Evaluative Conditioning Can be Modulated by Memory of the CS-US Pairings at the Time of Testing

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Abstract

Evaluative conditioning (EC) is the valence change of a (typically neutral) stimulus (CS) that is due to the previous pairing with another (typically valent) stimulus (US). It has been repeatedly shown that EC effects are stronger or existent only if participants know which US was paired with which CS. Knowledge of the CS-US pairings is usually measured temporally close to both the conditioning phase and the CS valence measurement phase. Hence, the relation between EC and knowledge about the pairings could indicate either that participants need to become aware of the pairings at some point or that they need to remember them during the CS valence test. We isolated the impact of memory during the CS valence test in a study that encompassed two sessions. During the first session, participants were presented with CS-US pairings. The valence of the CSs was measured in a second session several days later using both a rating scale and an affective priming procedure. Memory for the pairings was measured both during the first and the second session. Using item-based multilevel analysis, we found that EC in the second session was related to memory for the pairings during the second session, but not to the memory for the pairings measured immediately after the learning phase. For the pairs that were remembered during the first session, but not during the second session, no EC effect was found. These results suggest that memory for CS-US pairings during valence measurement can be relevant for EC effects to occur.

Key words: Evaluative conditioning, contingency awareness, contiguity memory, implicit attitudes

1. Introduction

Evaluative conditioning (EC) is a change in the valence of a stimulus (conditioned stimulus or CS) that is due to pairings with another stimulus (unconditioned stimulus or US; De Houwer, 2007). A great deal of research on EC has investigated the question whether knowledge about the pairing of the CS and the US is necessary for EC effects to occur (see Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010; Lovibond & Shanks, 2002; Shanks, 2010 for reviews). This knowledge is often referred to as contingency awareness. In most cases, however, knowledge about CS-US pairings is assessed at a time when the pairings are no longer present. Furthermore, what is typically assessed is knowledge about the CS-US co-occurrences rather than about the statistical contingency. For these reasons, we will use the term "contiguity memory" when referring to knowledge of CS-US pairs that is available after the learning phase. The term "contiguity knowledge" encompasses both contiguity memory and contiguity awareness in that it refers to knowledge of CS-US pairs at the time it is assessed (i.e., during or after the learning phases).

Several studies on EC suggested that EC can occur independently of contiguity knowledge (e.g., Baeyens, Eelen, Van den Bergh, 1990; Baeyens, Eelen, Van den Bergh, & Crombez, 1990; Dickinson & Brown, 2007; Hammerl & Grabitz, 2000; Hütter, Sweldens, Stahl, Unkelbach, & Klauer, in press; Walther & Nagengast, 2006). Other studies, however, found a strong dependency of EC and contiguity knowledge (e.g., Bar-Anan, De Houwer, & Nosek, 2010; Dawson, Rissling, Schell, & Wilcox, 2007; Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Purkis & Lipp, 2001; Stahl, Unkelbach, & Corneille, 2009). Moreover, several authors argued that some of the studies showing evidence for EC without contiguity knowledge were not based on the appropriate methodology (e.g., Field, 2000; Lovibond & Shanks, 2002; Pleyers et al., 2007; Shanks, 2010). Recent evidence based on a process dissociation approach, however, suggests that in some cases the evidence for EC without contiguity knowledge might also have been underestimated (Hütter et al., in press). To date, there seems to be some agreement that under most conditions, EC effects are strongly related to participants ability to at least report the valence of the US a certain CS was paired with, which is supported by the meta-analytical result that contiguity knowledge is the most important moderating factor of EC effects, explaining 37 % of its variance (Hofmann et al., 2010). The conditions under which EC *without* contiguity knowledge can be found, remain a debated issue.

When considering the relation between EC and contiguity knowledge, it is important to take several issues into account. First of all, a distinction has been made between *identity knowledge*, that is, knowledge about which individual US was paired with a CS, and *valence knowledge*, that is, knowledge about the valence of the US a CS was paired with (Stahl, et al., 2009). Evidence suggests that valence knowledge is sufficient to observe EC (e.g., Stahl et al., 2009). Second, Pleyers and colleagues (2007; also see Baeyens, Eelen, & Van den Bergh, 1990) have brought attention to the fact that contiguity knowledge can be analyzed at the level of the participant or at the level of the specific stimulus pair. Given that one participant can be able to report some stimulus pairs without being able to report others, the authors argued that contiguity knowledge should be analyzed at the stimulus level. Pleyers and colleagues argued that evidence for EC in the absence of contiguity knowledge might have been overestimated because of a failure to analyze contiguity knowledge at the stimulus level.

Finally, researchers have discussed the importance of the point in time at which contiguity knowledge is measured (e.g., Baeyens, Eelen, & Van den Bergh, 1990; Bar-Anan, De Houwer, & Nosek, 2010; Fulcher & Cocks, 1997; Gawronski & Walther, in press; Purkis & Lipp, 2001; Shanks & St. John, 1994). These authors have pointed out that because participants might forget some of the CS-US pairs that they consciously detected, the common procedure of assessing knowledge about CS-US pairs after the learning phase does not provide a good index of contiguity awareness and encoding processes at the time of learning. So far, however, only a couple of studies measured contiguity awareness at the time of learning (Baeyens, Eelen, & Van den Bergh, 1990; Purkis and Lipp, 2001).

As memory is typically measured both relatively closely to the learning and to the valence measurement phase, at least two interpretations of a close relation between EC and contiguity knowledge can be made: According to the first interpretation (the conscious-encoding hypothesis) it is necessary that participants become aware of the pairings at some point in time (most likely during the conditioning phase) but it is not necessary that they still have contiguity memory during valence measurement. Hence a new CS valence could become established if the input of the learning process (i.e., the CS-US pairing) is at some point in time consciously represented. Once the new valence has been learned, however, it becomes independent of knowledge about the pairings. According to the second interpretation (the recollection-during-measurement hypothesis), it is not sufficient that participants are aware of the stimulus pairings at some point in time. They also need to remember the pairings when CS valence is measured. Hence, a change in valence due to EC remains dependent on memory for the CS-US pairings. Even after a new valence has been established, it will disappear again once the CS-US pairings that led to the EC effect are forgotten.

