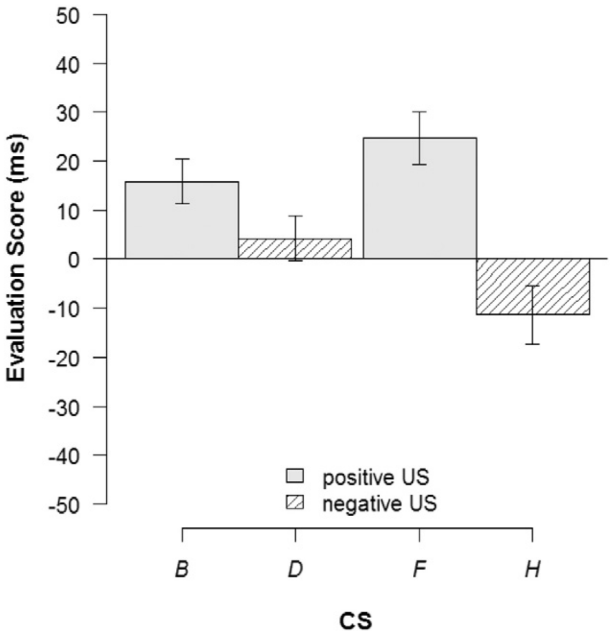

Fig. 5. Implicit evaluation scores ($RT_{neg.\ target} - RT_{pos.\ target}$) of the blocked (B, D) and control CSs (F, H) in Experiment 2, based on the response times in the affective-priming task.

'ERROR!' was presented on the screen (in red color) for 1000 ms if the response was incorrect. The next trial started after an intertrial interval of 500 ms. Each of the four CSs was presented three times prior to each of the 20 target words, resulting in a total of 240 trials. The order of the trials was randomized.

Finally, at the end of the experiment, participants were asked for evaluative and contingency judgments regarding each individual CS (see Experiment 1).

3.2. Results

3.2.1. Contingency learning

Again, the US predictions during the conditioning phase indicate successful contingency learning in Experiment 2 (see Fig. 2). The average accuracy of predictions (with a response deadline) increased from 50.5% correct ($SD = 50.0\%$) in the first block to 82.4% correct ($SD = 38.2\%$) in the last block. A 2 (presentation mode: isolated vs. compound) × 20 (block) repeated-measures ANOVA revealed a significant main effect of block, $F(19, 950) = 14.15$; $p < .001$; $\eta^2_G = 0.10$ (confirming the learning effect), and a marginally significant main effect of presentation mode, $F(1, 50) = 3.65$; $p = .062$; $\eta^2_G = 0.01$, suggesting that accuracy was higher for isolated CSs (75.1% correct for I and J) than for compound CSs (70.8% correct for EF and GH). There was no interaction between block and presentation mode, $F(19, 950) = 0.57$; $p = .93$.

The final contingency judgments also indicate that participants learned the CS–US contingencies: contingency ratings for CSs that predicted the smiling character were significantly higher ($M = 0.72$; $SD = 0.25$) than ratings of CSs that predicted the frowning character ($M = 0.26$; $SD = 0.25$), $t(50) = 12.28$; $p < .001$.

A 2 (US type) × 2 (presentation mode: isolated vs. overshadowed) repeated-measures ANOVA on the ratings revealed a significant main effect of US type, $F(1, 50) = 167.47$; $p < .001$; $\eta^2_G = 0.60$. More importantly, we also found a significant US type × presentation mode interaction, $F(1, 50) = 5.13$; $p = .028$; $\eta^2_G = 0.02$, indicating overshadowing (isolated CSs: $M_I = 0.20$; $SD_I = 0.21$ vs. $M_J = 0.76$; $SD_J = 0.24$; overshadowed CSs: $M_{EF} = 0.27$; $SD_{EF} = 0.25$ vs. $M_{GH} = 0.70$; $SD_{GH} = 0.25$). The main effect of presentation mode was not significant, $F(1, 50) < .01$; $p = .99$.

Another 2 (US type) × 2 (compound type) repeated-measures ANOVA testing for blocking effects also revealed a main effect of US type, $F(1, 50) = 95.89$; $p < .001$; $\eta^2_G = 0.43$, as well as a significant interaction with compound type, $F(1, 50) = 5.49$; $p = .023$; $\eta^2_G = 0.02$, indicating that differential contingency knowledge was weaker for blocked CSs ($M_B = 0.27$; $SD_B = 0.24$ vs. $M_D = 0.61$; $SD_D = 0.27$) than for control CSs (see above). There was no main effect of compound type, $F(1, 50) = 0.41$; $p = .53$.

