Competition between Conditioned Stimuli in Evaluative Conditioning

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ABSTRACT

Evaluative conditioning (EC) is a change in the evaluation of a stimulus (CS) after the stimulus co-occurred with positive stimuli (US_{pos}) or negative stimuli (US_{neg}). Using different designs, three experiments paired one CS (CS_1) with a US and examined whether EC decreased when the US also occurred with CS_2. The experiments found that sharing a US with another CS decreased EC, although Experiment 2 found that effect only for a CS that occurred with US_{pos} and not for CS that occurred with US_{neg}. Experiments 2 and 3 refuted the alternative account that the EC of CS_1 is moderated by any additional occurrences of the US without CS_1, rather than by the occurrences of the US with CS_2. Together, these results suggest that cue-competition decreases EC when two CSs occur separately with the same US. We discuss two possible accounts for the finding: a contrast effect on judgment and competition on mental resources. We argue that current EC theories are limited in explaining the present finding because they are missing explicit assumptions about what influences evaluative response.

Keywords: Evaluative Conditioning, Evaluative Learning, Cue-competition, Contrast effect, Evaluation

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Evaluating objects as positive or negative helps humans guide their behavior and thought to maximize satisfaction and minimize misery. Because likes and dislikes have a large influence on human behavior, researchers study the factors that influence evaluative judgment. One simple factor that has been found to influence evaluation is the co-occurrence of the target object with other stimuli. People tend to like objects that co-occurred in the past with positive stimuli and dislike objects that co-occurred with negative stimuli. This effect is Evaluative Conditioning (EC; De Houwer, 2007).

It is easy to implicate EC as a contributor to almost any evaluative learning event. For instance, if a neighbor helps Jane to cook a meal, Jane might use many high-level judgment processes to conclude that the neighbor is positive, but Jane's evaluation might also be sensitive to the mere co-occurrence of the neighbor (or the mental representation of the neighbor) with many positive concepts (the abstract concept *help*, the pleasant taste of the meal, the positive feeling of relief that the meal is ready, and so on). Because almost any evaluative information about an object involves co-occurrence between the object and valence, EC is probably a central factor in evaluative learning (for reviews, see De Houwer, Thomas, & Baeyens, 2001; Walther, Weil, & Langer, 2011). The present experiments extend EC research by investigating the effects of pairing two objects with the same affective stimuli. Specifically, we investigated whether the effect of the co-occurrence of one object (the conditioned stimulus; CS) with a positive or a negative stimulus (the unconditioned stimulus; US) on the evaluation of the CS is moderated by the co-occurrence of another CS with the same US.

The present research question has practical and theoretical importance. Practically, insensitivity of EC to such cue-competition would suggest that people who want to use co-occurrence with affective stimuli to increase or decrease liking toward a specific object should not worry themselves with the co-occurrences of other objects with affective stimuli. On the other hand, if cue-competition influences EC, then control on the co-occurrence of other objects with affective stimuli is important. For instance, a student who plans to win her teacher's affection by co-occurring as often as possible with a smile may also benefit from preventing other students to appear smiling in front of the teacher.

From a theoretical standpoint, the possibility that EC of one CS is sensitive to the co-occurrence of another CS with USs would suggest that EC is not the result of mere contiguity—an assumption that had hardly been contested so far (for an exception, see Purkis & Lipp, 2010). Currently, it is commonly assumed that only the co-occurrence with the US is important for the transfer of affect from the US to the CS. This assumption fits most of the theories that have been proposed to explain EC (De Houwer et al., 2001; Hofmann et al., 2010). If cue-competition moderates EC, then most current theories would require some update.

Almost all existing theories for EC propose a mechanism that operates with each CS-US co-occurrence, rather than a more global process that considers the overall schedule of stimuli co-occurrence in the learning context. According to the *holistic account* (Martin & Levey, 1978, 1994), the CS-US co-occurrence forms a holistic representation that represents both stimuli in a single representation. Then, EC occurs because the CS activates that holistic representation, including the evaluative aspects of the US. According to the *referential account* (Baeyens, Eelen, Crombez & Van den Bergh, 1992), each CS-US co-occurrence contributes to the formation of an association between the two, until the CS activates the mental representation of the US, including the US's valence. Baeyens et al. (1992; Baeyens, Hermans & Eelen, 1993) argued that this referential mechanism is based on mere co-occurrence – each co-occurrence strengthens the association based on a simple Hebbian algorithm that is sensitive only to temporal contiguity and stimulus salience (Beckers, De Vick, & Baeyens, 2009). According to the *implicit misattribution account* (Jones, Fazio, & Olson, 2009), EC occurs because people attribute to the CS the affective reaction that was elicited by the US. It follows from this account that only the CS-US co-occurrence is responsible for the change in evaluation of the CS, and co-occurrences of another CS with the same US should have no impact on the EC.

The holistic, referential and implicit misattribution accounts all describe EC as a result of an incremental process that occurs separately with each additional CS-US co-occurrence. From that description, sensitivity of EC of one CS to the co-occurrence of another CS with the US is not a straightforward assumption. It requires an additional assumption that allows for changes in the CS evaluation as a result of an event that does not include the CS at all. The propositional account for EC (De Houwer, 2009) is more compatible with considerations that go beyond each separate CS-US co-occurrence because it contends that EC is the result of a belief in the proposition that the CS and the US co-occur. It seems reasonable to assume that endorsement of such a belief may require a broad view on the learning context and the schedule of stimuli co-occurrence in that context. Furthermore, the translation of the belief that a CS co-occurs with a US to a change in the evaluation of the CS (i.e., the EC effect) is not straightforward (Baeyens, Vansteenwegen, & Hermans, 2009; Shanks ,2007), and may be sensitive to other information—including the co-occurrence of the US with another CS. For instance, a person might evaluate six co-occurrences of CS_1 with a positive US (US_{pos}) as a more positive attribute of CS_1, if CS_2 appears only two times with USpos than if CS_2 appears 20 times with US_{pos}. However, like the other EC accounts, the propositional account did not explicitly predict sensitivity to cue-competition. Therefore, if the present research finds that the EC of one CS can be moderated by the co-occurrences of another CS with the same US, all EC theories will need to make additional assumptions to explain this effect.

Blocking and Overshadowing

Researchers of learning have studied several phenomena that involve the co-occurrence of two CSs with the same US. The large majority of these phenomena involved the co-occurrence of the US with a compound stimulus comprised of two different CSs. The co-occurrence of a CS_1CS_2 compound with the US is called *overshadowing*, and it often results with a weaker conditioned response to each of the CSs in comparison to the response observed when the CS occurs alone with the US (Mackintosh, 1974; Pavlov, 1927). Reduction in the conditioned response is also the typical result of *blocking* (Kamin, 1969), a procedure that adds CS_2-US co-occurrences before or after the CS_1CS_2-US co-occurrences (the reduction is in comparison to a condition that did not add CS_2-US co-occurrences).

There are only a few studies that examined blocking and overshadowing in EC (Beckers, De Vicq, & Baeyens, 2009; Dwyer, Jarratt, & Dick, 2007; Lipp, Neumann, & Mason, 2001; Purkis & Lipp, 2010; Walther, Ebert, & Meinerling, 2011). Most of these experiments failed to find strong evidence for reduced evaluative response. Dwyer, Jarratt, and Dick (2007) presented food images (the CSs) with images of obese (US_{neg}) or normal body (US_{pos}) shapes. Some CSs always occurred with another CS and with the US (an overshadowing condition), whereas other CSs occurred only with the US (control condition). Participants preferred food images that co-occurred with normal body shapes than food images that co-occurred with obese body shapes.

This EC effect was equally strong in the overshadowing and the control conditions, providing no evidence of overshadowing.

In a study on blocking, Beckers, De Vicq, and Baeyens (2009) paired symbol strings (CSs) with gain (US_{pos}) or loss (US_{neg}) of candy (the participants were children). Twenty trials paired the CS_{pos} with a CS_1CS_3 compound stimulus, and another 20 trials paired the US_{neg} with a CS_2CS_4 compound stimulus. In the blocking condition, these 40 trials were preceded with 20 CS_3-US_{pos} co-occurrences and 20 CS_4-US_{neg} co-occurrences. In the control condition, the 40 trials were preceded with 20 CS_5-US_{pos} co-occurrences and 20 CS_6-US_{neg} co-occurrences. Blocking would have caused a weaker EC effect in the blocking than in the control condition. However, both conditions showed an EC effect of a similar strength, failing to find any evidence of blocking.

In another research, Walther, Ebert, and Meinerling (2011) found some evidence suggesting overshadowing. Participants observed CSs of three types that co-occurred with the USs (liked and disliked people). The three types were: a brand name, a product image, and a compound of brand+product. Walther et al. found EC on single CSs (brand names that co-occurred with a US, and product images that co-occurred with a US) but not on compound stimuli. However, deviating from standard overshadowing procedures, participants in that experiment evaluated each compound stimulus as a whole, and did not provide separate ratings of each CS in the compound. To fix that, Walther et al. used the same stimuli in another experiment that tested the sensitivity of EC to blocking. In that experiment participants provided separate rating of each CS, even if it appeared in a compound stimulus during learning. That experiment found no evidence of blocking.