In the current study, we aimed to single out the influence of recollective memory that is specific for the point in time at which valence is measured. As knowledge available *at the time that* CS valence is measured and knowledge that was available *before* are likely correlated, existing data on the (typically positive) effect of contiguity memory assessed close to valence measurement, do not allow the conclusion that this effect is specifically due to memory at this point in time. We therefore conducted a study that allowed us to better isolate the impact of contiguity knowledge at the time of testing. In our study, the conditioning phase and the valence measurement phase were implemented in two different sessions with several days in between. Contiguity memory was measured during both sessions, that is, first in the session with the conditioning phase and then in the session in which CS valence was measured. This allowed us to assess whether contiguity memory in Session 2 (i.e., contiguity knowledge at the time of testing) specifically predicts EC as assessed in Session 2 over and above contiguity memory in Session 1 (i.e., contiguity knowledge before testing).

We are aware of only one study that used a similar approach. Fulcher and Cocks (1997) also assessed contiguity knowledge at different points in time, albeit using a somewhat unusual conditioning procedure that included presenting each CS-US pair for 20 seconds with an imagery task. The authors found that memory immediately after the learning session was related to EC effects on evaluative ratings that took place two months later. They found no evidence for the role of memory during the second session. In the current study, we will test the influence of memory before and during the valence measurement session in a more prototypical EC paradigm. Moreover, we will measure the EC effect both on an explicit (rating) and an implicit (affective priming) measure. We will return to the study by Fulcher and Cocks in the Discussion.

Although it has been shown that valence memory is sufficient for EC effects to occur (Stahl et al., 2009), we focus on identity memory. For the current research question it is important to measure as precisely as possible the memory regarding a certain CS at two different points in time and to avoid an impact of correct guessing on our measure of contiguity knowledge. Assume that we would consider a participant to have knowledge of a CS-US pair as soon as (s)he correctly indicates the valence of the US that was paired with a

CS (i.e. positive, neutral, or negative). In that case, the chance of correct guessing is one in three. The chance of correctly selecting a specific US by chance is typically lower (i.e., one divided by the number of USs the participant can select from). Using identity instead of valence knowledge is thus a more conservative approach to studying the role of contiguity knowledge in EC. To further decrease the impact of guessing, we also asked participants how sure they were of the indicated pair.

2. Experiment

2.1 Method

2.1.1 Participants. The final sample included 44 students enrolled at Ghent University (40 women, 4 men) who received either course credit or a monetary reward of 8 € for their participation. All participants reported normal or corrected to normal vision and were between 18 and 33 years old (*M* = 20.82; *SD* = 3.06). One additional person participated in Session 1, but not in Session 2, and was therefore excluded from all analyses.

2.1.2 Materials. The CSs were 18 Chinese ideographs (see Payne, Cheng, Govorun, & Stewart, 2005). When presented on the computer screen, they measured 8 by 8 cm. The USs were 18 pictures taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). Six of these (1463, 2057, 2091, 2655, 4599, 5830) had clear positive valence, six were of neutral valence (7000, 7002, 7035, 7235, 7491, 7550), and six had clear negative valence (9300, 9330, 9404, 9415, 9430, 9622). They measured 9 by 7 cm when presented on the computer screen. CSs were assigned to USs by counterbalancing the valence category with which a CS was paired across participants and randomly selecting the specific US within that valence category.

The CSs were also the primes in the affective priming procedure. Positive and negative Dutch nouns selected from Hermans and De Houwer (1994) were used as targets in the affective priming procedure (English translations of positive and negative targets: holidays, wish, hug, present, spring, party; accident, illness, fear, grief, garbage, worries). All stimuli were presented on 19" screens with a 100 Hz refresh rate. The experiment was run using EPrime software.

2.1.3 Procedure. Participants were invited for two experimental sessions of approximately 25 minutes each. Session 1 consisted of a conditioning phase, during which the participants saw the CS-US pairings, a first CS rating phase, and a first CS-US contiguity memory test. Session 2 consisted of a second CS rating phase, a second CS-US contiguity memory test, and an affective priming task.

2.1.3.1 Session 1 – conditioning phase. After participants had given informed consent, they were seated in front of a computer screen on which all instructions appeared. They were informed that during the first phase they would see different stimuli on the screen and were asked to pay attention to these. Participants then saw all 18 CS-US pairs six times each. The 108 trials were separated into three blocks of 36 trials, which appeared immediately one after the other. During each block, each of the 18 pairs was shown twice in completely random order. One trial consisted of the simultaneous presentation of a CS and a US next to each other in the center of the screen for one second. The CS appeared to the left and the US to the right in half of the trials and vice versa in the other half of the trials. The inter trial interval was two seconds.

2.1.3.2 Session 1 – CS ratings. Participants were informed that they would see again several Chinese characters and that their task would be to indicate how positive (visually pleasant) or negative (visually unpleasant) their general impression of the visual appearance of each of the characters is. Participants were asked to indicate their impression of each character on a scale from -10 to +10, and it was mentioned that this would allow them to be precise when making their judgment. The 18 CSs were then shown on the screen one-by-one in random order with a rating scale ranging from -10 to +10 below it. The end and midpoints of the scales were labeled as positive, neutral, and negative, respectively. To rate a character, participants could click on a value with the computer mouse.

2.1.3.3 Session 1 – contiguity memory test. Participants were informed that their task would be to indicate with which photo a Chinese character was paired during the first phase. On each trial, one of the 18 CSs was shown in the center of the screen, surrounded by six USs on the left and right side, which were indicated by the numbers 1 to 6. Two of the USs were positive, two were neutral, and two were negative. One of the six USs was the one with which the CS was paired during the conditioning phase. The other USs were selected randomly for each trial, as was their exact position on the screen. The participant was asked to enter the number corresponding to the US, he or she thought was paired with the CS during the conditioning phase. After each trial, the participant was asked how sure he or she was with his/her selection by indicating one of the options “very sure”, “rather sure”, or “unsure (just guessed)”. Contiguity memory was assessed for all 18 CSs in random order.