3.2.2. Evaluative conditioning

The evaluative ratings of the crucial CSs are illustrated in Fig. 4. A 2 (US type) × 2 (presentation mode: isolated vs. overshadowed) repeated-measures ANOVA revealed a significant main effect of US type, $F(1, 50) = 90.28$; $p < .001$; $\eta^2_G = 0.45$, confirming an overall EC effect. More importantly, Experiment 2 also revealed a significant US type × presentation mode interaction on evaluative ratings, $F(1, 50) = 14.26$; $p \leq .001$; $\eta^2_G = 0.04$, indicating that overshadowing reduced the magnitude of EC. A Bayesian analysis of overshadowing effects on EC suggests that the alternative hypothesis (overshadowing) was about 1535.1 times more likely than the null hypothesis. There was no main effect of presentation mode on evaluative ratings, $F(1, 50) = 0.12$; $p = .73$.

The 2 (US type) × 2 (compound type) repeated-measure ANOVA on evaluative ratings also revealed a main effect of US type, $F(1, 50) = 68.00$; $p < .001$; $\eta^2_G = 0.33$, but no interaction with presentation mode, $F(1, 50) = .03$; $p = .86$. The Bayes factor indicates that the null hypothesis (no blocking) was 8.8 times more likely than the alternative hypothesis. There was no main effect of compound type, $F(1, 50) = 0.70$; $p = .41$.

The dissociation between evaluative and contingency ratings regarding blocking was further tested by a 2 (US type) × 2 (compound type) × 2 (rating: evaluative vs. contingency) repeated-measures ANOVA. This analysis revealed a significant 3-way interaction, $F(1, 50) = 4.69$; $p = .035$; $\eta^2_G = 0.01$, confirming that the magnitude of the blocking effect differed between contingency and evaluative ratings. The 3-way ANOVA also revealed significant main effects of US type, $F(1, 50) = 81.51$; $p < .001$; $\eta^2_G = 0.33$, and compound type, $F(1, 50) = 6.12$; $p = .017$; $\eta^2_G = 0.01$, as well as a US type × compound type interaction, $F(1, 50) = 5.69$; $p = .021$; $\eta^2_G = 0.01$.

The participants' response times in the affective priming task were used to obtain an additional implicit measure of EC. RTs from trials with incorrect responses as well as RTs greater than 1.5 interquartile ranges above the third quartile of the individual distribution were not included in the analysis of the affective-priming data. Data from participants with more than 25% of the trials being excluded were not included in the analysis (3 participants). For the remaining 48 participants, these criteria resulted in an exclusion of 13.9% of all trials.

Implicit evaluation scores were computed for each CS (B, D, F, and H) by subtracting the response times to positive target words preceded by the respective CS from the response times to negative target words preceded by the same CS. Positive evaluation scores indicate a positive evaluation of the respective prime (CS), whereas negative evaluation scores indicate negative evaluations (e.g., Gawronski, Walther, & Blank, 2005). A 2 (US type) × 2 (compound type: blocked vs. control) repeated-measures ANOVA on the implicit evaluation scores (see Fig. 5) revealed a significant main effect of US type, $F(1, 47) = 17.76$; $p < .001$; $\eta^2_G = 0.10$, confirming an implicit EC effect. More importantly, there was also a significant US type × compound type interaction, $F(1, 47) = 5.89$; $p = .019$; $\eta^2_G = 0.03$, indicating that the implicit EC was weaker for the blocked CSs B and D ($\Delta RT_{B-D} = 11.7$ ms) than for the control CSs F and H ($\Delta RT_{F-H} = 36.0$ ms). Post-hoc comparisons indicate that there was a significant implicit EC effect for control CSs, $t(47) = 4.38$; $p < .001$, but not for blocked CSs, $t(47) = 1.71$; $p = .09$. Thus, in contrast to the explicit evaluative ratings, implicit attitude measures seem to be affected by blocking. The ANOVA revealed no main effect of compound type, $F(1, 47) = 0.69$; $p = .41$. Post-hoc comparisons revealed that there was a significant EC effect for both blocked, $t(21) = 5.05$; $p < .001$, and control CSs, $t(21) = 6.52$; $p < .001$, though.

