Return of experimentally induced chocolate craving after extinction in a different context: Divergence between craving for and expecting to eat chocolate

Dinska Van Gucht, Debora Vansteenwegen, Tom Beckers, Omer Van den Bergh*

Department of Psychology, University of Leuven, Tiensestraat 102, B-3000 Leuven, Belgium

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Abstract

Unlike in fear conditioning, little attention has been devoted to extinction and renewal in appetitive conditioning, despite its relevance for extinction-based addiction treatments. We developed a paradigm, using a specific tray as a conditioned stimulus (CS) for eating chocolate (unconditioned stimulus, US), to investigate the effects of context change on acquisition and extinction of conditioned chocolate craving using an ABA renewal design. In Study 1 (n = 32), participants successfully acquired chocolate craving, but unlike what is commonly observed in fear conditioning, craving did not extinguish. In Study 2, we separately assessed craving and US expectancy in a between-subjects design (n = 64). US-expectancy data showed acquisition, extinction and renewal in the ABA group. The craving data did not follow this pattern, suggesting different mechanisms for craving and US expectancy. Similarities and differences between craving and US expectancy, as well as practical implications, are discussed.

Introduction

Craving for chocolate, the food most frequently craved in Western cultures (Pelchat, 1997; Rogers & Smit, 2000; Rozin, Levine, & Stoess, 1991), is not harmful for the majority of people (Lafay et al., 2001). However, as a potential element of an unhealthy life style, like every food consumed in excess, it can contribute to weight problems, and in some cases rise to the level of binge eating (Kales, 1990). Next to that, it may also subjectively be experienced as unwanted. Chocolate craving is highly prevalent in the general population, especially in women (in 40% of females and 15% of males; Rozin et al. (1991), with prevalence differing by culture, see e.g., Osman & Sobal, 2006). Because it is largely unconfounded by psychiatric co-morbidity (unlike, for example, alcohol dependence and binge eating; Jansen, 1998), it allows to investigate craving and craving reduction techniques in a relatively unconfounded manner and in easily accessible populations (Weingarten & Elston, 1991).
For any attempt to reduce chocolate craving, it is relevant to understand the cues and processes underlying the craving response to chocolate. Several processes have been proposed either citing the pharmacological characteristics of chocolate (e.g., Polivy, Coleman, & Herman, 2005), the mood-enhancing effects of chocolate (Parker, Parker, & Brotchie, 2006), or the involvement of sex hormones (e.g., Zellner, Garriga-Trillo, Centeno, & Wadsworth, 2004), but none of them appear satisfactory to explain chocolate craving (for a more elaborate discussion, see Van Gucht et al., 2008). For example, comparing the role of sensory and pharmacological properties of chocolate revealed that the former but not the latter satisfied the craving response (Michener & Rozin, 1994). In line with this, chocolate cravers reported that non-chocolate substitutes were inadequate to abate their craving (Polivy et al., 2005; Weingarten & Elston, 1991). In sum, results suggest that pharmacological factors play little—if any—role in the satisfaction of craving (Rogers & Smit, 2000).

Cultural differences, for example the observation that Spanish women report much less premenstrual chocolate craving than American women (Osman & Sobal, 2006; Zellner et al., 2004) could be framed by assuming that chocolate craving is triggered by classically conditioned food cues. Jansen (1998) and Zellner and Edwards (2001) suggested that conditioning is strongly involved in the production of food (and thus also chocolate) craving. Neutral stimuli or cues that have been repeatedly associated with food intake can, over time, come to elicit anticipatory reactions such as explicit outcome expectancies, autonomic responses (e.g., salivation) and subjective craving. So, with repeated consumption of chocolate during the perimenstruum, moods and typical feelings during this period may become conditioned cues for the high incentive value of the sensory properties of chocolate.

In classical conditioning, extinction refers to the loss of conditioned responding (such as craving) when a cue (like chocolate) that has previously been associated with a significant event (like eating), is repeatedly presented by itself (Pavlov, 1927; Rescorla, 2001). Therefore, the conditioning model of food craving (Jansen, 1998; Zellner & Edwards, 2001) provides a valuable heuristic tool for devising techniques to reduce chocolate craving. Van Gucht et al. (2008) indeed showed that repeated cue exposure (the clinical equivalent of extinction) successfully reduced chocolate craving in female chocolate cravers, both in terms of self-reported craving (a subjective measure of craving), and in terms of the amount of saliva secreted (an objective measure of craving), between sessions.