Finally, Purkis and Lipp (2010; see also Lipp, Neumann, & Mason, 2001) tested a variation of soperconditioning with EC. In superconditioning (Rescorla, 1971, 2004), the response to the target CS (CS_1) that is paired with the US as a part of a compound stimulus (i.e., CS_1CS_2-US co-occurrences) is stronger if the other CS in the same compound (CS_2) was previously paired with no-US. In close parallel to that design, Purkis and Lipp (2010) paired two shape stimuli (CS_1 and CS_2) as a part of a compound stimulus (CS_1CS_3 and CS_2CS_4) with happy faces (US_{pos}). The other stimulus in the compound was either paired earlier with an angry face (CS_3US_{neg}) or did not appear earlier (no previous CS_4 occurrences). It was found that the stimulus that appeared in a compound stimulus with another CS that was earlier paired with the opposite US was preferred over the CS that appeared with a CS that did not appear in the past (i.e., CS_1 was preferred over CS_2). This may suggest cue-competition because the CS was not judged only according to its co-occurrences with USs, but also according to the co-occurrence of another CS with USs.

In summary, cue-competition in EC was tested with designs that paired compound CSs with USs. Most of these studies found no evidence of cue-competition. Therefore, so far, there is little evidence that the EC of one CS is moderated by the co-occurrence of another CS with USs.

Separate Pairing of Two CSs with the Same US

Although the present research question pertains to cue-competition, it does not pertain to compound stimuli. Rather, the present question is whether the influence of the co-occurrence of one CS with US on the evaluation of that CS can be moderated by the co-occurrence of another CS, separately, with the same US. In a previous study, Bar-Anan and Dahan (2013) found initial evidence for such moderation. CS_1 (an alien creature) appeared eight times with US_{pos} (pleasant music) and eight times with US_{neg} (unpleasant scream). The co-occurrence schedule of CS_2

(another alien creature) was manipulated between participants. Half of the participants experienced 16 CS_2-US_{pos} co-occurrences and half experienced 16 CS_2-US_{neg} co-occurrences. The evaluation of CS_1 was more positive when CS_2 co-occurred with US_{neg} than when CS_2 co-occurred with US_{pos}. That finding was not the result of a general shift in evaluative standards: it did not affect the evaluation of a third stimulus (alien creature) or the evaluation of the USs. It seems that the co-occurrence of CS_1 with affective stimuli influenced its evaluation but this influence was sensitive to (i.e., moderated by) the co-occurrence of CS_2.

The purpose of the present research was to follow Bar-Anan and Dahan's (2013) initial evidence that EC is sensitive to cue-competition. First, we sought for more evidence that the EC of one CS is sensitive to co-occurrence of another CS with USs. In Bar-Anan and Dahan's experiment, the focus was on a CS that co-occurred an equal number of times with US_{pos} and US_{neg}. However, typical EC research has investigated the effect of the co-occurrence of a CS with a US of one valence. Therefore, in the present research (Experiments 2 and 3), we tested whether the effect of the co-occurrence of a CS with a single US on the evaluation of the CS is sensitive to the co-occurrences of another CS with the same US.

The second purpose of the present research was to distinguish between two factors that could explain the sensitivity of the EC of one CS to additional occurrences of the US with another CS. Specifically, we tested whether such sensitivity reflects sensitivity to cue-competition or a more general sensitivity to statistical contingency. In simple terms, if we find that EC of CS_1 decreases when the US that occurs with CS_1 also occurs with CS_2, then the reason could be the CS_2-US *co-occurrences* (cue-competition) or simply the additional occurrences of the US without CS_1 (a change in the CS_1-US statistical contingency).

Rescorla (1968) defined contingency as the probability of an occurrence of a US in the presence of a CS contrasted with the probability of US occurrence in the absence of the CS. If in eight out of 16 times that a CS occurred the US_{pos} also occurred, and the US_{pos} never occurred without the CS—then the contingency is the probability of US occurrence when CS occurs contrasted from the probability of US occurrence when the CS is absent (50% – 0% = 50%).

Sensitivity to statistical contingency can explain Bar-Anan and Dahan's (2013) previous finding. That experiment presented 48 trials: 16 with CS_1, 16 with a filler stimulus, and 16 with CS_2. CS_1 always co-occurred eight times with US_{pos} and eight times with US_{neg}. A filler stimulus always appeared 16 times with no US. The manipulation varied the number of additional occurrences of the USs. CS_2 co-occurred 16 times with the US_{neg} or 16 times with the US_{pos}. When CS_2 co-occurred with US_{neg}, the CS_1-US_{neg} contingency was 8/16 – 16/32 = 0%, and the CS_1-US_{pos} contingency was 8/16 – 0/32 = 50%. When CS_2 co-occurred with the US_{pos}, the contingencies of CS_1 with US_{neg} (50%) and US_{pos} (0%) were the opposite. Therefore, Bar-Anan and Dahan's result can be construed as an effect of contingency on EC. When CS_1 had a stronger contingency with US_{pos} than with US_{neg} it was liked more than when it had stronger contingency with US_{neg} than with US_{pos}. Like cue-competition, the possibility that statistical contingency influences EC is largely incompatible with EC theories and past evidence (De Houwer et al., 2001). However, in a meta-analysis of EC, Hoffmann et al. (2010) concluded that there is still very little evidence that pertains to the role of contingency in EC.

As already noted, it is also possible to explain Bar-Anan and Dahan's previous finding with a cue-competition account. That account contends that when CS_2 co-occurred with US_{pos} it competed with CS_1 on the association with US_{pos} and no stimulus competed with CS_1 on its association with US_{neg}. When CS_2 co-occurred with US_{neg}, the competition was the opposite. The evaluation of CS_1 was more sensitive to the US that co-occurred with CS_1 without competition from other CSs.

Overview of the Experiments

We conducted three experiments that tested whether cue-competition decreases EC, and whether it occurs only because cue-competition changes the statistical contingency of the CS. Experiment 1 was a replication of Bar-Anan and Dahan's experiment, with the addition of two conditions that presented the same statistical contingency manipulation as in Bar-Anan and Dahan's experiment, but without any cue-competition. These two conditions used presentations of a US alone (US_{alone}), rather than CS_2US. In other words, Experiment 1 manipulated statistical contingency with and without increasing cue-competition. We tested whether the statistical contingency would moderate EC regardless of the cue-competition level, or only when the contingency manipulation included cue-competition (i.e., used CS_2US presentations).

In Experiment 2, more similar to what is done in typical EC procedures, CS_1 co-occurred with a US of a single valence (positive or negative). In two conditions, CS_1 co-occurred with US_{neg}, and in two conditions it co-occurred with US_{pos}. The US that co-occurred with CS_1 also appeared in 33% of the trials that did not present CS_1 (i.e., CS_1-US contingency was 100% - 33% = 66.7%). We manipulated whether the US occurred alone on the additional trials, or with CS_2. In that way, we manipulated cue-competition without changing the statistical contingency. We tested whether that manipulation would influence the evaluation of the CS.

In Experiments 1 and 2 we manipulated cue-competition by presenting or omitting the presentation of CS_2. That confounded cue-competition with the number of CSs presented during learning. To avoid that confound, two CSs occurred (separately) in all the conditions of Experiment 3. That experiment used a relatively complex design to provide independent manipulations of cue-competition and statistical contingency without manipulating the number of CSs.

Experiment 1

Table 1 presents the experiment's design. In all four conditions, the target CS (CS_1) co-occurred an equal number of times with US_{pos} and US_{neg}. Two conditions replicated Bar-Anan and Dahan's (2013) experiment: in one of them a CS_2 co-occurred always with US_{pos}, and in the other the CS_2 co-occurred always with US_{neg}. This manipulated statistical contingency using cue-competition (Table 1, first two rows). Two additional conditions presented the exact same design, but without CS_2. One condition presented additional presentations of the US_{pos} alone, and the other condition presented additional presentations of the US_{neg} alone. This manipulated statistical contingency without cue-competition. We examined whether statistical contingency manipulation would influence the evaluation of the CS_1, regardless of whether that manipulation used cue-competition (additional presentations of a CS_2 with a US) or not (additional presentations of the US without CS_2).

Table 1

Experiment 1: Design

Trials	**Competition**	**Statistical contingency**	
		CS_1-US_{pos}	**CS_1-US_{neg}**
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 CS_2-US_{pos}	Yes	0%	50%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 CS_2-US_{neg}	Yes	50%	0%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 US_{pos}	No	0%	50%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 US_{neg}	No	50%	0%

Method

Participants. A hundred and forty seven participants (101 women, M_{age}= 23.87, SD_{age} = 1.60) completed the experiment in separate cubicles in groups of 1-3, in exchange to course credit or monetary compensation. We originally planned to run 60 participants. After 60 participants, the pattern of the results was the same as reported here, and a crucial statistical test (the interaction between statistical contingency and cue-competition) did not reach statistical significance. Because we worried that the experiment lacked power to find that effect, we decided to continue running the experiment until the semester ended. The crucial statistical test remained non-significant.