3.3. Discussion

In line with our first experiment, Experiment 2 provided further evidence for overshadowing in EC. That is, CSs that were trained alone produced greater changes in valence than CSs that were trained as compounds. In contrast, although blocking was again found to have no impact on explicit measures of EC, we did find blocking effects on contingency ratings. This dissociation suggests that contingency learning and EC may not necessarily be based on the same learning mechanism. The occurrence of a blocking effect on contingency judgments implies that the increased cognitive load during learning (due to the response deadline) may have affected certain inferences which in turn led to the acquisition of contingency knowledge. For instance, it might be speculated that a causal interpretation of the CS–US relationship resulted in a blocking effect (in line with, Sternberg & McClelland, 2012). The absence of a blocking effect on explicit EC measures, on the other hand, indicates that the change in valence was not based on the same inferences that yielded contingency knowledge.

Interestingly, we also found some indication of a blocking effect on the implicit valence measure. Specifically, an implicit EC effect was found only for control CSs, but not for blocked CSs. This finding might indicate that the absence of a blocking effect on the evaluative rating measure (which is the most typical index of EC effects) could be an artifact that is due to the operation of propositional processes at the time of testing (compare Gast, De Houwer, & De Schryver, 2012).

4. Experiment 3

The aim of Experiment 3 was to investigate whether EC is sensitive to cue competition if learning is based on simple association-formation processes. In line with Sternberg and McClelland (2012), we required participants to respond rapidly, thus providing little time for reflection or making inferences. This in turn should bias participants to learn the CS–US contingencies through an error-correcting, pathway-strengthening process. Previously, this type of learning was found to produce cue-competition in contingency learning regardless of whether or not the instruction promotes a causal interpretation (Sternberg & McClelland, 2012). Cue competition is thus also expected to moderate EC effects that are based on association strengthening, at least with regard to an implicit measure of valence which is not subject to inferential processes at a later stage.

4.1. Method

4.1.1. Participants

Twenty-two undergraduate students at the University of Wisconsin-Madison (6 women) were recruited to participate in Experiment 3. Ages ranged between 18 and 22 years ($M = 19.5$; $SD = 1.1$). The duration of the experimental session was about 45 min, and all participants were compensated with course credit.

4.1.2. Materials and procedure

Apparatus, materials and experimental design (see Table 1) were identical to Experiments 1 and 2. However, participants were given a different task during the learning stage. Each trial started with a central fixation cross for 250 ms. Then, the CS drawings (4° × 4°) were presented in the center for 350 ms, followed immediately by an outcome character (4° × 4° and randomly positioned at 3° eccentricity either above or below the center). The participants' task was to quickly respond to the character by pressing the left or right arrow key depending on whether the smiling or frowning character was presented (note that the position of the outcome character was task-irrelevant). Similar to Sternberg and McClelland's RT task, the response window started at 400 ms and decreased by 50 ms every 50 trials until a 200 ms response window was reached on trial 201. If participants pressed a key within the response window, a feedback ('CORRECT' or 'WRONG') was presented on the screen together with the actual RT (in ms). If no response was given within the response window, a text message was prompted on the screen ('BE FASTER!'). Each type of trial was presented on 50 trials in random order, resulting in a total of 400 learning trials.[3] Participants were not explicitly instructed to learn the CS–US contingencies. Knowledge about the contingencies, however, would obviously help participants to respond more quickly.

The learning stage was followed by evaluative ratings, and contingency ratings, which were conducted in the same way as in Experiments 1 and 2. The rating phase was followed by an affective priming task (identical to Experiment 2) to obtain an additional implicit measure of CS evaluations.[4]

4.2. Results

4.2.1. Contingency learning

The response times during the conditioning phase can be used as a measure of contingency learning in the RT task of Experiment 3. Collapsing across different types of trials, the average RT decreased from $M = 316$ ms ($SD = 63$ ms) in the first block of 20 trials to $M = 97$ ms ($SD = 56$ ms) in the last block of 200 trials (see Fig. 2; note that the response deadline decreased from 400 to 200 ms). Overshadowing effects were tested by comparing the RTs on trials with isolated cues (I and J) and compound cues (EF and GH). A 2 (presentation mode) × 20 (block) repeated-measures ANOVA, however, revealed only a significant block effect, $F(19, 399) = 126.19$; $p < .001$; $\eta^2_G = 0.71$, but no significant main effect of presentation mode, $F(1, 21) = 1.13$; $p = .30$ ($M_{I/J} = 147$ ms; $M_{EF/GH} = 150$ ms). There was also no interaction between block and presentation mode, $F(19, 399) = 0.74$; $p = .78$. The accuracy of responses during the RT task increased significantly from the first (53% correct) to the last block (66.3%) of the learning phase (note that the low accuracy was due to the high number of missed responses: no response was given prior to the deadline in 39% of the trials), $F(19, 399) = 1.67$; $p = .039$; $\eta^2_G = 0.03$, but it was not subject to an overshadowing effect, as indicated by the absence of a main effect of presentation mode, $F(1, 21) = 2.21$; $p = .15$. There was no interaction with regard to accuracy, $F(19, 399) = 0.70$; $p = .81$.