Notwithstanding the success of cue exposure in reducing chocolate craving, binge eating (Jansen, Broekmate, & Heymans, 1992), urge to drink alcohol (Drummond, Tiffany, Glautier, & Remington, 1995), and a wide range of anxiety responses (for meta-analytical reviews, see for example Abramowitz, 1996; Clum, Clum, & Surls, 1993; Taylor, 1996), many people relapse after being successfully “cured”. Return of fear after successful cue exposure therapy is a well-documented phenomenon (Rachman, 1989), as is relapse into addiction (Havermans & Jansen, 2003).

As a result, important questions remain, such as how to explain the return of responses like fear and craving after they have been successfully extinguished through cue exposure, and how to translate such explanations into clinical practice to improve extinction-based therapies. Bouton (2000) and others (e.g., Conklin & Tiffany, 2002) argue that we should not give up on cue exposure yet. Modern learning theory can provide a valuable model to conceptualize problems of maintenance of behavior change. Particularly, research has shown that extinction does not necessarily involve the destruction of previously acquired associations, but rather reflects new learning (Bouton, 2002). As a result, after extinction, a conditioned cue becomes ambiguous as it may evoke both old and new associations. This ambiguity can be resolved by the context in which the cue is presented. Several effects of context on extinction performance have been documented, amongst which are renewal (Bouton & Bolles, 1979) and spontaneous recovery (Pavlov, 1927). Renewal is defined as the return of previously extinguished conditioned responding when a context switch takes place after extinction. For example, translating renewal clinically, a patient whose craving for alcohol is successfully extinguished by cue exposure therapy in a treatment clinic risks relapse through renewal of craving upon changing contexts such as when returning home. Spontaneous recovery is the return of conditioned responding through the mere passage of time and can be seen as a special case of renewal when time is considered as a context.

In the domain of fear conditioning, the mechanisms of extinction and renewal have been investigated extensively in animal studies (e.g., Bouton & Bolles, 1979; Bouton & King, 1983; Bouton & Peck, 1989; Harris, Jones, Bailey, & Westbrook, 2000; Rauhut, Thomas, & Ayres, 2001), laboratory studies with humans (Effting & Kindt, 2007; Vansteenwegen et al., 2005; Vansteenwegen, Francken, Vervliet, Declerq, Eelen, 2006;
Vansteenwegen, Vervliet, Hermans, Beckers, Baeyens, Eelen, 2006; Vervliet, Vansteenwegen, Baeyens, Hermans, & Eelen, 2005), clinical analog studies (Vansteenwegen et al., 2007), and treatment outcome studies (Mineka, Mystkowski, Hladek, & Rodriguez, 1999; Mystkowski, Mineka, Vernon, & Zinbarg, 2003). The wealth of findings documenting context dependency of extinction suggests ways to counter renewal, such as increasing the number of extinction trials (Denniston, Chang, & Miller, 2003), conducting exposure in multiple contexts (Chelonis, Calton, Hart, & Schachtman, 1999; Gunther, Denniston, & Miller, 1998; Vansteenwegen et al., 2007), and reminding the subjects of the extinction context by means of retrieval cues (Brooks & Bouton, 1994; Vansteenwegen, Francken et al., 2006; Vansteenwegen, Vervliet et al., 2006).

In contrast to these findings in the fear domain, and notwithstanding the widespread use of cue exposure in the treatment of addiction, far less translational research has been conducted on extinction and its context dependency in the appetitive domain (for a few exceptions see Collins & Brandon, 2002; Thewissen, Snijders, Havermans, van den Hout, & Jansen, 2006). This substantial lacuna was also noticed by Conklin and Tiffany (2002) in a recent meta-analytical review. They argued that the limited efficacy of cue exposure in the treatment of addiction may be improved by relying on findings on animal and human fear extinction. One aim of the research reported here was to help fill this gap.