Materials. The neutral stimuli were drawings of human-like creatures, each with unique shape and colour (Bar-Anan & Dahan, 2013). We counterbalanced between participants the assignment of three creatures (blue, brown and green) to the roles of a CS_1, Filler, and the novel stimulus (see the procedure below). The CS_2 (if it appeared in the participant's session) was the same red creature for all participants. The affective stimuli were auditory (Bar-Anan & Dahan, 2013): a relaxing musical melody (US_{pos}) and a horrifying human scream (US_{neg}).

Learning procedure. The procedure was similar to the one used by Bar-Anan and Dahan (2013). The study was conducted on desktop computers. We instructed the participants to pay attention to the creatures because we were going to ask questions about them later. Trials with a CS started with a 5,500 ms presentation of the CS. 500 ms after the creature appeared, the US played for five seconds in the participants' headphones. The CS and the US disappeared at the same time. After each trial, there was a silent blank screen for 1,500 ms. In trials with no CS (occurred only in the no-competition conditions), the US played on a blank screen for five seconds.

There were four blocks of 12 trials. In each block, two trials presented CS_1 with the US_{pos}, and two trials presented CS_1 with the US_{neg}. Four trials presented the filler stimulus with silence. Another four trials were different between the four between-participants conditions.

First, we manipulated whether these four trials presented the US_{pos} or the US_{neg} (i.e., we manipulated the valence of the *majority US*). Second, we manipulated whether the majority US was played on a blank screen (US_{alone} conditions) or while presenting the CS_2 (the CS_2 conditions). Trial order was randomised at the beginning of each block.

Measures. Participants rated their liking of each creature, on a scale from 1 (Dislike very much) to 9 (Like very much). The questionnaire presented the CS_1, the filler stimulus, and a novel stimulus in a random order. Then, participants rated the CS_2 on the same scale.

Next, we measured co-occurrence memory with eight open-ended questions that asked: ‘‘How many times, in your estimation, was the human sound [musical sound] played when the red [blue][green][brown] creature appeared?’’ There were two questions for each of the four creatures (CS_1, CS_2, the filler stimulus, and a novel stimulus)—one about the US_{pos}, and one about the US_{neg}.

Finally, participants rated how positive or negative they felt when hearing each of the USs during the task, on a scale of 1 (very negative) to 9 (very positive), and how silent trials made them feel (on the same scale). In all experiments, we asked participants to evaluate the USs to test whether the manipulations might have influenced the CS evaluation by changing the US evaluation. Although we sometimes found an effect of the manipulations on the US evaluation, it was never in the direction that could explain the effect of the manipulations on the CS.

Results and Discussion

Main analysis. The evaluation of each of the stimuli in each of the four conditions is presented in Table 2. We conducted a 2 (majority US: US_{pos}, US_{neg}) x 2 (majority US presentation: with CS_2, alone) ANOVA on the CS_1 evaluation. The first factor represented the statistical contingency manipulation and the second factor represented the cue-competition manipulation. The analysis found only a main effect of statistical contingency, $F(1, 143) = 29.98$, $p = .008$, $\eta_p^2 = .05$, indicating that participants rated the CS_1 as more positive when the US_{neg} occurred 16 times without CS_1 than when the US_{pos} occurred 16 times without CS_1. There was no main effect of cue-competition, $F(1, 143) = .14$, $p = .71$. Importantly, there was no significant interaction between the statistical contingency and cue-competition, $F(1, 143) = .91$, $p = .34$, $\eta_p^2 < .01$. In other words, there was no evidence that the statistical contingency manipulation required a competing CS in order to influence the evaluation of CS_1.

Table 2

Experiment 1: Evaluation as a function of the presentation and identity of additional US trials

	Additional US presented with CS_2			***Additional US presented alone***		
Additional 16 trials	**US_{pos}-CS_2**	**US_{neg}-CS_2**	***Effect size***	**US_{pos}**	**US_{neg}**	***Effect size***
CS_1	4.19 (1.91)	5.42 (1.75)	0.67*	4.39 (2.31)	4.97 (2.06)	0.27
Filler	5.42 (1.84)	5.81 (2.12)	0.20	6.14 (1.96)	5.41 (2.45)	-0.33
Novel	5.28 (1.67)	5.06 (1.82)	0.13	5.19 (1.98)	5.41 (1.39)	0.13
CS_2	6.69 (2.04)	2.33 (1.90)	2.21*	--	--	
US_{pos}	7.11 (1.67)	7.50 (1.83)	0.22	7.86 (1.73)	8.00 (1.47)	0.09
US_{neg}	2.94 (1.37)	2.33 (1.20)	0.47*	2.56 (1.66)	2.31 (1.13)	-0.18
Silence	5.03 (2.18)	5.81 (1.77)	0.39	4.94 (1.62)	5.56 (1.93)	0.35

Notes. The effect sizes are for contingency manipulation, for each stimulus, in each competition condition. * indicates a significant difference ($p < .05$) between the two contingency conditions.

When we examined the effect of statistical contingency in each cue-competition condition, we found significant context effect *only* when the majority US occurred with CS_2, $F(1, 143) = 26.88$, $p = .01$, $\eta_p^2 = .04$, and not when the majority US occurred alone, $F(1, 143) = 1.58$, $p = .21$, $\eta_p^2 = .01$. In other words, Experiment 1 found evidence that the presentation of a US without a CS influences the evaluation of the CS when the US was presented with another

CS. However, the experiment failed to find evidence that the presentation of a US alone influences the evaluation of the CS. However, the lack of interaction in the analysis indicates that we did not find statistically reliable evidence that additional US occurrences were more effective in reducing EC when the US occurred with another CS (cue-competition) than when it occurred alone (statistical contingency). That conclusion will seem more reliable only when considering the evidence from all three experiments together.

Other effects. The effects of the manipulation on the evaluation of all the other stimuli in the experiment are presented in Table 2. We repeated the same ANOVA on the evaluation of each of these stimuli (excluding the CS_2 that did not exist when the majority US occurred alone). We found three significant effects, all seem spurious or of little importance. We found a main effect for the statistical contingency on the evaluation of silence, F (1, 143) = 5.02, p = .03, η_p^2 = .03, indicating more positive evaluation of the silence when the US_{neg} occurred 24 times in the experiment, than when the US_{pos} occurred 24 times in the experiment (Table 2). Perhaps participants appreciated the silence more when most of the trials played an annoying scream than when most of the other trials played a pleasant tune. We also found a marginally significant main effect of statistical contingency on the evaluation of the US_{neg}, F (1, 143) = 3.71, p = .06, η_p^2 = .03, indicating a more negative evaluation of the US_{neg} when it occurred 24 times than when it occurred only 8 times. Perhaps an annoying sound becomes much more annoying when it repeats more often. Finally, we found a main effect for the cue-competition condition on the US_{pos} evaluation, F (1, 143) = 5.11, p = .03, η_p^2 = .03, indicating stronger liking of the US_{pos} when the majority US was presented 16 times alone than when it was presented 16 times with the CS_2

(Table 2). That last finding might reflect an EC effect, in which the relatively neutral valence of the CS reduced the liking of the US_{pos}.

Importantly, the analyses on other stimuli did not find any evidence that the effect of the manipulation on the CS_1 was due to changes in the evaluation of the USs, or due to a general change of standards in the evaluation dimension. This replicates Bar-Anan and Dahan's (2013) findings, and suggests that the manipulation reflected a moderation of EC—the effect of the co-occurrence with affective stimuli on CS_1.

Memory. Memory measures after EC procedures are difficult to interpret because they can reflect awareness of the co-occurrence during learning, inference of the co-occurrence from the evaluation of the CSs, or forgetting of a co-occurrence that participants detected during learning (Gawronski & Walther, 2012; Reingold & Merikle, 1988). Therefore, throughout this article, we report memory results for completeness, but can offer only weak inferences.

Each participant reported how many times each CS appeared with each US. The memory score for each CS was the difference between the number of times that the participant estimated that the CS co-occurred with the US_{pos} and the number of times estimated for CS-US_{neg} co-occurrence. Therefore, a positive memory score indicated that the participant remembered more occurrences of the CS with the US_{pos} than with the US_{neg}. For CS_1, forty seven (32%) participants had an accurate memory (a zero memory score). For the CS_2, 57 (80%) participants estimated that it co-occurred more often with the US that it indeed co-occurred, 13 (18%) participants estimated that it appeared an equal number of times with each US, and 1 participant estimated that it occurred more often with the US with which it did not occur at all.

The memory score of the CS_1 was related to its evaluation, $r(147) = .25$, $p = .002$, but was not significantly related to the CS_2's memory score, $r(72) = -.17$, $p = .154$. We examined whether the manipulation influenced the C_1's memory score. We repeated the same ANOVA as in the main analysis with the CS_1's memory score as the dependent variable (DV) instead of its evaluation. This analysis found no significant effect, *ps* > .102. Therefore, we found no evidence that the statistical contingency (manipulated with or without cue competition) of the CS_1 influenced people's memory of the CS_1's co-occurrence with affective stimuli.