The contingency judgments at the end of Experiment 3 further indicate that the participants acquired knowledge about the CS–US contingencies (even though participants were not explicitly instructed to learn these contingencies). The contingency ratings of drawings that preceded a frowning character ($M = 0.82$; $SD = 0.26$) were significantly higher than those of drawings that preceded a smiling character ($M = 0.16$; $SD = 0.27$), $t(21) = 10.25$; $p < .001$.

The 2 (US type) × 2 (presentation mode) repeated-measures ANOVA on the subsequent contingency ratings (CSs E, F, G, H, I, and J), however, revealed both a significant main effect of US type $F(1, 21) = 115.59$; $p < .001$; $\eta^2_G = 0.72$ as well as an interaction with presentation mode, $F(1, 21) = 8.09$; $p = .009$; $\eta^2_G = 0.05$, with greater differentiation for isolated CSs ($M_I = 0.12$; $SD_I = 0.23$ vs. $M_J = 0.89$; $SD_J = 0.22$) than for CSs that were trained as part of a compound ($M_{EF} = 0.18$; $SD_{EF} = 0.28$ vs. $M_{GH} = 0.75$; $SD_{GH} = 0.30$). There was no main effect of presentation mode, $F(1, 21) = 1.39$; $p = .25$.

Moreover, with regard to the blocking effect, a 2 (US type) × 2 (compound type) repeated-measures ANOVA on the contingency ratings of B, D, F, and H confirmed the main effect of US type, $F(1, 21) = 90.42$;

[3] Due to the RT-based contingency learning task, more trials were required in Experiment 3 in order to reach the same total presentation time and the same level of contingency learning as in the conditioning phases in Experiments 1 and 2 (see Fig. 2). Moreover, a greater number of trial repetitions was required to analyze contingency learning effects on an RT measure (compare Sternberg & McClelland, 2012; employing 24 trial repetitions in the prediction and 72 trial repetitions in the RT task).

[4] Note that, in contrast to Experiment 2, the affective priming task was conducted after the explicit ratings in order to rule out any influences of the additional stimulus presentations and pairings (i.e., CSs paired with positive and negative words) on the evaluative ratings.

$p < .001$; $\eta^2_G = 0.65$, but did not reveal an interaction with compound type, $F(1, 21) = 1.25$; $p = .28$ ($M_B = 0.14$; $SD_B = 0.24$ vs. $M_D = 0.81$; $SD_D = 0.27$), thus providing no any evidence for blocking in contingency judgments. There was also no main effect of compound, $F(1, 21) = 0.05$; $p = .81$.

4.2.2. Evaluative conditioning

Fig. 6 depicts the evaluative ratings of the crucial CSs that were presented during the learning phase. A 2 (US type) × 2 (presentation mode: isolated vs. overshadowed) repeated-measures ANOVA revealed a significant EC effect for the CSs F, H, I, and J, $F(1, 21) = 6.00$; $p = .024$; $\eta^2_G = 0.06$. However, there was no interaction with presentation mode, $F(1, 21) = 0.32$; $p = .57$, indicating that overshadowing did not affect EC in Experiment 3. The Bayes factor suggests that the null hypothesis (no overshadowing) was about 4.7 times more likely than the alternative hypothesis. There was no main effect of presentation mode, $F(1, 21) = 0.02$; $p = .87$.

The dissociation between EC and contingency knowledge regarding overshadowing was further tested by a 3-way ANOVA, revealing a significant 3-way interaction between US type, presentation mode, and rating type (evaluative vs. contingency), $F(1, 21) = 5.58$; $p = .028$; $\eta^2_G = 0.02$. This interaction suggests that overshadowing moderated contingency knowledge more than EC. The ANOVA further revealed a significant main effect of US type, $F(1, 21) = 71.61$; $p < .001$; $\eta^2_G = 0.41$, and a significant interaction between US type and presentation mode, $F(1, 21) = 58.19$; $p < .001$; $\eta^2_G = 0.24$.