In addition, it remains an open issue to what extent distinct conditioned responses, such as subjective craving and outcome expectancies, correlate for instance in their degree of sensitivity to extinction. There are instances of acquired responding for which research has shown that disruption of conditioned stimulus (CS)–unconditioned stimulus (US) contingencies does not necessarily lead to extinction of conditioned responding. In particular, evaluative conditioning research has demonstrated that acquired likes and dislikes are quite insensitive to extinction (for a review see De Houwer, Thomas, & Baeyens, 2001). Accordingly, an additional aim was to assess to what extent conditioned craving responses and outcome expectancies would be similarly sensitive to extinction.

To summarize, in the present studies, we wanted (1) to develop a paradigm to induce differential acquisition of chocolate craving in humans, (2) to investigate extinction and context effects such as renewal and spontaneous recovery, and (3) to examine the relationship between different conditioned responses. We modeled our design after the studies of Collins and Brandon (2002) and Thewissen et al. (2006), and modified it into a differential ABA design.

**Experiment 1**

In this first experiment, in the acquisition phase two neutral stimuli were presented, one that was repeatedly paired with the opportunity to eat chocolate (CS+) and one that was never paired with the opportunity to eat chocolate (CS−). We expected to find a significant difference in responding between the two CS types by the end of the acquisition phase, indicating differential acquisition. In a subsequent extinction phase, the two stimuli were presented without the US (i.e., eating chocolate). One group received extinction in the same context in which acquisition took place (AAA group), whereas the other group received extinction in a different context (ABA group). We expected the acquired difference in responding to disappear by the end of the extinction phase in both groups. Following extinction, all participants were presented with both stimuli in their original acquisition context, upon which we expected to observe a renewed difference between CS types for the ABA group because of the context switch.

Responding on every trial was assessed by asking the participants to rate their subjective craving. Afterwards, participants were also asked to indicate their expectancies to get to eat chocolate (i.e., retrospective US expectancies).

**Method**

**Participants**

Thirty-two first year psychology students (27 women) at the University of Leuven, aged between 17 and 21 years (\(M = 18.37, \ SD = .84\)), participated in return for course credit.
Settings

In a pilot study \((n = 32)\) with a similar design as the studies that are reported here, we obtained differential acquisition of subjective chocolate craving. In this pilot study, two different rooms were used to manipulate context. However, manipulation checks showed that both contexts differed in terms of their perceived reference to chocolate and in terms of their physical characteristics, which caused a loss of the acquired differential craving upon changing contexts in the ABA group. Therefore, in order to create two different contexts, we now opted for using different lighting conditions in one and the same room, a context manipulation successfully used by Vansteenwegen et al. (2005). The room was small and largely empty and it only contained a chair for the experimenter and a simple couch for the participant adjacent to a little table. There were no windows and the floor was covered by wall-to-wall carpet. In the dark context, only two small lights—and no central lighting—were turned on, whereas in the light context the central lighting and the two small lights were switched on. Both the dark and the light context served as context A and context B, counterbalanced across participants.

Stimuli

Before the experiment, all participants were asked what their favorite kind and brand of chocolate was so that for every participant we could prepare 28 individually packed pieces of their favorite chocolate in aluminum foil. One piece of chocolate was approximately 2 cm². Two serving trays containing a piece of chocolate (one tray rectangular and white, the other round and green) were used as conditioned stimuli. One of the trays (CS+) was sometimes followed by the US (i.e., eating chocolate), while the other one (CS−) was never followed by the US. The assignment of the trays as CS+ and CS− was counterbalanced across participants.

Measures

Acquisition, extinction and test phase

The main dependent measure in this experiment was self-reported craving for chocolate, as assessed on a 100 mm visual analog scale (VAS). The VAS was accompanied by the following question: “How strong is your craving for chocolate at this moment?” and ranged from no craving at all to extremely strong craving (the scale did not contain any other marks or labels).