Experiment 2

Experiment 1 found evidence that the EC of one CS depends not only on the co-occurrence of that CS with USs, but also on the occurrence of the US without the CS. This may suggest that, contrary to the results of a few previous experiments (e.g., Baeyens et al., 1993; Baeyens, Crombez, De Houwer & Eelen, 1996; Baeyens, Hendrickx, Crombez & Hermans, 1998), EC is sensitive to statistical contingency. It may also suggest that Bar-Anan and Dahan (2013) were too quick to attribute the effect replicated in Experiment 1 as evidence that the EC of one CS is sensitive to the co-occurrence of another CS with the same US. Rather, perhaps Bar-Anan and Dahan found special circumstances (e.g., equal co-occurrence with US_{pos} and US_{neg}), in which statistical contingency strongly moderates EC.

On the other hand, Experiment 1 found a significant effect of statistical contingency only when it was manipulated with additional CS-US co-occurrences and not when it was manipulated with additional US occurrences alone. Therefore, we considered the results of Experiment 1 inconclusive regarding the question whether the influence of statistical contingency on EC depends on (or is stronger when there is) a competition between the co-occurrences of two stimuli with the same US. In Experiment 2, we investigated the effect of cue-competition with a different design (Table 3 presents the design summary). The CS always co-occurred with a single US. We manipulated between participants the valence of that US (US_{pos} or

US_{neg}). We also manipulated whether that US co-occurred with one CS or two CSs (separately). When there was only one CS, we added presentations of the US without any CS to keep the statistical contingency constant. In that way, we manipulated cue-competition without manipulating statistical contingency, and examined whether more competition would decrease the EC effect.

Table 3

Experiment 2: Design summary

Trials	**Competition**	**Statistical contingency**	
		CS_1-US_{pos}	**CS_1-US_{neg}**
12 CS_1-US_{pos}, 12 CS_2-US_{pos}, 24 US_{neg}	Yes	67%	-67%
12 CS_1-US_{pos}, 12 US_{pos}, 24 US_{neg}	No	67%	-67%
12 CS_1-US_{neg}, 12 US_{neg}, 24 US_{pos}	No	-67%	67%
12 CS_1-US_{neg}, 12 CS_2-US_{neg}, 24 US_{pos}	Yes	-67%	67%

Method

Participants. Sixty two participants (41 women, M_{age}= 23.90, SD_{age} = 1.55) completed the experiment in separate cubicles in groups of 1-3, in exchange to course credit or monetary compensation. We planned to run sixty participants but included 62 because we suspected that we might need to exclude two participants that might have participated in a study with similar stimuli in the past. Because the results were the same with and without these participants, we eventually included all the participants in the analyses.

Materials. The stimuli were the same as in Experiment 1, but we only used two of the four creatures used in Experiment 1 (the red and the blue creatures).

Learning procedure. The procedure was the same as in Experiment 1. The trial sequence was similar but with different durations. Each trial began with a 10,500 ms presentation of the CS. 500 ms after the creature appeared, the US played for ten seconds in the participants' headphones. The CS and the US disappeared at the same time. At the end of each trial, there was a silent blank screen for 1,400 ms. In trials that did not present the CS, the US played with a blank screen for 10 seconds.

There were three blocks of 16 trials. Four trials presented the CS_1 with the same US (US_{pos} in the *US-positive* condition, and US_{neg} in the *US-negative* condition). Eight trials played the other US (e.g., US_{neg} in *US-positive* condition, and US_{pos} in the *US-negative* condition) with a blank display. Another four trials presented the same US that co-occurred with CS_1. In the *no-competition* condition, that US played with a blank display. In the *cue-competition* condition, that US was presented with CS_2. In the *no-competition* condition, the identity of the CS_1 (red or blue) was counterbalanced between participants. In total, each block played an equal number (eight) of US_{pos} and US_{neg}.

Measures. The measures were identical to Experiment 1, excluding the questions about stimuli that appeared in Experiment 1 but not in Experiment 2.

Results and Discussion

Main analysis. The main DV was the evaluation of the CS(s). In the *cue-competition* condition, it was the average evaluation of the CS_1 and CS_2. The results are presented in the first row of Table 4. We submitted that DV to a 2 (US that co-occurred with the CS: positive, negative) x 2 (number of CSs: 1, 2) ANOVA. A main effect for the co-occurring US revealed the expected EC effect, $F(1, 58) = 24.4$, $p < .0001$, $\eta_p^2 = .30$, reflecting more positive evaluation of the CS(s) when the CS(s) co-occurred with US_{pos} ($M = 6.16$, $SD = 2.04$), than when the CS(s) co-occurred with US_{neg} ($M = 3.27$, $SD = 2.02$). There was no main effect for the number of CSs, $F(1, 58) = 1.56$, $p = .217$, $\eta_p^2 = .03$.

Table 4

Experiment 2: Evaluation as a function of US valence and number of CSs

	CS occurred with US_{pos}			*CS occurred with US_{neg}*		
	Number of CSs			*Number of CSs*		
	1	*2*	*Effect size*	*1*	*2*	*Effect size*
CS	6.75 (2.07)	5.09 (1.91)	0.83	3.15 (2.30)	3.50 (1.43)	0.18
Red CS	6.45 (1.69)	4.82 (2.09)	0.86	2.60 (1.84)	3.09 (1.76)	0.27
Blue CS	7.11 (2.52)	5.36 (2.58)	0.69	3.70 (2.67)	3.91 (1.87)	0.09
US_{pos}	7.45 (1.82)	7.55 (1.92)	0.05	8.10 (1.33)	8.73 (0.47)	0.63
US_{neg}	2.65 (1.73)	1.82 (0.75)	0.62	2.20 (1.36)	2.55 (1.29)	0.26

Notes. The effect sizes are for the competition effect, for each stimulus, in each US condition; The red CS and blue CS rows present the evaluation of the red and the blue stimulus when the stimulus appeared in the learning task (we counterbalanced the identity of the CS in the no-competition conditions).

The critical test was the interaction. An interaction effect would reflect different EC effect when the same US co-occurred with two CSs an identical number of times than when it co-occurred with only one CS. The interaction was marginally significant, $F(1, 58) = 3.66$, $p = .06$, $\eta_p^2 = .06$, reflecting a possibly smaller EC effect when the US occurred 12 times with each of two CSs, $F(1, 58) = 3.56$, $p = .064$, $\eta_p^2 = .06$, than when the US occurred 12 times with one CS and 12 times alone, $F(1, 58) = 33.16$, $p < .0001$, $\eta_p^2 = .36$. As detailed in Table 4, the reason for this possible interaction was mainly that the CS that co-occurred with US_{pos} was liked more when only one CS co-occurred with US_{pos}, than when two CSs co-occurred with US_{pos}, $F(1, 58) = 5.00$, $p = .03$, $\eta_p^2 = .08$. However, when the co-occurring US was negative, there was no significant effect of CS number, $F(1, 58) = 0.22$, $p = .64$, $\eta_p^2 < .01$.

Table 4 also shows that the overall pattern of results held true for each of the two stimuli (red and blue) used as CSs, increasing our confidence that although the interaction was only marginally significant, this was not a chance finding. In summary, we found evidence that cue-competition reduces the EC effect on a CS that co-occurred with a positive stimulus (CS_{pos}), but did not find the same evidence regarding a CS that co-occurred with a negative stimulus (CS_{neg}). Therefore, we believe that a conclusion that cue-competition moderates EC even without a change in statistical contingency would seem reliable only when considering the accumulated evidence found in all three experiments.

Other effects. We repeated the same ANOVA twice, once with the US_{pos} as the DV, and once with the US_{neg} as the DV. We did not expect any effect, and five of the six effects were indeed non-significant, *ps* > .12. The only significant effect was a main effect of the identity of the US that co-occurred with the CS(s) on the evaluation of the US_{pos}, $F(1, 58) = 5.09$, $p = .03$, $\eta_p^2 = .08$, indicating that the US_{pos} was liked more when it did not appear with a CS ($M = 8.32$, $SD = 1.14$), than when it appeared with a CS ($M = 7.48$, $SD = 1.82$). Like in Experiment 1, this might reflect an EC effect in which the US_{pos} becomes slightly less positive after co-occurrence with a relatively neutral stimulus (the CS).

Memory. The memory score was computed as in Experiment 1. When there were two CSs, the memory score was the average of the memory score for the two CSs. The memory and the evaluation scores of the CS(s) correlated, $r(62) = .547$, $p < .0001$. This is not surprising because the valence of the US that co-occurred with the CS(s) was expected to influence evaluation and memory in a similar manner.

Accurate memory was a positive memory score when the CS(s) co-occurred with US_{pos}, and a negative memory score when the CS(s) co-occurred with US_{neg}. Ten (14%) participants did not have an accurate memory. Excluding inaccurate participants from the main analysis increased its statistical significance, and found a significant interaction between number of CSs and the valence of the Co-occurring US, $F(1, 48) = 5.65$, $p = .022$, $\eta_p^2 = .10$, indicating a stronger EC effect when there was one CS, $F(1, 48) = 43.58$, $p < .0001$, $\eta_p^2 = .47$, than when there were two CSs, $F(1, 48) = 4.09$, $p = .049$, $\eta_p^2 = .08$. This may reflect less attention of people with inaccurate memory to the experiment, and therefore less sensitivity to the manipulations.