Another 2 (US type) × 2 (compound type) repeated-measures ANOVA on the ratings of B, D, F, and H also revealed a significant EC effect, $F(1, 21) = 13.00$; $p = .002$; $\eta^2_G = 0.15$, but no interaction, $F(1, 21) = 0.31$; $p = 0.58$. According to Bayesian analysis, the null hypothesis (no blocking) was 4.7 times more likely than the alternative hypothesis. There was no significant main effect of compound type, $F(1, 21) = 2.05$; $p = 0.17$.

Implicit evaluation scores were calculated from the affective priming data in the same way as in Experiment 2. 16.6% of all trials were excluded due to outliers or incorrect responses. The implicit evaluations of B, D, F, and H are depicted in Fig. 7. A 2 (US type) × 2 (compound type) repeated-measures ANOVA on these scores revealed a main effect of US type, $F(1, 21) = 66.38$; $p < .001$; $\eta^2_G = 0.38$, and a significant interaction between compound type and US type, $F(1, 21) = 5.40$; $p = .030$; $\eta^2_G = 0.04$, suggesting that the implicit EC effect was more pronounced for control CSs ($\Delta RT_{F-H} = 70.3$ ms) than for blocked CSs ($\Delta RT_{B-D} = 39.7$ ms).

4.3. Discussion

In Experiment 3, we sought to inhibit inferential learning by having participants respond to the USs under high time pressure. And indeed, it is clear that this change markedly altered the learning process. First, the overall magnitude of EC in Experiment 3 was smaller than in Experiments 1 and 2 (in which participants predicted the USs during conditioning), suggesting that inferential learning may lead to stronger EC effects than association-strengthening. Moreover, in contrast to Experiments 1 and 2, having participants conduct a fast-paced RT task during learning did not produce overshadowing effects on EC. This indicates that the sensitivity of EC to cue competition may depend on the availability of cognitive resources during learning that allow inferences about the CS–US relationship to be drawn. However, while the fast-paced RT task eliminated overshadowing in EC, it did not eliminate overshadowing effects on contingency learning. Experiment 3 thus provides additional support for the assumption that EC and contingency learning are not necessarily based on the same learning process (e.g., a propositional one; De Houwer, 2009). Consistent with the two previous experiments (and in line with most previous studies; e.g. Beckers et al., 2009; Laane et al., 2010), the evaluative ratings did not also provide any evidence of blocking, suggesting that EC may (under some circumstances) be more sensitive to certain simple forms of cue competition (i.e., overshadowing), than to other more indirect forms of cue competition (i.e., blocking). This issue will be discussed in depth below.

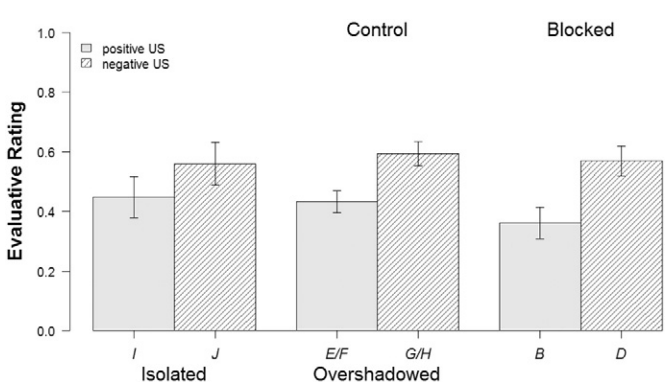

Fig. 6. Overshadowing and blocking effects on the evaluative ratings of individual CSs presented in Experiment 3 (0 = dislike, 1 = like).

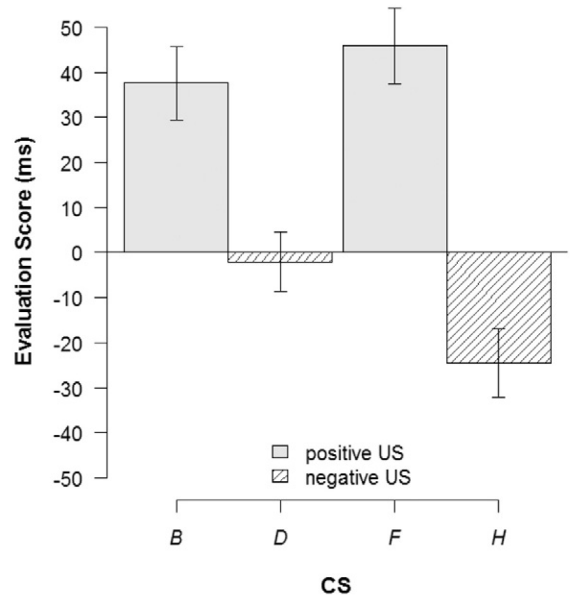

Fig. 7. Implicit evaluation scores ($RT_{neg.\ target} - RT_{pos.\ target}$) of the blocked (B, D) and control CSs (F, H) in Experiment 3, based on the response times in the affective-priming task.