Post-experimental questionnaire

In addition to the craving ratings, participants were also asked to retrospectively draw the evolution of their US expectancies during the experiment. They were presented with a graph, containing on the Y-axis a 100-point US expectancy scale ranging from 0 (certainly no chocolate) to 100 (certainly chocolate). The X-axis was divided according to the three phases (labeled A, E and T) of the experiment. In the AAA group no explanation was given about the phases (since participants in this group did not notice any contextual changes). Although these participants were not told explicitly about the three different phases, they did see different phases depicted in the graph. So, participants in the AAA group could think back of the shorter phase in the beginning of the experiment where they received chocolate and of the longer period without eating chocolate, and perceive the last phase as ’almost the end of the experiment’. Participants in the ABA group were told that the first phase was before the lights were switched on (/off), the second phase was after the lights were switched on (/off), and the third phase was after the lights were switched off (/on) again. They were asked to indicate to what extent they expected the US upon being presented with each of the CSs twice in each phase (at the beginning and at the end), resulting in six ratings each for the CS+ and the CS−.

Procedure

Participants were asked to refrain from eating chocolate 24 h prior to the experiment. In the pre-acquisition phase they met the experimenter, received an introduction about the experiment and were asked to fill out an
informed consent form. At the start of the acquisition phase they were shown the two serving trays and were told that one of the trays would sometimes be accompanied by the opportunity to taste chocolate and that the other would never be followed by the opportunity to eat chocolate. Unlike Thewissen et al. (2006), we did not tell explicitly which tray would be accompanied by the US. In the acquisition phase eight trials were conducted, four CS+ trials and four CS− trials, in a random order based on the toss of a coin, with the restriction that no more than two subsequent trials were of the same type.

A trial proceeded as follows: participants were presented with the serving tray and were instructed to pay attention to the color of the tray and to note their feelings and thoughts during that time. Participants were then presented with a first VAS on which they were asked to rate their craving for chocolate. The experimenter then placed the chocolate cue on the tray and asked the participant to take the piece of chocolate, unwrap it and start smelling the chocolate for approximately 1 min. Then the participant was again instructed to rate her/his craving on the next VAS. Next, the occurrence (CS+) or non-occurrence (CS−) of tasting the chocolate followed, depending on which tray they were presented with, after which the tray, along with the chocolate in case of a CS− trial, was removed from the participant’s sight. After a 30 s break, the next trial started.

Sixteen trials (eight CS+ trials, eight CS− trials, randomized as before) were presented in the extinction phase. Apart from the fact that participants were never allowed to taste the chocolate presented to them anymore, the course of the trials was identical as for the acquisition phase. For half of the participants (n = 16), this phase was carried out in the same context as acquisition (AAA group), for the other half (n = 16) extinction was carried out in the other context (ABA group).

All participants were then tested in their original acquisition context. Four test trials were presented (two for the CS+, two for the CS−). Half of the participants started with the CS+, the other half with the CS−. The second trial always contained the opposite CS as the first trial, the third and fourth trial were determined by the toss of a coin. As for the extinction phase, participants were never allowed to taste the chocolate presented to them in the renewal phase. No cover story or any explanation was given for the context switches during the course of the experiment.

Data analysis

Analyses were conducted on the second VAS scores of each trial. At that moment, participants had smelled the chocolate; they filled out the VAS right before the occurrence or non-occurrence of the US.1

A 2 (Group: AAA vs. ABA) × 2 (CS-type: CS+ vs. CS−) × 14 (Trial: 4 acquisition trials, 8 extinction trials, 2 test trials) ANOVA was performed on the reported subjective craving scores with group as a between-subjects factor and CS-type and trial as within-subjects factors. To assess the presence of acquisition, extinction and renewal effects, we performed a series of planned comparisons. The reliability of acquisition was evaluated by testing a CS-type × Trial (acquisition1 vs. acquisition4) interaction across groups (to establish acquisition overall) and by a Group × CS-type × Trial interaction (to check whether the acquisition effect differed between the two groups). To explore whether acquisition generalized to the next phase, we compared responding on the last acquisition trial to responding on the first extinction trial, by means of a CS-type × Trial (acquisition4 vs. extinction1) interaction across groups. If the Group × CS-type × Trial interaction (to test whether the generalization differed between the two groups) was significant, we also looked at generalization of acquisition within each group separately by testing simple interactions within each group. To evaluate extinction, we calculated a CS-type × Trial (extinction1 vs. extinction8) interaction across groups. In case of differences between the groups (suggesting a different degree of generalization of acquisition or of extinction between groups), this interaction was further examined within each group separately. To test for renewal, responding on the last extinction trial was compared with responding on the first test trial by means of a Group × CS-type × Trial (extinction8 vs. test1) interaction. If this interaction was significant, indicating a difference between groups in renewal of conditioned responding, we followed up on this analysis with simple CS-type × Trial (extinction8 vs. test1) interactions within each group. In a similar manner, a