2.1.3.4 Session 2 – CS ratings. Session 2 took place 9 or 10 days later at a time that had been arranged during the first session.[1] Prior to the second session, participants had been given no further information on whether the second session was somehow related to the first session. Session 2 took place in the same laboratory as Session 1. After participants had given informed consent, they were seated in front of a computer screen on which all instructions appeared. Participants were informed about the CS rating task with the same instruction as in

Session 1. They then rated all CSs again in random order with the same scale as used in Session 1.

2.1.3.5 Session 2 – contiguity memory test. Participants were informed that they would now be asked about recollections from Session 1. With the same instruction as in Session 1, they were then informed about the contiguity memory test. Participants then performed the same contiguity memory task as in Session 1 with new random US assignments for all CSs in random order.

2.1.3.6 Session 2 – affective priming. The affective priming procedure was conducted to obtain an implicit measure of the valence of the positively and negatively paired CSs. Neutrally paired CSs were not included in the affective priming procedure in order to keep it short. Participants were informed that they would see Chinese characters rapidly followed by words. They were asked to judge as quickly as possible whether the word was positive or negative, and press the right key (‘‘L’’) for positive and the left key (‘‘S’’) for negative words. They were asked to respond before the word disappeared from the screen after 750 ms. A trial started with the presentation of a fixation cross for 500 ms. After an interval of 500 ms, the prime (a CS) appeared on the screen for 200 ms. Immediately after the offset of the prime, the target appeared on the screen (stimulus onset asynchrony 200 ms), where it remained up to 750 ms or until the participant responded. If a participant responded after the disappearance of the target, the message “TOO SLOW!” was displayed in red letters for 1500 ms. The next trial started after an interval that varied randomly between 500 and 1500 ms.

Participants started with a practice block of twelve randomly ordered trials. Twelve Chinese characters not previously shown in the experiment were used as primes in combination with four positive and four negative nouns not used in the main part of the affective priming procedure. Participants received feedback on erroneous responses only during this practice phase. To increase motivation, participants were reminded again to work fast after the practice block. The main block started with four randomly ordered warm-up trials in which four of the practice primes were combined with two positive and two negative practice targets. In the main part of the affective priming procedure, each of the 12 CSs that was either paired with a positive or a negative US in the conditioning phase was used as a prime once with each of the 12 (six positive, six negative) targets. The main part of the affective priming procedure thus consisted of 144 trials. The 144 trials were presented in a new semi-random order for every participant with the following restrictions: The trials were divided into six blocks of 24 trials, in which each of the 12 CSs (six positive, six negative) was presented once with a positive and once with a negative target. The same target was never presented twice in a row.

2.2 Results

2.2.1 Choices during memory tests

On average participants selected the correct US for 14.09 (*SD* = 4.62) of 18 CSs in Session 1 and for 10.68 CSs (*SD* = 4.25) in Session 2. This difference in the number of correctly indicated pairs is significant, $t(43) = 7.96$, $p < .001$. More detailed information about choices on the contiguity knowledge tests during Session 1 and Session 2 can be found in Tables 1 and 2. Most importantly, the pattern of choices provides little evidence for the idea that participants chose USs based on the valence of the CSs rather than based on their actual memory of the CS-US pairings (see Bar-Anan et al., 2010, and Hütter et al., in press, for a discussion). At Session 1, the total number of incorrect selections was 172. In 34 (19.78 %) of these cases, an incorrect US of the correct valence was selected, which is almost identical to the 20 % that can be expected on the basis of chance (only one of the five incorrect US options had the same valence as the actual US). At Session 2, the total number of incorrect selections was 322. In 66 (20.50 %) of these cases a US of the correct valence was selected, which again is almost identical to what can be expected on the basis of chance. Although this analysis does not control for the effect for pre-experimental (i.e., unconditioned) differences in CS valence, it does suggest that guessing based on conditioned valence was, if present at all, not a dominant strategy.

To explore the possibility of an impact of conditioning independent valence on contiguity guessing, we grouped the 18 Chinese ideographs based on their overall (condition independent) ratings into three groups of most liked, neutral, and least liked Chinese ideographs. We used a binary logistic regression, whereby the standard errors were estimated using the Generalized Estimating Equations approach (e.g., Halekoh, Hojsgaard, & Yan, 2006), to test whether this grouping predicted whether an ideograph was judged to have been paired with a positive vs. negative US. We found no evidence for this, neither in Session 1 (liked ideographs: 87 positive US judgments vs. 89 negative US judgments; disliked ideographs: 80 positive vs. 95 negative), nor in Session 2 (liked ideographs: 84 positive vs. 107 negative; disliked ideographs: 79 positive vs. 80 negative), both $p > .40$.

2.2.2 EC and Contiguity Memory. The relationship of EC and contiguity memory was analyzed at the level of the CS-US pairs (Pleyers et al., 2007). We therefore classified each positively, neutrally, and negatively paired CS as remembered or not remembered both for Session 1 and Session 2 separately. Although the pattern of selected USs does not suggest that guessing had a strong impact on the response pattern (see Section 2.2.1), our selection of criteria aimed at further reducing a possible impact of guessing: A CS was classified as remembered for a given session if the participant correctly indicated the US it was paired with (i.e., correct identity memory) and if he/she indicated to be “rather sure” or “very sure” of his/her choice.[2] For mainly exploratory reasons, we also included certainty at Session 1 and certainty at Session 2 as factors in the analysis (see also Section 3).[3]

Analyzing the influence of these factors with a standard repeated measures ANOVA, would have led to substantial data loss, as for many participants at least one of the cells was empty. We therefore performed the statistical analysis of the rating and affective priming data with item-based linear mixed effects models (multilevel model analysis) as implemented in R package lme-4 (R Development Core Team, 2011). These models allow to base the analysis on items (rather than participants' means) and simultaneously control for random effects of participants and items while assessing relevant (fixed) factors of interest (Baayen, Davidson, and Bates, 2008; Hoffman & Rovine, 2007; Locker, Hoffman and Bovaird, 2007).