Finally, Experiment 3 also replicated the dissociation between explicit and implicit measures of EC regarding the blocking effect. That is, the implicit measure of EC did provide evidence of blocking, whereas the explicit evaluative ratings did not. This suggests that implicit evaluations might be sensitive to different processes than explicit (verbal) evaluations. For instance, additional inferences that are drawn at the time of testing (e.g., based on explicit contingency knowledge) might have a strong effect on explicit evaluative ratings, but not on implicit evaluations, and they could potentially have worked against a blocking effect on the explicit measure.

While the fast-paced RT task used in Experiment 3 certainly constrained the cognitive resources available during learning, it is unclear whether participants acquired "awareness" of the CS–US contingency while performing the RT task. Since contingency awareness during conditioning can be seen as an indicator of propositional learning (De Houwer, 2009), it could be argued that the RT task did not fully prevent participants from drawing inferences about the predictive relations between CSs and USs. Even though participants were not explicitly instructed to learn the contingencies, it was certainly helpful to pay attention to the predictive stimuli (the CSs) in order to quickly respond to the USs. And consistent with this, the subsequent contingency judgments show that participants indeed learned the contingencies by the end of the learning phase. However, we argue that it is most likely the case that the contingencies were learned through association-strengthening based on error-correction processes operating in neural circuits that are not penetrated by verbal propositional knowledge (Sternberg & McClelland, 2012). Even though this assumption cannot be tested based on the present data, it seems reasonable to surmise that it would require more time and mental resources to draw inferences on the basis of the evidence provided during a single trial of the learning task (i.e., short presentations of CSs and USs). Nevertheless, inferential learning could still have taken place on a between-trial basis, even though the short presentation times prevented inferences within a given trial. Thus, while we cannot rule out the possibility that the observed dissociations with regard to overshadowing may not be due to different underlying learning processes, it is unclear what alternative hypotheses would account for the full pattern of the present results. To better clarify this point, it would be worthwhile for future research to directly test whether overshadowing can be modulated by experimentally reducing contingency awareness during a prediction task (e.g., by means of a secondary task).

5. General discussion

5.1. Summary of results

Previous studies provided mixed evidence regarding the occurrence of cue competition in evaluative learning. Dwyer et al. (2007), for instance, did not observe overshadowing effects with food stimuli, whereas Walther et al. (2011) reported that changes in the liking of brands may be affected by overshadowing. Similarly, while there are many studies failing to find evidence of blocking in EC (e.g., Beckers et al., 2009; Laane et al., 2010), Tobler et al. (2006) did observe blocking effects on pleasantness ratings. These inconsistencies indicate that the boundary conditions enabling cue competition to affect EC are yet to be defined. The present study addressed this issue by investigating both overshadowing and blocking as a function of the specific learning process that drives the affective transfer. To this end, we examined EC effects in the context of different tasks designed to either enable or suppress the CS–US contingency knowledge being acquired through inferential learning.

We found that tasks that encourage inferential learning lead to robust overshadowing effects on both contingency learning and explicit EC (Experiments 1 and 2), whereas tasks designed to bias toward association strengthening results in overshadowing effects on contingency learning, but not on EC (Experiment 3). Moreover, blocking effects were found on the contingency-learning measure, but not on explicit measures of EC (in all experiments). Interestingly, implicit EC measures also showed some evidence of blocking (Experiments 2 and 3). These results suggest that (a) EC is, in principle, sensitive to cue competition (e.g., demonstrating overshadowing effects when based on inferential learning), (b) implicit measures of EC are potentially more sensitive to certain forms of cue competition than explicit measures, and (c) contingency learning and EC differ in terms of their sensitivity to cue competition, implying a dissociation in terms of the underlying learning processes. These conclusions will be discussed separately in the following sections.

5.2. Cue-competition effects on EC

In Experiments 1 and 2, participants were asked to learn the contingencies by predicting the US on each trial. This task was designed to bias participants toward inferential learning, and it produced reliable overshadowing effects on EC. That is, stronger EC effects were observed for CSs that were trained alone, as compared to CSs that were trained as part of a compound. Our finding thus clearly deviates from previous EC research finding no evidence of overshadowing (Dwyer et al., 2007). This discrepancy might be due to different types of learning processes driving the change in CS evaluations. Specifically, Dwyer et al. (2007) instructed their participants to merely count the number of CS occurrences during conditioning, but not to learn the CS–US contingencies. Learning may thus not have occurred on the basis of relational inferences (e.g., 'that certain CSs would predict the US'), but rather have been due to incidental association strengthening. In contrast, the first two experiments of the present investigation suggest that a task, which encourages participants to draw inferences about the predictive relationship between CSs and USs, does elicit overshadowing effects on EC.