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1In this experiment as well as in the following experiment, analyses on the first VAS scores revealed similar patterns as for the second VAS scores.
$2 \times 2 \times 6$ (Group $\times$ CS-type $\times$ Trial) ANOVA and subsequent planned comparisons were performed on the retrospective US-expectancy ratings. For the sake of clarity, figures present difference scores in responding between the CS+ and CS−.

**Results**

**Self-reported craving ratings**

**Acquisition**

Across groups we saw an increase in differentiation between the CS+ and CS− ratings going from the beginning to the end of the acquisition phase as shown by a CS-type $\times$ Trial (acquisition1 vs. acquisition4) interaction across groups, $F(1, 30) = 4.11, p = .05$ (see Fig. 1). There was no difference between groups in terms of acquisition as suggested by a non-significant Group $\times$ CS-type $\times$ Trial (acquisition1 vs. acquisition4) interaction, $F<1$.

**Generalization of acquisition**

The differentiation that was acquired did not generalize to the first extinction trial, as indicated by a significant CS-type $\times$ Trial (acquisition4 vs. extinction1) interaction across groups, $F(1, 30) = 4.88, p < .05$. The Group $\times$ CS-type $\times$ Trial (acquisition4 vs. extinction1) interaction revealed no difference between groups in terms of generalization, $F(1, 30) = 1.56, p = .22$.

**Extinction and renewal of conditioned responding**

Craving was not extinguished and this in both groups, CS-type $\times$ Trial (extinction1 vs. extinction8) interaction across groups, $F(1, 30) = 1.10, p = .30$ and Group $\times$ CS-type $\times$ Trial (extinction1 vs. extinction8) interaction, $F<1$. Because of the lack of generalization from acquisition to extinction we also compared differential responding at the end of acquisition (acquisition4) with differentiation at the end of extinction (extinction8): even then no extinction was present in either group, CS-type $\times$ Trial (acquisition4 vs. extinction8) interaction across groups, $F(1, 30) = 1.22, p = .28$ and Group $\times$ CS-type $\times$ Trial (acquisition4 vs. extinction8) interaction, $F<1$. Since in both groups, no extinction was present, renewal could not be assessed. Do note that on test1, responding to the CS+ was greater than responding to the CS− in the ABA group, $F(1, 30) = 11.36, p < .01$, but not in the AAA group, $F<1$. The interaction between groups on the test trial was significant, $F(1, 30) = 6.00, p < .05$.

![Fig. 1. Mean difference in chocolate craving (+SE) between the CS+ and CS−, for the AAA and ABA group, by trial in Experiment 1.](image-url)
Retrospective US-expectancy ratings

Acquisition
Across groups, participants learned to expect to get to eat chocolate more in the presence of the CS+ than in the presence of the CS− tray, as indicated by a significant CS-type × Trial (acquisition1 vs. acquisition4) interaction across groups, $F(1, 30) = 36.41, p < .001$ (see Fig. 2), with no differences between groups, as reflected by the non-significant Group × CS-type × Trial (acquisition1 vs. acquisition4) interaction, $F<1$.

The difference between CS-types was small but already significant on the first acquisition trial in the ABA group, $F(1, 30) = 5.31, p < .05$, and grew larger by the end of the acquisition phase, $F(1, 30) = 25.60, p < .001$, resulting in a significant CS-type × Trial (acquisition1 vs. acquisition4) interaction in this group, $F(1, 30) = 16.62, p < .001$. This shows acquired differentiation between CS-types.

Generalization of acquisition
The acquired differentiation generalized well to the first extinction trial, resulting in a non-significant CS-type × Trial (acquisition4 vs. extinction1) interaction across groups, $F<1$. No difference between groups in degree of generalization was present, as indicated by the non-significant Group × CS-type × Trial (acquisition4 vs. extinction1) interaction, $F<1$.