The relevant fixed factors included in this analysis are: *Valence* (CS_{neg}, CS_{neut}, CS_{pos}, coded -1, 0, 1, respectively), contiguity memory *at Session 1 (CM1*; *not remembered, remembered,* coded 0, 1, respectively), contiguity memory *at Session 2 (CM2*; *not remembered, remembered*, coded 0, 1, respectively), *certainty at Session 1 (Certainty 1*: *very sure, rather sure, unsure*, recoded into two dummy variables with 'very sure' as the baseline) and *certainty at Session 2 (Certainty 2: very sure, rather sure, unsure*, recoded into two dummy variables with 'very sure' as the baseline).

2.2.2.1 Model Building Strategy. The analysis of both the rating and the affective priming data consisted of the following steps. First, we defined a model with valence as a fixed factor and the grouping variables *participant* and Chinese *character* as random factors (by-participant and by-character random intercept). Next, we tested if by-participant and/or by-character random slopes for valence are additionally needed. In the following steps, the other predictors (CM1, Certainty 1, CM2, and Certainty 2) and the interactions of interest were added as fixed effects to the model one-by-one. Likewise, we tested if by-participant and/or by-character random slopes for these predictors were needed. Following West, Welch, and Galecki (2007), REML-based likelihood ratio tests were used for model comparison if the nested models only differed in the specified random terms. If two nested models only differed in their fixed-effects parameters, the likelihood ratio test was based on the ML estimation.

2.2.2.2 Ratings. Descriptive results are displayed in Figure 1. For the statistical analysis, valence was interpreted as an ordered factor, whereby the conditions negative, neutral, and positive were coded as -1, 0 and 1, respectively. It was not necessary to include the quadratic term of valence since no increase in fit was obtained by adding this term ($\chi^2(4) = 3.29$, $p = 0.51$) to the model. Both random effects of character and participant were necessary. Moreover, it was necessary to include by-participants random slopes for valence. To find out whether a standard EC effect was obtained, we first tested a base model that contained valence as the only fixed factor. The effect of valence was significant, $t = 4.391$, $p < .001$[4,5]. To investigate the influence of contiguity knowledge at Session 1 and 2 on the EC effect at Session 2, we tested a model that contained the following relevant fixed effect factors: the main effects of valence, CM1, Certainty 1, CM2, Certainty 2, and the two-way-interactions of valence and CM1, valence and Certainty 1, valence and CM2, and valence and Certainty 2. No better fit was obtained by including other two-way-interactions or three-way-interactions (see also Footnote 2).

The results of the final model are shown in Table 3. As can be seen, the only significant effect in this models is the interaction of valence and CM2, $t = 3.18$, $p = .001$, which indicates that EC effects are stronger for CSs for which participants show contiguity memory in the valence measurement session (i.e., Session 2). To better understand the nature of this interaction we conducted posthoc test of the effect of valence for CSs categorized as remembered and as not remembered. The EC effect for CSs remembered at Session 2 is significant, $t = 5.53$, $p < .001$. The EC effect for CSs not remembered at Session 2 is not significant, $t = 0.32$, $p = 0.75$. In addition, we tested more specifically whether there is an EC effect for the condition ‘remembered at Session 1, not remembered at Session 2’. No evidence was found for an effect for these ‘first remembered, later forgotten’ pairs, t = -0.63, p = 0.53. No other effects, including the interaction of valence and CM1, were significant in this model.[6]

2.2.2.3 Affective Priming. Due to a computer failure, for one participant no affective priming data were collected. For the analysis of the reaction time data, erroneous responses and response time outliers (RT < 250 ms or RT > 750 ms [the response deadline]), were excluded (9.43% and 2.52 % of all responses, respectively). Based on the remaining response latencies two mean scores for each CS and participant were calculated, one for trials in which the CS was paired with a positive target and one for trials in which it was paired with a negative target. Difference scores were then calculated for each CS and participant by subtracting mean RTs from trials with positive targets from mean RTs from trials with negative targets. An increase in the difference scores indicates more positive evaluations, although absolute values should not be interpreted because of possible unrelated target main effects (e.g., due to word frequency, response hand). Descriptive results are displayed in Figure 2.

In the linear mixed effects model analysis, both random effects of characters and participants were necessary. For the factor valence there were only two levels included in this analysis given that neutral CSs were not presented in the affective priming task. Again, we first tested the presence of a standard EC effect with a simple model containing valence as the only fixed factor. The effect of valence was significant, t = 2.08, p = .04. The more inclusive model contained the same fixed effects as the one used for the analysis of the rating data. No improvement of fit was obtained by including additional terms. The results for the fixed factors of the final model are presented in Table 4. The only significant effect in these models was the interaction of valence and CM2, $t = 2.14$, $p = .03$, indicating that also EC effects on the implicit measure are moderated by contiguity memory at Session 2. Posthoc tests showed that the EC effect was significant for pairs remembered at Session 2, $t = 2.58$, $p = .01$ but not for pairs not remembered at Session 2, $t = 0.39$, $p = .69$. Also for the condition ‘remembered at Session 1, not remembered at Session 2’, no significant EC effect was found, $t = 1.28$, $p = .20$. No other effects, including the interaction of valence and CM1 were significant in this model.[7]

3. Discussion

The aim of the current study was to systematically investigate the influence of contiguity knowledge at the time when the EC effect is assessed. We did so by assessing contiguity memory both during a first session that included the conditioning phase and during a second session that was completed nine to ten days after the first one and that included an explicit and an implicit measure of CS valence. To reduce the influence of guessing on our measures of contiguity memory, contiguity memory was defined as present for a CS if the correct US was identified and if the participant indicated to be at least rather sure of his or her choice.