A possible explanation for the moderation of EC by the number of CSs could be reduced attention to the co-occurrence, caused by the larger number of stimuli (i.e., creatures) during the learning procedure. However, memory accuracy was equal when there was one CS (*M* = .83, *SD* = .38) and when there were two CSs (M = .86, SD = .35), $t(60) = 0.39$, $p = .698$. To examine this question with a more sensitive measure, we replaced the binary accurate measure with a continuous measure computed as the memory score, only multiplied by -1 when the CS(s) co-occurred with US_{neg}. That accuracy score was virtually identical when there was one CS (*M* = 9.25, *SD* = 7.86) and when there were two CSs (*M* = 9.27, *SD* = 6.22), $t(60) = .01$. In summary, the memory measure did not provide any evidence that the number of CSs moderated EC by reducing memory accuracy regarding the CS-US co-occurrences in the learning procedure.

Experiment 3

Experiments 1 and 2 found results that may suggest that EC of one CS is sensitive to the co-occurrence of another CS with the same US. However, the evidence from these experiments was not always conclusive, once failing to find significant moderation (Experiment 1), and once finding cue-competition only for a CS_{pos}, but not for a CS_{neg} (Experiment 2). Seeking more conclusive results, Experiment 3 used a different design that examined the effects of cue-competition and statistical contingency independently.

In the learning phase of this experiment, participants always experienced three different trial types, each repeated 12 times. One trial type always presented CS_1 with one of the USs (e.g., CS_1-US_{pos} in 12 trials), the second trial type always presented CS_2 with one of the USs (e.g., CS_2-US_{pos} in 12 trials), and the third trial type played one of the USs with a blank display (e.g., US_{neg} in 12 trials). We manipulated the identity of the US in each of three trial types. Table 5 presents the four combinations of trial types that were used. We named the conditions according to the valence of the US that appeared in each of three trial types. We used non-capital letters for the USs that co-occurred with a CS, and capital letters for the US that occurred alone. For instance, the condition *pos-neg-NEG* indicates that US_{pos} co-occurred with CS_1, US_{neg} co-occurred with CS_2, and US_{neg} also occurred alone.

In two of the four conditions, one CS always co-occurred with US_{pos} and the other CS always co-occurred with US_{neg}. The difference between these two conditions was in the trials that played a US on a blank screen (without any CS). These trials played US_{neg} in one condition and the US_{pos} in another condition. This manipulated the statistical contingency of each CS, without manipulating the cue-competition. If statistical contingency moderates EC even when there is no cue-competition, then the identity of the US that occurred alone should moderate EC. When the US_{alone} trials play the US_{pos} (condition *pos-neg-POS* in Table 5), the CS_{neg} should be disliked more than when the US_{alone} trials play the US_{neg} (*pos-neg-NEG*). Similarly, when the US_{alone} trials play the US_{neg} (*pos-neg-NEG*), the CS_{pos} should be liked more than when the US_{alone} trials play the US_{pos} (*pos-neg-POS*).

The two other conditions induced cue-competition by pairing the two CSs with the same US. In one of these conditions (*pos-pos-NEG*), the CSs always co-occurred with US_{pos} and in the other condition (*neg-neg-POS*) the CSs always co-occurred with US_{neg}. For each of these two conditions, one of the no-competition conditions presented exactly the same contingency for the CS, but without cue-competition. For instance, each CS_{pos} in the *pos-pos-NEG* condition had a $CS\text{-}US_{pos}$ contingency of 100%-50% = 50%. The CS_{pos} in the *pos-neg-POS* had the exact same $CS\text{-}US_{pos}$ contingency. Cue-competition would cause less extreme liking of the CS_{pos} in the competition condition (*pos-pos-NEG*) than in the no-competition condition (*pos-neg-POS*), despite the equal statistical contingency. The same is true for the comparison of contingencies between the *neg-neg-POS* condition and the *neg-pos-NEG* condition. Cue-competition would cause less extreme disliking of the CS_{neg} in the neg-neg-POS condition, than in the *pos-neg-NEG* condition.

Table 5

Experiment 3: Design

		Competition	**Statistical Contingency**			
Condition	**Trials**		**CS_1-US_{pos}**	**CS_1-US_{neg}**	**CS_2-US_{pos}**	**CS_2-US_{neg}**
pos-pos-NEG	12 CS_1-US_{pos}, 12 CS_2-US_{pos}, 12 US_{neg}	Yes	50%	-50%	50%	-50%
pos-neg-NEG	12 CS_1-US_{pos}, 12 CS_2-US_{neg}, 12 US_{neg}	No	100%	-100%	-50%	50%
pos-neg-POS	12 CS_1-US_{pos}, 12 CS_2-US_{neg}, 12 US_{pos}	No	50%	-50%	-100%	100%
neg-neg-POS	12 CS_1-US_{neg}, 12 CS_2-US_{neg}, 12 US_{pos}	Yes	-50%	50%	-50%	50%

Note. To examine the effect of cue-competition, we compared the average evaluation of CS_1 and CS_2 in *pos-pos-NEG* with the evaluation of CS_1 in *pos-neg-POS*; and the average evaluation of CS_1 and CS_2 in *neg-neg-POS* with the evaluation of CS_2 in *pos-neg-NEG*; To examine the effect of statistical contingency, we compared the evaluations of CS_1 and CS_2 (separately) between *pos-neg-NEG* and *pos-neg-POS*.

Method

Participants. Ninety six participants (59 women, M_{age}= 24.81, SD_{age} = 2.66) completed the experiment in separate cubicles in groups of 1-3, in exchange of course credit or monetary compensation. We planned to run exactly 96 participants.

Materials. We used the same USs as in the previous experiments and three of the CSs used in Experiment 1 (the red, blue and brown creatures), randomly assigned to the roles of the two CSs, and the novel stimulus (that appeared only upon evaluation).

Learning procedure. The procedure was the same as in Experiment 1. The trial sequence was similar but with some changes. Each trial began with a fixation symbol (+) that appeared for 100 ms, and was replaced with the CS. The CS appeared for 10,400 ms. 400 ms after the CS appeared, the US played for ten seconds in the participants' headphones. The CS and the US disappeared at the same time. At the end of each trial, there was a silent blank screen for 2,400 ms. In US_{alone} trials, the US played immediately after the fixation disappeared, and no creature appeared.

There were three blocks of 12 trials. In each block, each of the CSs appeared in four trials. For each participant each CS always co-occurred with the same US. The remaining four trials in each block played one US with a blank display. One US occurred in four of the 12 trials (with one of the CSs or in the US_{alone} trials), and the other US occurred in the remaining eight trials. As detailed in Tables 1 and 4, we manipulated the identity of the US that occurred only four times (US_{pos} vs. US_{neg}), and whether that minority US occurred with a CS or alone.

Measures. The measures were identical to Experiment 1, excluding questions about stimuli that did not appear in Experiment 3.

Results and Discussion

Main analysis. The main DVs were the evaluations of the CS_{pos} and the CS_{neg}. In *Cue-competition* conditions, when both CSs co-occurred with the same US, the DV was the average evaluation of the two CSs. The results are presented in Table 6. For each CS type (CS_{pos} and CS_{neg}) we conducted a three-level one-way ANOVA to examine whether the manipulation influenced its evaluation. We found a statistically significant evidence for the effect of the manipulation on CS_{pos} evaluation, $F(2, 70) = 4.19$, $p = .019$, $\eta_p^2 = .11$, and a marginally significant evidence for the effect of the manipulation on CS_{neg} evaluation, $F(2, 70) = 2.70$, $p = .074$, $\eta_p^2 = .07$.

Table 6

Evaluation as a function of the types of trials in the learning procedure

Condition	Trial types	CS_{pos}	CS_{neg}	Novel	US_{pos}	US_{neg}
pos-pos-NEG	CS_1-US_{pos}, CS_2-US_{pos}, US_{neg}	5.50_c (1.61)	--	4.60_a (1.73)	7.56_b (1.66)	2.92_a (1.58)
pos-neg-NEG	CS_1-US_{pos}, CS_2-US_{neg}, US_{neg}	6.92_a (1.84)	2.83_b (1.97)	4.54_a (1.93)	7.96_{ab} (1.43)	2.33_{ab} (1.17)
pos-neg-POS	CS_1-US_{pos}, CS_2-US_{neg}, US_{pos}	6.50_a (1.84)	3.25_{ab} (1.65)	4.42_a (1.74)	8.04_{ab} (1.08)	2.17_b (1.31)
neg-neg-POS	CS_1-US_{neg}, CS_2-US_{neg}, US_{pos}	--	4.07_a (1.97)	4.30_a (1.96)	8.35_a (1.07)	2.48_{ab} (1.31)

Notes. In conditions *pos-pos-NEG* and *neg-neg-POS*, the evaluation of CS_{pos} and CS_{neg} (respectively) is the average of the evaluation of the two CSs; In each column, identical subscripts indicate no significant difference (tested with contrasts in a one-way ANOVA).

We broke each of the three-level ANOVAs to two planned comparisons, one examined the effect of cue-competition, and one examined the effect of statistical contingency. To examine the effect of cue-competition on the evaluation of the CS_{pos}, we compared the average evaluation of the CSs in the condition in which the two CSs occurred with the US_{pos} (condition *pos-pos-NEG* in Table 6) to the condition in which one CS occurred with US_{pos}, the other CS occurred with US_{neg}, and the US_{alone} was the US_{pos} (*pos-neg-POS*). For the CS_{pos}, these two conditions induced the same statistical contingency (50%). Despite the constant contingency, we found less liking of the CS_{pos} in the cue-completion condition ($M = 5.50$, $SD = 1.61$), than in the no-competition condition ($M = 6.50$, $SD = 1.84$), $F(1, 70) = 7.90$, $p = .006$, $\eta_p^2 = .10$.