Extinction
The acquired differentiation extinguished, as shown by a significant CS-type × Trial (extinction1 vs. extinction8) interaction across groups, $F(1, 30) = 8.98, p < .01$. No group differences were detected, as shown by the non-significant Group × CS-type × Trial (extinction1 vs. extinction8) interaction, $F(1, 30) = 2.77, p = .11$.

Renewal of conditioned responding
As can be seen in Fig. 2, there was a difference in renewed differential responding between groups, as confirmed by the significant Group × CS-type × Trial (extinction8 vs. test1) interaction, $F(1, 30) = 6.45, p < .05$. Renewal was present in the ABA group, $F(1, 30) = 12.73, p < .01$, while no renewal was evident in the AAA group, $F<1$, as suggested by simple CS-type × Trial (extinction8 vs. test1) interactions within each group.

Discussion
In self-reported craving, differential acquisition was obtained. However, subjective craving did not show sensitivity to extinction. In contrast, for retrospective US expectancy strong differential acquisition was
obtained, it was sensitive to our extinction manipulation and in the ABA group we observed a significant renewed differentiation when changing contexts after extinction, i.e., a renewal effect (no renewal was present in the AAA group). The divergence in results between the two measures led us to hypothesize that craving and expectancy might not be closely related in this appetitive paradigm. Therefore, we decided to measure US-expectancies online in a next experiment.

Experiment 2

The design of Experiment 2 closely resembled that of Experiment 1. However, to assess the possible divergence between craving and US expectancy, we separately assessed craving \((n = 32)\) and US-expectancy \((n = 32)\) online in a between-subjects design and compared them. With “online” we refer to ongoing measurements for every trial during the experiment, in contrast to measurements filled out retrospectively at the end of the experiment.

Also, we added a second session to the experiment in order to check for spontaneous recovery (i.e., the return of conditioned responding through the mere passage of time; Pavlov, 1927). This second session took place 72h after the first one, the first session being very comparable to the previous experiment. The second session started with an additional extinction phase, in the same context as the first extinction phase. After the second extinction phase, an additional test phase was presented to assess to what extent renewal would be affected by the additional extinction training in the second session.

Method

Participants

Sixty-four first year psychology students (55 women), aged between 17 and 22 years \((M = 18.03, SD = .79)\), participated in return for course credits.

Setting and stimuli

The experiment took place in the same room as Experiment 1. Again, we manipulated the lighting in order to create two different contexts (dark/light). The same stimuli were used as for the previous experiment.

Measures

Acquisition, extinction and test phase

For half of the participants \((n = 32)\), the main dependent measure was self-reported craving for chocolate on a 100 mm VAS. The other half of the participants \((n = 32)\) was asked to rate their expectancy of getting to eat chocolate on a 100 mm VAS. The expectancy VAS was accompanied by the question: “How strongly do you expect to be allowed to eat chocolate at this moment?” and the scale ran from “I certainly expect not to be allowed to eat chocolate” to “I certainly expect to be allowed to eat chocolate” (the scale did not contain any other anchors).

Post-experimental questionnaire

Participants were asked to retrospectively draw the evolution of both their craving and their US expectancy in the same way as in the previous experiment.

Procedure

The experiment consisted of two sessions with 72h between sessions. Participants returned for the second session at the same hour as they were tested on the first day. Participants were asked to refrain from eating chocolate 24h prior to each session.
Session 1
The first session was very similar to Experiment 1, with two exceptions. First, half of the participants ($n = 32$) were instructed to rate their craving on the VASs, the other half ($n = 32$) were asked to indicate to what extent they expected to be able to eat chocolate (i.e., US expectancy). Second, in the test phase, only two test trials were presented (one for the CS+, one for the CS−). Half of the participants started with the CS+, the other half started with the CS−.

Session 2
The second session started with a second extinction phase, in the same extinction context as for the first session (for participants in the ABA group, this was context B; for participants in the AAA group, this was context A). Again 16 trials (eight for the CS+, eight for the CS−) were presented, in which participants were never allowed to taste the chocolate, randomized as before.

After that, a second test phase followed, in the original acquisition context A, in which four test trials were presented (two for the CS+, two for the CS−). Half of the participants started with the CS+, the other half started with the CS−. The second trial always contained the other CS then the first trial, the third and fourth trial were determined by the toss of a coin.