Importantly, we found a systematic influence of contiguity memory at Session 2 on the EC effect on both an explicit and an implicit valence measure at Session 2. A significant EC effect was found only for pairs that were remembered during the valence measurement session. Contiguity memory at Session 1, on the other hand, did not have a significant influence on EC as indexed by the explicit or the implicit measure of CS valence. Also, the effect of contiguity memory at Session 2 was not further moderated by contiguity memory at Session 1. Crucially, for the pairs that were remembered at Session 1, but not anymore at Session 2 (the first remembered, then forgotten pairs), no EC effect was found.

To defend the position that contiguity memory during the learning session (Session 1) and not during the measurement session (Session 2) is most relevant, the following argument might be made: Pairs that were categorized as remembered for Session 2 might already have been remembered *better* at Session 1 without this being reflected in contiguity memory at Session 1. In this case, the higher quality of memory at Session 1 might have led to better memory at Session 2 and to the EC effect. The certainty reports can inform us whether this explanation holds in the present data. For both the explicit and the implicit valence measure, certainty at Session 1 did not significantly moderate the EC effect. Hence, we have no evidence for such an indirect influence of memory during the learning session on EC effects.

The variable contiguity memory was not manipulated experimentally. Therefore, the conclusion that contiguity knowledge at Session 2 is a cause or a precondition for the EC effect has to be drawn with caution. It can be argued that an EC effect appears independently from contiguity memory and biases memory of the US in the direction of the acquired valence of a CS, which is therefore more likely categorized as remembered (see Bar-Anan et al., 2010; Gawronski & Walther, in press; and Hütter et al., in press, for detailed discussions). Several arguments, however, speak against this interpretation of the current data pattern. First, the pattern of correct and incorrect responses did not suggest a substantial impact of guessing based on the conditioned or unconditioned valence. While there was a substantial number of CSs for which the correct US was selected, the number of CSs for which an incorrect US of the correct valence was selected was not higher than expected from guessing based on the conditioned valence. Also an estimate of the unconditioned valence of the Chinese ideographs did not predict whether a participant thought it was paired with a positive or negative US. Hence, there is little evidence for valence-based guessing in the current study. Second, we used identity memory as criterion. Therefore, even if participants would have selected USs during the memory test based on their liking of the CS, they would still select an incorrect US on half of the trials (i.e., there were two US options for each US valence). Hence, the number of correct guesses based on valence is reduced compared to a valence memory criterion. Third, to further exclude correct selections based on guessing, we classified correctly identified stimuli as remembered only when participants indicated to be at least rather sure. When we conducted an additional analysis with an even stricter memory criterion (i.e., only choices that participants were very sure of), a similar pattern of results was observed. For these reasons, we think that it is more likely that contiguity memory during valence measurement was a precondition for the EC effect than the other way around.

The current results are in line with a number of recent studies that showed the necessity of contiguity knowledge in stimulus based analyses (e.g., Pleyers et al., 2007) and go beyond these studies by demonstrating that specifically memory during valence measurement can determine EC effects. On the other hand, the current results stand in contrast with recent work by Hütter and colleagues (in press). These authors developed a process-dissociation paradigm to overcome the valence-based guessing bias and used it to demonstrate that EC can occur independently of contiguity memory, both immediately after the conditioning phase and after a delay of 24 hours When interpreting these contrasting findings, it is important to note, however, that the two lines of research have a different focus. In contrast to Hütter and colleagues, we investigated the influence of memory on EC, and did not focus on the question of whether EC without memory is possible. Although we found no significant EC without memory, and although we believe that our test was not strongly biased by valence-based guessing, it has to be pointed out that our results do not exclude the possibility that EC can occur without contiguity memory. Nevertheless, it might be interesting to consider whether one of the several differences in the procedures and materials of our study and those of Hütter and colleagues might explain the different results. It might for example be relevant that in our study a specific CS was always paired with a specific US, while in the study by Hütter and colleagues a specific CS was paired with multiple USs. As the authors point out, single vs. multiple pairings might lead to EC via different processes. For example, single pairings might lead to stimulus-stimulus learning, while multiple pairings might lead to stimulus-response learning (Sweldens, van Osselaer, & Janiszewski, 2010). Future research might investigate the intriguing possibility that single vs. multiple pairings might also lead to different results regarding the necessity of contiguity knowledge for EC.

Our results give important information about the processes underlying EC effects. A current debate in the literature on EC deals with the question whether EC effects are due to the automatic formation of associations between the CSs and the USs (e.g., Baeyens, Eelen, Crombez, & Van den Bergh, 1992; Baeyens, Eelen, & Crombez, 1995; Gawronski & Bodenhausen, 2006) or to the non-automatic formation of conscious propositional knowledge about the relation between the CSs and the USs (e.g., Corneille, Yzerbyt, Pleyers, & Mussweiler, 2009; De Houwer, 2007; De Houwer, 2009; Förderer & Unkelbach, in press; Gast & De Houwer, 2011; Hofmann et al., 2010, Mitchell, De Houwer, & Lovibond, 2009; Zanon, De Houwer, & Gast, this issue). The necessity of contiguity knowledge for EC effects is an argument for propositional models because it suggests a causal relationship between propositional knowledge (of the pairings) and EC effects (see Lovibond & Shanks, 2002, for more details). Still, it is not completely impossible for associative models to account for a relation of EC and contiguity knowledge. If one assumes that a CS-US association of certain strength can produce both propositional contiguity knowledge and changes in liking, then it can be explained why propositional knowledge and EC are correlated (e.g., Gawronski & Bodenhausen, 2011; also see Lovibond & Shanks, 2002). The current study, however, suggests that EC does not only relate to the acquisition of propositional contingency knowledge, but that it also depends on the maintenance of this knowledge. This finding is more parsimoniously explained by assuming that EC effects are due to propositional contingency knowledge than by assuming that EC effects are due to associations that appear and disappear at the same time as propositional knowledge. Our results, however, also go beyond the basic assumption of propositional models, which claim that associative learning effects are “the result of the non-automatic generation and evaluation of propositions about the relations between events” (De Houwer, 2009, p. 1). The current results suggest EC effects are not only dependent on the generation of propositions, but also on their maintenance.