We repeated the same test for the CS_{neg}, comparing the average evaluation of the CSs in the condition in which the two CSs occurred with the US_{neg} (*neg-neg-POS*) to the condition in which one CS occurred with US_{neg}, the other CS occurred with US_{pos}, and the US_{alone} trials played the US_{neg} (*pos-neg-NEG*). We found less extreme disliking of the CS_{neg} in the cue-completion condition (*M* = 4.07, *SD* = 1.97), than in the no-competition condition (*M* = 2.83, *SD* = 1.97), F(1, 70) = 5.25, *p* = .025, $\eta_p^2 = .07$. Therefore, Experiment 3 found significant evidence for the effect of cue-competition on both the CS_{pos} and CS_{neg}, even when statistical contingency was kept constant.

Next, we examined the effect of statistical contingency when there was no cue-competition, by comparing the CS evaluation in the two conditions in which each of the two CSs co-occurred with a different US. The difference between these two conditions was the US that occurred in the US_{alone} trials. When the US_{neg} was the more frequent US (*pos-neg-NEG*), we expected more extreme liking of the CS_{pos} and less extreme disliking of the CS_{neg}, than when US_{pos} was the more frequent US (*pos-neg-POS*). The results were in the expected direction for the CS_{pos}, and in the opposite direction for the CS_{neg}, but both differences were far from significant, for CS_{pos}: F(1, 70) = 0.67, *p* = .416, $\eta_p^2 < .01$; for CS_{neg}: F(1, 70) = 0.61, *p* = .436, $\eta_p^2 < .01$. Therefore, like in Experiment 1, we could not find significant moderation of EC by statistical contingency, when it did not involve cue-competition.

Table 7 presents the effect of experimental condition on each of the three stimuli that were used as CSs in the experiment. In all six columns, the pattern of results always reflects a cue-competition effect: When each of the stimuli was a CS_{pos}, it was liked the least when it was one of two CS_{pos}'s. When each of the stimulus was a CS_{neg}, it was disliked the least when it was one of two CS_{neg}'s. Although the number of participants in each cell prevents powerful test of statistical significance for each stimulus in each CS role, the effects sizes of all six comparisons reveal small to large effects of cue-competition. The chances that six comparisons would show a difference in the same direction are 1.6%. The effects of statistical contingency seem more random, revealing the opposite effect in three of the six comparisons. This constant pattern in all stimuli increases our confidence in the findings revealed with the main ANOVA.

Table 7

Evaluation as a function of role (CS_{pos} vs. CS_{neg}) and experimental condition

Stimulus Role	**CS_{pos} (co-occurred with US_{pos})**			**CS_{neg} (co-occurred with US_{neg})**		
Trial types \ Stimulus	**Blue**	**Red**	**Brown**	**Blue**	**Red**	**Brown**
CS_1-US_{pos}, CS_2-US_{pos}, US_{neg}	6.24 (1.56)	5.00 (2.43)	5.27 (1.94)			
CS_1-US_{pos}, CS_2-US_{neg}, US_{neg}	6.63 (1.41)	7.14 (1.35)	7.00 (2.55)	3.00 (1.69)	2.50 (2.33)	3.00 (2.07)
CS_1-US_{pos}, CS_2-US_{neg}, US_{pos}	6.78 (2.22)	6.63 (1.85)	6.00 (1.41)	3.25 (1.39)	3.63 (2.07)	2.88 (1.55)
CS_1-US_{neg}, CS_2-US_{neg}, US_{pos}				5.07 (2.43)	3.87 (1.73)	3.31 (1.82)
Cue-competition effect size	0.28	0.76	0.43	0.99	0.67	0.16
Contingency effect size	-0.08	0.31	0.49	-0.16	-0.51	0.07

Notes. The cue-competition effect size is the Cohen's d of the comparison between the two conditions that had identical statistical contingency but different cue-competition level; The statistical contingency effect size is the Cohen's d of the comparison between the two conditions that had no cue-competition and differed in their statistical contingency.

Other analyses. In a four-level one-way ANOVA, we found no effect of condition on the evaluation of the novel stimulus, F(3, 92) = 0.12, p = .945, $\eta_p^2 < .01$, the US_{neg}, F(3, 92) = 1.41, p = .245, $\eta_p^2 = .04$, or the US_{pos}, F(3, 92) = 1.41, p = .244, $\eta_p^2 = .04$. In the previous experiments we found that the US_{pos} was liked more when it occurred alone and not with any of the CSs. Table 6 shows that the pattern of US_{pos} evaluation displayed the same effect. A contrast revealed that the US_{pos} was liked more in the *neg-neg-POS* condition, in which it always occurred alone, and the two CSs co-occurred with the US_{neg} (M = 8.35, SD = 1.07), than in the *pos-pos-NEG* condition, in which it occurred only with CSs and never alone (M = 7.56, SD = 1.66), F(1, 92) = 4.14, p = .044, $\eta_p^2 = .04$. As in Experiments 1 and 2, this might reflect an EC effect in which the US_{pos} losses some of its positivity after co-occurring with a relatively neutral CS(s). As in the previous experiments, the evaluation of the US_{neg} did not show a similar pattern. Future research might investigate whether this reoccurring result was due to the specific USs used in the present research, or reflects a general finding: positive stimuli are prone to decrease in positivity after co-occurring with a neutral stimulus, whereas co-occurrence with a neutral stimulus does not influence the evaluation of negative stimuli.

Memory. We computed separate memory scores for CS_{pos} and CS_{neg}, using the same method as in the previous experiments. We did not find a relation between the CS_{pos} memory and evaluation scores, $r(73) = .07$, $p = .56$, or between the CS_{neg} memory and evaluation scores, $r(71) = -.06$, $p = .64$. However, for each stimulus separately, the correlation between memory and evaluation was significant, $rs(96) = .52, .32, .40$, $ps < .002$, for the brown, red and blue stimuli, respectively. These correlations probably reflect the expected effect of the co-occurrence (with US_{pos} versus US_{neg} or no co-occurrence at all) on memory and evaluation.

We did not expect participants to remember the exact number of the co-occurrences (12) for each stimulus; only that CS_{pos} appeared more often with US_{pos} than with US_{neg} and that CS_{neg} appeared more often with US_{neg} than with US_{pos}. Eighty five (89%) participants remembered that correctly. The main analysis produced exactly the same effects when excluding the 11 participants who had inaccurate memory. That suggests that these effects were not caused by a few participants who did not remember the co-occurrences correctly.

We repeated the same ANOVAs conducted in the main analyses, only replacing the evaluation score with the memory score. For the CS_{pos} memory score, we found a main effect of condition, $F(2, 70) = 7.41$, $p = .001$, $\eta_p^2 = .17$. The memory score was more positive in the *pos-neg-POS* condition ($M = 16.83$, $SD = 7.68$), than in the other two conditions (*pos-neg-NEG*: $M =$

11.29, *SD* = 5.81; *pos-pos-NEG*: *M* = 10.48, *SD* = 5.01), $F(1, 70) = 14.58$, $p < .001$, $\eta_p^2 = .17$. We do not have an explanation for this effect.

The effect of the manipulation on the memory regarding the CS_{neg} was marginally significant, $F(2, 70) = 2.49$, $p = .091$, $\eta_p^2 = .05$. This marginal effect was caused by a significantly more positive memory score in the *neg-neg-POS* condition (*M* = -9.00, *SD* = 7.85) than in the *pos-neg-NEG* condition (*M* = -13.96, *SD* = 8.20), F(1, 68) = 4.94, $p = .029$, $\eta_p^2 = .07$. This difference resembles the difference found between these two conditions in the evaluation of the CS_{neg} (see Table 6). The difference might reflect a cue-competition effect on memory, with a smaller estimation of the number of co-occurrences with the US_{neg} in the competition condition, than in no-competition condition. However, because we found no relationship between the memory and the evaluation scores of the CS_{neg}, there is little support for the possibility that the effect of cue-competition on one of these variables (e.g., memory) mediated the effect of cue-competition on the other variable (e.g., evaluation).

General Discussion

Three experiments tested whether the effect of the co-occurrence of a neutral stimulus with an affective stimulus on the evaluation of the neutral stimulus (the Evaluative Conditioning effect) is moderated by the co-occurrence of another neutral stimulus with the same affective stimulus. This is a case of cue-competition that does not involve pairing a compound stimulus with the US. In each experiment, we attempted to test the effect of cue-competition on EC, without confounding it with the effect of statistical contingency.

In Experiment 1, we manipulated the statistical contingency of a CS that co-occurred an equal number of times with US_{pos} and US_{neg}. We manipulated the contingency by adding occurrences of one of the USs alone (no cue-competition) or with another CS (cue-competition).

We did not find a significant effect of statistical contingency when it was manipulated without cue-competition. We found a significant effect of statistical contingency on the CS evaluation only when the additional US co-occurred with a CS. However, this moderation was not significance. That is, we found no significant interaction between statistical contingency and competition condition.