In contrast to the first two experiments of the present study, participants in Experiment 3 were not explicitly instructed to learn the predictive CS–US relations, but were instead asked to rapidly respond to the occurrence of the US. As there was little time to reflect and make inferences in this task, the contingencies should thus have been learned largely through quick association-formation processes (compare Sternberg & McClelland, 2012; see the discussion of Experiment 3 for limitations). This incidental learning task also produced robust overall EC effects (though smaller than in Experiments 1 and 2), but it did not reveal any indication of overshadowing. If anything, descriptively the EC effect was even smaller for CSs that were trained in isolation than for CSs that were trained in compounds. This observation is perfectly in line with previous research on overshadowing (Dwyer et al., 2007), arguing that EC *can* be based on simple association strengthening resulting from repeated co-occurrences of the CS and the US (and thus not being sensitive to contingency manipulations and cue competition; c.f. Baeyens & De Houwer, 1995).

Moreover, none of our experiments provided evidence for blocking effects on explicit evaluative ratings. This null finding is in line with the vast majority of previous studies on blocking in EC (e.g., Beckers et al., 2009; Laane et al., 2010; Walther et al., 2011). Thus, there seem to be discrepancies between different types of cue competition. Blocking, of course, is a much more "indirect" form of cue competition than overshadowing. Specifically, the processing of a stimulus should be influenced by contingency information regarding a co-occurring stimulus, information which necessarily has to be picked up across different trials. The present data show that even inferential learning does not necessarily produce indirect cue-competition effects on explicit stimulus evaluations. In other words, "inferential EC" seems to be more sensitive to direct forms of cue-competition like overshadowing (i.e., cue competition occurring when a CS is "directly" experienced as part of a compound) than to indirect cue-competition effects like blocking (i.e., cue competition based on information that is being gathered on separate trials). This might be due to the fact that direct cue competition may provide for less ambiguous inferences than indirect cue competition. For instance, with regard to overshadowing, an inference-based EC effect might be weaker for co-occurring CSs than for isolated CSs because most participants draw certain inferences from their knowledge about the CS–US pairings (e.g., 'that two CSs together have the same affective value as another CS alone'). A blocking procedure, in contrast, may cause less homogeneous inferences across different individuals and thus not necessarily lead to a systematic effect on stimulus evaluations. Alternatively, a divided-attention account might also be able to explain overshadowing effects on EC. Previous studies indicate that EC can be modulated by attention (e.g., Blask, Walther, Halbeisen, & Weil, 2012; Field & Moore, 2005; Kattner, 2012; Pleyers, Corneille, Yzerbyt, & Luminet, 2009). Since co-occurring CSs may receive less attention than CSs that are presented alone, the weaker EC effect for overshadowed CSs could also be due to a lack of attention. However, as attention was not manipulated experimentally in the current study, the data do not allow us to distinguish between an inferential and an attentional account of overshadowing. Moreover, with an attentional account of overshadowing, it would be difficult to explain why divided attention did not have an effect on EC in Experiment 3.

Taken together, the observed discrepancies in cue competition as a function of the learning task indicate that there may be different types of EC effects. In particular, EC effects that are based on contiguity-based association strengthening (Baeyens & De Houwer, 1995) do not seem to be affected by cue competition (see Experiment 3 and Dwyer et al., 2007), whereas another form of affective transfer that is based on inferential learning (De Houwer, 2009) may be modulated by certain types of cue competition (see Experiments 1 and 2).

5.3. Divergence of implicit and explicit measures of EC

There is some indication in Experiments 2 and 3 that implicit measures of EC were moderated by blocking. In both experiments, smaller implicit EC effects were observed for the blocked CSs (B and D), as compared to control CSs (F and H). In Experiment 2, the implicit EC effect for blocked CSs even failed to reach significance (in contrast to the EC effect for control CSs). Implicit measures of EC might thus be more sensitive to blocking than explicit ratings. This suggests that stimulus evaluations per se may actually be sensitive to indirect cue competition effects like blocking, but explicit pleasantness ratings might not be an appropriate means to register these subtle effects (e.g. due to the heterogeneity of inferences or additional inferences about the CSs that are drawn during testing; e.g., Gast, De Houwer, & De Schryver, 2012). On the other hand, though further research is certainly required to substantiate this assumption, the present data suggest that implicit EC effects are sensitive to blocking regardless of whether the affective transfer is based on inferential learning (Experiment 2) or association strengthening (Experiment 3).