Current propositional models focus on the necessity of availability of propositional knowledge at some point, but they are less explicit about the way in which contiguity knowledge might lead to EC effects. We see two possibilities that are in line with the current results. The first possibility is that the CS triggers a conscious memory of the US, which is accompanied by a positive or negative evaluation that automatically influences the evaluation of the CS. This option describes a learning process that is non-automatic (*conscious* memory is necessary) and a performance process that is automatic (conscious memory *unintentionally* influences CS evaluation). The second possibility is that people see the fact that a CS was paired with a US of a certain valence as sufficient reason for liking or disliking the CS (De Houwer, Field, & Baeyens, 2005). In this case, both the learning of propositions and their impact on liking are assumed to be non-automatic.

It is important to realize that the current results do not imply that people are always able to point out the cause of their likes and dislikes. First of all, not all likes and dislikes are due to EC, but can for example be inborn, due to emotion processes, or based on other types of learning. Second, our study does not preclude that under different conditions EC effects could still occur after the pairings are forgotten. It would be interesting to examine these conditions in future research. One could, for instance, argue that a longer passage of time could allow for such a finding (see for example Baeyens, Crombez, Van Den Bergh, & Eelen, 1988; Fulcher & Cocks, 1997). We doubt, however, that the passage of time alone would allow these effects. In our study, participants had already forgotten a considerable amount of stimulus pairings after nine or ten days. For these stimuli no EC effects were found. A longer interval might have increased the number of forgotten pairs, but we consider it unlikely that the results would have been qualitatively different and assume that also for these pairs the EC effect would have faded with contiguity memory.

A different result might be expected if another process is induced that allows maintenance of the acquired attitude towards the CS independently of CS-US memory. On a cognitive process level, the formation of a direct mental link between the CS and the evaluative response (an S-R link) might account for EC in the absence of CS-US memory. Once such a link is formed, it can be said that the valence “intrinsically” belongs to the CS (e.g., Baeyens et al., 1992). While EC in most cases seems to be based on a mental link between the CS and the US (S-S link, e.g., Walther, Gawronski, Blank, & Langer, 2009), it has been shown that under some conditions it is based on an S-R link (Gast & Rothermund, 2011a, Gast & Rothermund, 2011b, Jones et al., 2009; Sweldens et al., 2010). If, for example, the participant judges stimuli on the evaluative dimension during conditioning, a direct S-R link is formed (Gast & Rothermund, 2011a). Under conditions that promote the formation of S-R links, the memory for the stimulus pairings might not be necessary. It seems also possible to form a link between the CS and an evaluative response *after* the conditioning phase (and thus after the initial learning of the CS-US contingency). If, for example, the acquired attitude towards a CS is repeatedly expressed or thought about, the CS might become linked to these repeated thoughts, responses, and evaluations. This might perpetuate the evaluation that was initially due to the contingency with the US. These supportive new links do not necessarily have the form of a simple S-R link. Once a stimulus starts being liked or disliked, it is possible that a whole network of supportive valence congruent ideas and justifications develops around it.

The results of Fulcher and Cocks (1997) could be interpreted in this light. In contrast to the present study, Fulcher and Cocks found evidence that EC is related more to contiguity knowledge immediately after the learning session than during CS valence testing. This difference in results might be attributed to several differences between the experiments. For example, contiguity memory was measured with a free recall test by Fulcher and Cocks, which is (although the authors used liberal criteria) arguably less able to identify all recollections than the multiple-choice test used in our study. Another difference with our study was that participants in the Fulcher and Cocks study were asked during the conditioning phase to imagine how the CSs (pictures of plants) and the USs (valent words unrelated to plants) interacted. This task might have induced processes that allowed maintaining CS valence independent of contiguity memory. Being explicitly asked to imagine the interaction of CS and US, the CS might have become linked to concepts different from the US, but evaluatively congruent with it or even directly to congruent evaluative responses. Similarly, participants might have re-interpreted the CSs in an evaluatively congruent way. Such processes might have made the new CS valence independent from the US and therefore allowed EC effects without CS-US contiguity memory at the later valence measurement. Further research might investigate these and other possible boundary conditions for the necessity of contiguity memory during valence measurement.

The current research might be relevant for attitude research beyond EC. In attitude research it is widely accepted that people are often unaware of the sources of their attitudes (e.g., Nisbett & Wilson, 1977). For EC, however, there is comparatively little evidence that it can occur without knowledge of the source of the attitude, that is, the stimulus pairings. While research on verbally reported attitudes focuses on awareness while the attitude is being expressed, EC research focuses more on the learning process itself. Most previous evidence suggesting the necessity of contiguity knowledge for EC either was or at least could have been attributed to encoding processes during learning. The present research, however, suggests that contiguity knowledge is relevant not only during learning, but also when the new attitude is measured. The current results, therefore, seem to be even more at odds with the widely reported inability to report causes of an attitude than previous findings on EC and contiguity memory. An important difference between the two research areas is that they typically focus on different aspects of the cause for an attitude. While research on contiguity knowledge in EC focuses on the stimulus constellation as the cause (but see e.g., Baeyens et al., 1988; Bar-Anan et al., 2010), research on verbal reports typically focuses on whether a person is aware of the causal process, that is of the relation between the stimulus constellation and the attitude (see also Moors & De Houwer, 2006). In both areas it might therefore be interesting to focus more also on the respective other aspect of the cause of an attitude change.

To summarize, our results show for the first time that contiguity memory during CS valence measurement can be a precondition for finding EC effects. We think that we have chosen a prototypical EC paradigm, and that this finding is therefore relevant for interpreting findings on EC and contiguity memory. It is nevertheless possible that under different conditions memory during valence measurement is not necessary. Future research might investigate these boundary conditions.