In Experiment 2, for each type of CS (CS_{pos} and CS_{neg}) we manipulated cue-competition without manipulating the statistical contingency. Twelve trials paired one CS with a US (positive for some participants, negative for the others). The same US occurred in additional 12 trials without the CS. In the no-competition condition, the US occurred alone in the additional 12 trials. In the cue-competition condition, the US occurred with another CS. We found the typical EC effect: Participants evaluated the CS more positively when it co-occurred with US_{pos} than when it occurred with US_{neg}. Importantly, when the CS co-occurred with US_{pos}, participants liked the CS less in the cue-competition condition than in the no-competition condition. However, the cue-competition effect was not significant when the CS co-occurred with US_{neg}.

In Experiment 3, we paired two CSs with the same US (cue-competition) or each with a US of the opposite valence (no-competition). In addition, we added US occurrences without a CS. We manipulated the valence of that US to create conditions that differed only in cue-competition but had equal statistical contingency, and conditions that differed in statistical contingency but had equal cue-competition level (see Table 6). In Experiment 3, we found no effect of statistical contingency and significant effects for cue-competition on the evaluations of the CS_{pos} and the CS_{neg}.

In summary, none of the experiments found significant evidence to suggest that statistical contingency moderates EC without cue-competition, and all the experiments found at least some evidence that cue-competition moderates EC. Therefore, when considering the results of the three experiments together, we conclude that EC of one CS is sensitive to co-occurrences of another CS with the same US, and that this effect does not depend (and is not based) on variation in statistical contingency.

Why Does Competition Moderate EC?

Cue-comparison. Bar-Anan, De Houwer, and Nosek (2010) found evidence that some people consider a co-occurrence of a target object with affective stimuli valid evidence that the target shares valence with the affective stimuli with which it co-occurs. In other words, some people consider co-occurrence with affective stimuli an evaluative attribute, just like the attribute “honest” or “smiles often.” Based on that conclusion, Bar-Anan and Dahan (2013) suggested that like other evaluative attributes, *co-occurrence with affective stimuli* is sensitive to contrast effects. In contrast effects, an attribute of the target object is judged as more or less extreme depending on the contextual standard of that attribute. For instance, moderately physically attractive people were evaluated as more attractive if they were presented in the same set with unattractive people than if they were presented in the same set with attractive people (Kenrick & Gutierres, 1980). Bar-Anan and Dahan (2013) suggested that a similar effect occurs in EC: the co-occurrence of the CS with a US is compared to the co-occurrence of another CS with the same US. For instance, in Experiment 1, a CS that co-occurred an equal number of times with positive and negative affective stimuli was considered more positive when the other CS in the learning context occurred only with negative stimuli than when the other CS occurred only with positive stimuli.

This *cue-comparison* account is less straightforward as an explanation of the results of Experiment 2 and 3. We found that EC was less extreme when two CSs occurred with the same

US (separately), than when only one CS occurred with the US. To apply the cue-comparison account to these findings, one may contend that when a CS co-occurs with a positive US, the CS seems less positive if another CS also displays the same co-occurrence. In evaluative attributes terms, perhaps a person who displays an honest behavior seems more positive if there is no other person who displays similar honest behaviors. But, if two people display a similarly honest behavior, then the honesty may seem less unusual, less indicative of the person (Kelley, 1973), and generally—a less positive behavior. We are unaware of studies in impression formation research that tested that assumption, but it fits most accounts of the contrast effect in judgment (e.g., Asch, 1946; Hamilton & Zanna, 1974; Manis, Nelson & Shedler, 1988; Stevens, 1958; Upshaw, 1969).

Competition on resources. A different account (or rather, a family of accounts) that can explain the cue-competition effect found in the present experiments is competition on mental resources. According to this account, when more CSs are associated with the same US it is more difficult to encode each co-occurrence and/or to retrieve the mental representation of the CS-US co-occurrence that influences the evaluation of the CS. For instance, if the co-occurrence forms in people's memory an association between the CS and the US—or between the CS and the evaluative aspects of the US (e.g., the evaluative response)—then perhaps that association is weaker when more CSs are linked to the same US. This might be analogous to the *fan effect* found in memory research (Anderson, 1974; Anderson & Reder, 1999)—the number of facts known about a concept is positively related to the time that it takes people to retrieve each fact. The more CSs are associated with a US, the more difficult it is to retrieve each CS-US association, and therefore, the less influential this association on the CS evaluation is.

A competition on resources account was also suggested by Pineño & Matute's (2005) to explain a similar cue-competition finding in human Pavlovian conditioning and predictive learning. These authors found that cue-competition between CSs that were trained apart reduced the conditioned response (Matute & Pineño, 1998a, 1998b; Pineño & Matute, 2000; Pineño, Ortega, & Matute, 2000). Pineño & Matute (2005) suggested that upon retrieval, a competing CS_2 that co-occurred with a US may inhibit the conditioned response to CS_1 that co-occurred with the same US. They suggested that the effect might be analogous to retrieval inhibition in memory (Bjork, 1989). The CS_1-response association is inhibited by a CS_2-response association. Adapted to EC, this suggests that the evaluative response to the CS is retrieved less easily (and therefore less potently) when the same response (or US) was also conditioned to another CS.

Matute and her colleagues (Escobar, Matute, & Miller, 2001; Ortega & Matute, 2000) found evidence suggesting that the cue-competition in their procedures occurs during performance (retrieval). The present findings do not provide evidence whether the cue-competition effect occurred upon evaluation or before that. We also note that in the procedure investigated by Matute and her colleagues, the co-occurrences of the competing CSs with the US are not intermixed. Rather, the interfering CS is usually paired with the US *after* the target CS has been paired with it. Considering that difference, and the possibly unique nature of evaluative response (De Houwer et al., 2001), different mechanisms may cause the effect reported in the current research and the cue-competition effect researched in human Pavlovian conditioning and causal learning. It is also worth noting that most of the present experiments did not find evidence that cue-competition influenced memory of co-occurrence. Therefore, any account based on competition on mental resources would need to explain why the competition influenced evaluation but not memory. In contrast, the memory results do not threat the cue-comparison account.

Integration with Present Theories of EC

None of the present EC theories explicitly predicted the present finding. Bar-Anan and Dahan's (2013) cue-comparison account is based on the propositional account for EC (De Houwer, 2009), but it adds the assumption that people treat co-occurrence with affective stimuli as an evaluative trait that is valid evidence for evaluation. This is an addition to the propositional account because it explains how and why the belief in the proposition that the CS and the US co-occur leads to the EC effect (see also De Houwer, Baeyens, & Field, 2005).

Because EC accounts other than the propositional account suggest processes that occur incrementally in each separate CS-US co-occurrence, they are less compatible with Bar-Anan and Dahan's (2013) suggestion that a comparison between co-occurrences of CSs moderates EC. However, it seems that all the EC accounts are not refuted by the hypothesis that after their formation, CS-US associations may compete with each other on mental resources. EC accounts have focused mostly on the reasons that lead to the formation of an association between the CS and evaluative aspects of the US; EC accounts have been generally silent regarding the processes that may occur after the formation of that association (or of any other mental representation that translates later to the evaluative response). Therefore, the assumption that the activation of an evaluative response to the CS is sensitive to the association between another CS and the same response (or other evaluative aspects of the US) can be added to any EC account without refuting the account's prior assumptions.

Because EC is the effect of co-occurrence on evaluative *response*, we think that EC accounts must break their silence regarding the rules that govern evaluative response. The present finding demonstrates why EC accounts should be integrated with evaluation models (e.g., Fazio, 2007; Gawronski & Bodenhausen, 2011; Petty, Brinol & DeMarree, 2007) to provide stronger theoretical framework that could explain EC and the many factors that modulate this effect.

Limitations and Further Directions

The main limitation of the present research is that all three experiments used the same stimuli. It would be important to replicate these effects with other stimuli. Further research should ascertain that similar cue-competition effects are found in EC with USs of other sensory modality, mainly taste and vision. Second, the present experiments paired the CSs with a single US. However, many EC procedures pair the CSs with multiple USs of the same valence (e.g., positive images, Olson & Fazio 2001). It would be of theoretical importance to examine whether cue-competition in EC is limited to competition on co-occurrence with a specific US, on co-occurrence with specific evaluative response, or with specific valence. Such investigation might help clarify whether EC is based on stimulus-response or stimulus-stimulus associations (for a discussion on that issue, see Walther, Weil, & Langer, 2011). Third, it would be informative to test the limit of competition in terms of number of CSs. Would four CSs that co-occur with the same US produce smaller EC than two CSs? It is possible that competition operates in an all-or-none basis: either there is competition or not; and once there is competition—the number of competing CSs does not increase the competition effect.

Further research could also investigate whether cue-competition in EC is sensitive to re-evaluation of the competing CS. For instance, a future experiment could replicate one of the present experiments, only adding another block that presents additional co-occurrences of the competing CS, this time without the US, or with the opposite US. If extinction or counterconditioning of the competing CS would reduce the cue-competition effect on the target CS, then it would suggest that the cue-competition effect is the result of interference during the evaluative response rather than weak associations between the CS and evaluative aspects of the US.