One reservation regarding the implicit measure used in the present study refers to the similarity between the learning task and affective-priming task. Particularly in Experiment 3, participants quickly categorized a stimulus that was preceded by a CS, depending on its affective value in both tasks (either the US or the target word). Even though simple stimulus–response learning was unlikely, due to orthogonal response-key mappings (up/down in the learning task, and left/right in the affective-priming task), the overall implicit EC effect may have been amplified by previous stimulus mappings. This might explain why we found comparatively large implicit EC effects (about 30–60 ms RT difference), relative to other studies using an affective-priming task (20–30 ms RT difference; e.g., Gast & Rothermund, 2011a,b). Nevertheless, the modulation of the implicit EC effect suggests that blocking did affect the implicit CS evaluations.

5.4. Discrepancy between EC and contingency learning

In line with Laane et al. (2010), the current investigation also provided further evidence for a dissociation between EC and contingency learning regarding the occurrence of cue competition. First, in our data cue competition had more impact in general on contingency learning than on EC. Both the concurrent US predictions and the post-learning contingency judgments demonstrated robust overshadowing and blocking effects (only in Experiment 3, there was no blocking effect on contingency judgments), whereas evaluative ratings were (a) sensitive to overshadowing only when cognitive resources for inferential learning were available, and (b) totally insensitive to blocking. As outlined by Laane et al. (2010), the absence of blocking in EC suggests that this form of learning is characterized by a lack of cue competition and a contiguity-based learning mechanism (e.g., in line with the referential account of EC; Baeyens & De Houwer, 1995). The present study lends support to this assumption with regard to indirect cue competition effects (i.e., blocking was found for contingency learning, but not for EC). On the other hand, the occurrence of overshadowing effects when cognitive resources are available implies that the (explicit) liking of a stimulus can be shaped by more direct forms of cue competition if the individual is able to draw certain inferences about the CS–US contingency. When learning was based on quick association strengthening, however, overshadowing effects were observed for contingency learning but not for EC.

Altogether, these findings suggest that EC and the acquisition of contingency knowledge may not necessarily be based on the same learning mechanism. More precisely, indirect cue competition effects on EC seem to especially depend on the availability of cognitive resources (suggesting inferential learning), whereas cue competition effects on the acquisition of contingency knowledge may be based on association strengthening. The present results are probably best explained by assuming that the EC effect can be due to very different learning processes (De Houwer, 2007). That is, an affective transfer can occur (a) as a result of resource-demanding inferences about the relationship between CS and US or (b) as a result of association strengthening processes that require less cognitive resources. Cue competition effects on EC seem to be driven mainly by inferential learning. Cue competition effects on contingency learning, on the other hand, were much less susceptible to the manipulation of the learning process. This discrepancy suggests that EC and contingency learning are not necessarily based on the same mechanism. The dissociation between EC and contingency learning with regard to blocking, for instance, suggests that evaluative learning, in contrast to contingency learning, does not depend on the CS–US contingency (see Kattner, 2014). Unlike other forms of conditioning, EC might rather be based on the contiguity between CS and US (Baeyens & De Houwer, 1995).

5.5. Conclusions

The present study provided evidence for cue competition in EC being dependent on the underlying learning process. Overshadowing was demonstrated when EC was based on inferential learning, but not when it was based on fast association strengthening. Blocking, in contrast, was not found to have any effect on explicit evaluative ratings, regardless of the learning process. This suggests that explicit EC is more sensitive to certain direct forms of cue competition than to indirect cue competition. However, modulations of the implicit EC effect suggest that indirect cue competition may also have a subtle effect on stimulus evaluations, regardless of the underlying learning process. Even though further research is needed to rule out alternative explanations of the blocking effect on implicit evaluations, this result questions the use of explicit ratings as the common (and exclusive) measure to test cue competition effects in EC (e.g., Beckers et al., 2009; Dwyer et al., 2007; Laane et al., 2010; Tobler et al., 2006). Finally, dissociations were found between both concurrent and post-conditioning measures of contingency learning and EC, in that cue competition effects on contingency learning do not necessarily transfer to stimulus evaluations. Taken together, the present data strongly suggest that affective transfer is not a homogeneous phenomenon, but may instead result from various learning processes exhibiting different functional characteristics, with some of them being more sensitive to cue competition than others.

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