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6. Appendix

Table 1

Distribution of correct and incorrect assignments of US to CS at Session 1

Correct US 620			Incorrect US 172					
			Correct valence 34			Incorrect valence 138		
Very certain	Rather certain	Un-certain	Very certain	Rather certain	Un-certain	Very certain	Rather certain	Un-certain
467	113	40	2	11	21	5	45	88

Table 2

Distribution of correct and incorrect assignments of US to CS at Session 2

Correct US 470			Incorrect US 322					
			Correct valence 66			Incorrect valence 256		
Very certain	Rather certain	Un-certain	Very certain	Rather certain	Un-certain	Very certain	Rather certain	Un-certain
215	160	95	5	18	43	14	70	172

Table 3

Fixed effects and their interactions from the linear mixed effects model analysis of the rating data using REML estimation

Predictor	*B*	*SE(B)*	*t*	*p*
Intercept	0.50	0.87	0.57	0.57
Valence[a]	-0.49	1.06	-0.46	0.64
CM1 (remembered)	1.20	0.66	1.81	0.07
Certainty 1[b]			$\chi^2(2) = 5.37$	0.07
Certainty 1 (rather sure)	-0.63	0.47	-1.35	0.18
Certainty 1 (unsure)	0.67	0.79	0.86	0.39
CM2 (remembered)	-0.33	0.52	-0.6	0.53
Certainty2			$\chi^2(2) = 2.10$	0.35
Certainty2 (rather sure)	-0.41	0.42	-0.96	0.33
Certainty2 (unsure)	0.20	0.62	0.33	0.74
Valence x CM1 (remembered)	1.30	0.87	1.50	0.13
Valence x Certainty 1			$\chi^2(2) = 0.54$	0.77
Valence x Certainty 1 (rather sure)	0.09	0.57	0.15	0.88
Valence x Certainty 1 (unsure)	0.69	1.02	0.68	0.50
Valence x CM 2 (remembered)	**2.01**	**0.63**	**3.18**	**<.01**
Valence x Certainty 2			$\chi^2(2) = 4.26$	0.12
Valence x Certainty 2 (rather sure)	-0.94	0.53	-1.78	0.08
Valence x Certainty 2 (guessing)	-0.21	0.77	-0.27	0.78

[a]As we used dummy coding the effect of valence and other main effects cannot be interpreted directly from the table. The average effect of valence over all conditions as derived from deviation coding is $t = 3.55$, $p < .001$, but is qualified by the interaction with memory at Session 2.

[b]For effects including more than two levels, the likelihood ratio test from the model comparison is given.

Table 4

Fixed effects and their interactions from the linear mixed effects model analysis of the reaction time data using REML estimation

Predictor	*B*	*SE(B)*	*t*	*p*
Intercept	4.84	16.04	0.30	0.76
Valence[a]	-7.50	21.83	-0.34	0.73
CM1 (remembered)	-3.26	12.96	-0.25	0.80
Certainty 1[b]			$\chi^2(2) = 0.74$	0.69
Certainty 1 (rather sure)	-7.32	8.70	-0.84	0.40
Certainty 1 (unsure)	0.28	15.74	0.02	0.99
CM2 (remembered)	-5.20	9.50	-0.55	0.58
Certainty2			$\chi^2(2) = 3.49$	0.17
Certainty 2 (rather sure)	6.90	7.86	0.88	0.38
Certainty 2 (unsure)	-5.56	11.49	-0.48	0.63
Valence x CM1 (remembered)	-1.90	17.96	-0.11	0.92
Valence x Certainty 1			$\chi^2(2) = 0.48$	0.79
Valence x Certainty 1 (rather sure)	7.88	12.12	0.65	0.52
Valence x Certainty 1 (unsure)	3.71	21.09	0.18	0.86
Valence x CM 2 (remembered)	**28.88**	**13.53**	**2.14**	**0.03**
Valence x Certainty 2			$\chi^2(2) = 3.38$	0.18
Valence x Certainty 2 (rather sure)	-10.10	11.18	-0.90	0.37
Valence x Certainty 2 (unsure)	11.04	16.10	-0.69	0.49

[a]As we used dummy coding the effect of valence and other main effects cannot be interpreted directly from the table. The average effect of valence over all conditions as derived from deviation coding is $t = 2.041$, $p = 0.04$, but is qualified by the interaction with memory at Session 2.

[b]For effects including more than two levels, the likelihood ratio test from the model comparison is given.

Figure 1

Mean CS ratings for the factors valence, contiguity memory at Session 1, and contiguity memory at Session 2. No data are available for the condition positive valence, not remembered at Session 1, remembered at Session 2. Error bars represent standard errors for cell means calculated based on individual CS ratings (not participant means).