Further research could also investigate why cue-competition occurs in EC when the CSs are presented in separate trials, and not when they appear together as a compound stimulus (Beckers, De Vicq, & Baeyens, 2009; Dwyer, Jarratt, & Dick, 2007; Walther, Ebert, & Meinerling, 2011). For instance, perhaps participants considered the compound stimulus as one concept with two equal elements, rather than as two different stimuli. Therefore, instead of competing, each element of the compound stimulus received all the evaluative attributes of the whole stimulus. Future research could attempt to explicitly manipulate the construal of the compound stimulus as a whole or as an arbitrary combination of two stimuli, and test whether the latter construal would produce cue-competition effects.

Summary

The present research found evidence for competition between stimuli in evaluative conditioning. When two CSs co-occurred separately with the same US, the effect of the co-occurrence on the evaluation of the CS was smaller than the effect of that co-occurrence when only one CS co-occurred with the US. These results suggest that mere CS-US co-occurrence is not the only factor that influences EC. Our finding suggests that the overall schedule of co-occurrences between multiple CSs and the US also contributes to the EC effect. Future research that would investigate the mechanism behind this effect and the effect’s boundary conditions could advance our understanding of the factors that govern EC. Such advance may contribute to the expansion of current EC theories to explicitly address open questions about how the exposure to CS-US co-occurrences influences subsequent evaluative response.

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Tables

Table 1

Experiment 1: Design

Trials	Competition	Statistical contingency	
		CS_1-US_{pos}	**CS_1-US_{neg}**
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 CS_2-US_{pos}	Yes	0%	50%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 CS_2-US_{neg}	Yes	50%	0%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 US_{pos}	No	0%	50%
8 CS_1-US_{pos}, 8 CS_1-US_{neg}, 16 CS_3, 16 US_{neg}	No	50%	0%

Table 2

Experiment 1: Evaluation as a function of the presentation and identity of additional US trials

	Additional US presented with CS_2			***Additional US presented alone***		
Additional 16 trials	**US_{pos}-CS_2**	**US_{neg}-CS_2**	***Effect size***	**US_{pos}**	**US_{neg}**	***Effect size***
CS_1	4.19 (1.91)	5.42 (1.75)	0.67*	4.39 (2.31)	4.97 (2.06)	0.27
Filler	5.42 (1.84)	5.81 (2.12)	0.20	6.14 (1.96)	5.41 (2.45)	-0.33
Novel	5.28 (1.67)	5.06 (1.82)	0.13	5.19 (1.98)	5.41 (1.39)	0.13
CS_2	6.69 (2.04)	2.33 (1.90)	2.21*	--	--	
US_{pos}	7.11 (1.67)	7.50 (1.83)	0.22	7.86 (1.73)	8.00 (1.47)	0.09
US_{neg}	2.94 (1.37)	2.33 (1.20)	0.47*	2.56 (1.66)	2.31 (1.13)	-0.18
Silence	5.03 (2.18)	5.81 (1.77)	0.39	4.94 (1.62)	5.56 (1.93)	0.35

Notes. The effect sizes are for contingency manipulation, for each stimulus, in each competition condition. * indicates a significant difference ($p < .05$) between the two contingency conditions.

Table 3

Experiment 2: Design summary

Trials	**Competition**	**Statistical contingency**	
		CS_1-US_{pos}	**CS_1-US_{neg}**
12 CS_1-US_{pos}, 12 CS_2-US_{pos}, 24 US_{neg}	Yes	67%	-67%
12 CS_1-US_{pos}, 12 US_{pos}, 24 US_{neg}	No	67%	-67%
12 CS_1-US_{neg}, 12 US_{neg}, 24 US_{pos}	No	-67%	67%
12 CS_1-US_{neg}, 12 CS_2-US_{neg}, 24 US_{pos}	Yes	-67%	67%

Table 4

Experiment 2: Evaluation as a function of US valence and number of CSs

	CS occurred with US_{pos}			*CS occurred with US_{neg}*		
	Number of CSs			*Number of CSs*		
	1	*2*	*Effect size*	*1*	*2*	*Effect size*
CS	6.75 (2.07)	5.09 (1.91)	0.83	3.15 (2.30)	3.50 (1.43)	0.18
Red CS	6.45 (1.69)	4.82 (2.09)	0.86	2.60 (1.84)	3.09 (1.76)	0.27
Blue CS	7.11 (2.52)	5.36 (2.58)	0.69	3.70 (2.67)	3.91 (1.87)	0.09
US_{pos}	7.45 (1.82)	7.55 (1.92)	0.05	8.10 (1.33)	8.73 (0.47)	0.63
US_{neg}	2.65 (1.73)	1.82 (0.75)	0.62	2.20 (1.36)	2.55 (1.29)	0.26

Notes. The effect sizes are for the competition effect, for each stimulus, in each US condition; The red CS and blue CS rows present the evaluation of the red and the blue stimulus when the stimulus appeared in the learning task (one was selected randomly for each participants in the no-competition conditions).

Table 5

Experiment 3: Design

Condition	Trials	Competition	Statistical Contingency			
			CS_1-US_{pos}	CS_1-US_{neg}	CS_2-US_{pos}	CS_2-US_{neg}
pos-pos-NEG	12 CS_1-US_{pos}, 12 CS_2-US_{pos}, 12 US_{neg}	Yes	50%	-50%	50%	-50%
pos-neg-NEG	12 CS_1-US_{pos}, 12 CS_2-US_{neg}, 12 US_{neg}	No	100%	-100%	-50%	50%
pos-neg-POS	12 CS_1-US_{pos}, 12 CS_2-US_{neg}, 12 US_{pos}	No	50%	-50%	-100%	100%
neg-neg-POS	12 CS_1-US_{neg}, 12 CS_2-US_{neg}, 12 US_{pos}	Yes	-50%	50%	-50%	50%

Note. To examine the effect of cue-competition, we compared the average evaluation of CS_1 and CS_2 in *pos-pos-NEG* with the evaluation of CS_1 in *pos-neg-POS*; and the average evaluation of CS_1 and CS_2 in *neg-neg-POS* with the evaluation of CS_2 in *pos-neg-NEG*; To examine the effect of statistical contingency, we compared the evaluations of CS_1 and CS_2 (separately) between *pos-neg-NEG* and *pos-neg-POS*.

Table 6

Experiment 3: Evaluation as a function of the types of trials in the learning procedure

Condition	Trial types	CS_{pos}	CS_{neg}	Novel	US_{pos}	US_{neg}
pos-pos-NEG	CS_1-US_{pos}, CS_2-US_{pos}, US_{neg}	5.50_c (1.61)	--	4.60_a (1.73)	7.56_b (1.66)	2.92_a (1.58)
pos-neg-NEG	CS_1-US_{pos}, CS_2-US_{neg}, US_{neg}	6.92_a (1.84)	2.83_b (1.97)	4.54_a (1.93)	7.96_{ab} (1.43)	2.33_{ab} (1.17)
pos-neg-POS	CS_1-US_{pos}, CS_2-US_{neg}, US_{pos}	6.50_a (1.84)	3.25_{ab} (1.65)	4.42_a (1.74)	8.04_{ab} (1.08)	2.17_b (1.31)
neg-neg-POS	CS_1-US_{neg}, CS_2-US_{neg}, US_{pos}	--	4.07_a (1.97)	4.30_a (1.96)	8.35_a (1.07)	2.48_{ab} (1.31)

Notes. In conditions *pos-pos-NEG* and *neg-neg-POS*, the evaluation of CS_{pos} and CS_{neg} (respectively) is the average of the evaluation of the two CSs; In each column, identical subscripts indicate no significant difference (tested with contrasts in a one-way ANOVA).

Table 7

Evaluation as a function of role (CS_{pos} vs. CS_{neg}) and trial-types condition

Stimulus Role	**CS_{pos} (co-occurred with US_{pos})**			**CS_{neg} (co-occurred with US_{neg})**		
Trial types \ Stimulus	**Blue**	**Red**	**Brown**	**Blue**	**Red**	**Brown**
CS_1-US_{pos}, CS_2-US_{pos}, US_{neg}	6.24 (1.56)	5.00 (2.43)	5.27 (1.94)			
CS_1-US_{pos}, CS_2-US_{neg}, US_{neg}	6.63 (1.41)	7.14 (1.35)	7.00 (2.55)	3.00 (1.69)	2.50 (2.33)	3.00 (2.07)
CS_1-US_{pos}, CS_2-US_{neg}, US_{pos}	6.78 (2.22)	6.63 (1.85)	6.00 (1.41)	3.25 (1.39)	3.63 (2.07)	2.88 (1.55)
CS_1-US_{neg}, CS_2-US_{neg}, US_{pos}				5.07 (2.43)	3.87 (1.73)	3.31 (1.82)
Cue-competition effect size	0.28	0.76	0.43	0.99	0.67	0.16
Contingency effect size	-0.08	0.31	0.49	-0.16	-0.51	0.07

Notes. The cue-competition effect size is the Cohen's d of the comparison between the two conditions that had identical statistical contingency but different cue-competition level; The statistical contingency effect size is the Cohen's d of the comparison between the two conditions that had no cue-competition and differed in their statistical contingency.