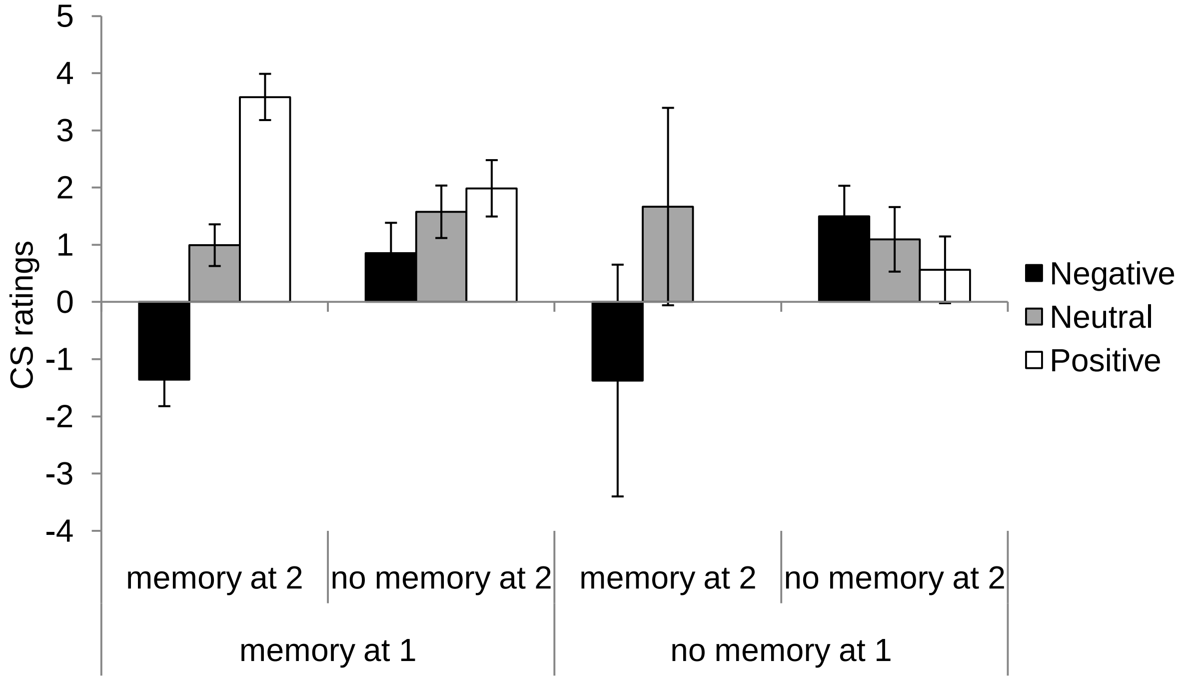
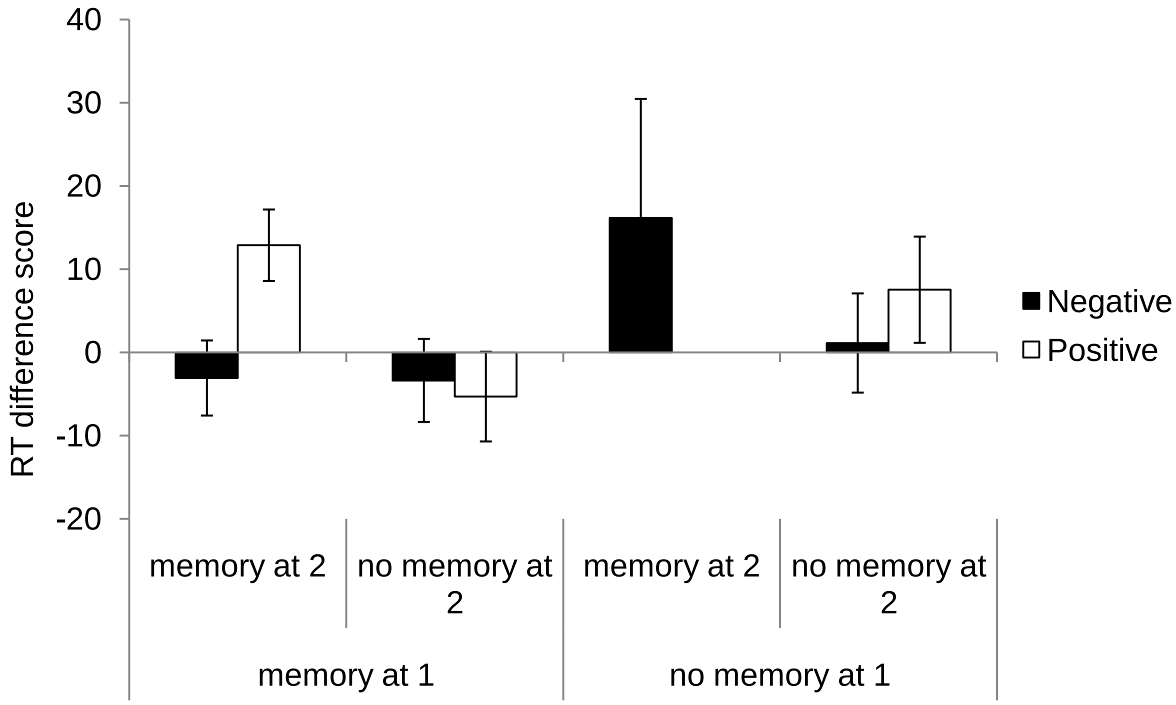


Figure 2

Mean CS difference scores for the factors valence, contiguity memory at Session 1, and contiguity memory at Session 2 based on mean RTs (negative targets trials - positive target trials) in the affective priming task. No data are available for the condition positive valence, not remembered at Session 1, remembered at Session 2. Error bars represent standard errors for cell means calculated based on individual CSs.



Footnotes

[1] One participant missed the second appointment and participated later, which resulted in an interval of 13 days between Session 1 and Session 2.

[2] Analyses in which only correct selection was used as contiguity memory criterion (and certainty as a separate factor) led to a similar result pattern and to the same conclusions.

[3] Due to linear dependency of the factors CM1 and Certainty 1, as well as CM2 and Certainty 2, respectively, only the main effects and not the interactions of the respective factors could be included in the model.

[4] P-values are estimates based on the degrees of freedom for the z-distribution, which is similar to the t-distribution when case numbers (i.e. participants × characters) are high.

[5] The ratings in Session 1 also showed an EC effect, $t = 7.72$, $p < .001$.

[6] We conducted two additional analyses. The first one used a valence memory criterion. CSs were categorized as remembered when the participant selected either the correct US or a wrong US of the same valence. In this analysis both the interaction of valence with memory at Session 1, $t = 2.34$, $p = .02$, and valence with memory as Session 2, $t = 5.28$, $p < .001$, are significant. The second additional analysis used a criterion according to which only those CSs were categorized as remembered for which participants selected the correct US and indicated to be very sure. In this analysis only the interaction of valence and contiguity memory at Session 2 was significant, $t = 4.04$, $p < .001$.

[7] In an analysis with valence memory as criterion (see Footnote 6 for details) the interaction of valence and contiguity memory at Session 2 is the only significant effect, $t = 3.05$, $p = .002$. In an analysis with the stricter criterion (correct selection and ‘very sure’) no significant

results were found. There is a tendency, however, towards an interaction of valence and contiguity memory at Session 2, $t = 1.585$, $p = .11$.