Data analysis

Again, for both measures separately, analyses were conducted on the scores for the second VAS, filled out right before the (non-)occurrence of the US. $2 \times 2 \times 23$ ANOVAs were performed on the self-reported craving scores and the US-expectancy ratings.

Session 1
To assess the presence of acquisition, extinction and renewal effects, we performed a series of planned comparisons as described previously.

Session 2
To evaluate spontaneous recovery, we compared responding on the last extinction trial of session 1 to responding on the first extinction trial of session 2, by means of a CS-type $\times$ Trial (extinction8 vs. extinction9) interaction across groups. A Group $\times$ CS-type $\times$ Trial interaction was used to test whether there was a difference in spontaneous recovery between groups. To assess further extinction in session 2, we calculated a CS-type $\times$ Trial (extinction9 vs. extinction16) interaction across groups. To test for renewal, responding on the last extinction trial was compared with responding on the first test trial by means of a Group $\times$ CS-type $\times$ Trial (extinction16 vs. test2) interaction. If this interaction was significant, simple interactions within each group were calculated in order to test in which group renewal occurred.

Results

Self-reported craving ratings

Session 1
Acquisition. A small increase in differentiation between the CS+ and CS− ratings from the beginning to the end of the acquisition phase was present (see Fig. 3), as indicated by the CS-type $\times$ Trial (acquisition1 vs. acquisition4) interaction across groups, $F(1, 30) = 3.48, p = .07$. This acquisition effect did not differ between groups, as reflected by a non-significant Group $\times$ CS-type $\times$ Trial (acquisition1 vs. acquisition4) interaction, $F<1$.

Generalization of acquisition. The loss of acquired differentiation from the end of acquisition to the first extinction trial was not significant, CS-type $\times$ Trial (acquisition4 to extinction1) interaction, $F(1, 30) = 2.57, p = .12$, with no difference between groups, $F<1$. 
Extinction and renewal of conditioned responding. The difference in craving was not extinguished and this in neither group, CS-type × Trial (extinction1 vs. extinction8) interaction across groups, $F<1$ and Group × CS-type × Trial (extinction1 vs. extinction8) interaction, $F<1$. Therefore, renewal could not be assessed.

Session 2
Spontaneous recovery. No spontaneous recovery of conditioned responding after 72 h, and no differences between groups were present as suggested by both the CS-type × Trial (extinction8 vs. extinction9) interaction, $F(1, 30) = 1.60$, $p = .22$, and the Group × CS-type × Trial (extinction8 vs. extinction9) interaction, $F<1$.

Extinction. Although no significant spontaneous recovery was present, there was a significant difference in responding to the CSs on the first extinction trial of session 2, both in the AAA group, $F(1, 30) = 22.58$, $p < .001$, and in the ABA group, $F(1, 30) = 9.27$, $p < .01$. This difference disappeared by the end of the extinction phase, resulting in a significant CS-type × Trial (extinction9 vs. extinction16) interaction across groups, $F(1, 30) = 11.37$, $p < .01$. There were no differences between groups in terms of extinction, Group × CS-type × Trial (extinction9 vs. extinction16), $F<1$.

Renewal of conditioned responding. The non-significant Group × CS-type × Trial (extinction16 vs. test2) interaction, $F(1, 30) = 1.06$, $p = .31$, demonstrated that no difference existed in renewed differential responding between groups. CS-type × Trial (extinction16 vs. test2) interactions within each group indicated no renewal effect in either the ABA group, $F<1$, or the AAA group, $F(1, 30) = 1.21$, $p = .28$.

US-expectancy ratings

Session 1
Acquisition. In both groups, we see a significant differential acquisition effect as confirmed by the CS-type × Trial (acquisition1 vs. acquisition4) interaction across groups, $F(1, 30) = 46.90$, $p < .001$ (see Fig. 4). The groups did not differ in their degree of acquired differentiation, resulting in a non-significant Group × CS-type × Trial (acquisition1 vs. acquisition4) interaction, $F<1$.

Generalization of acquisition. The acquired differentiation generalized well to the first extinction trial, as shown by the non-significant CS-type × Trial (acquisition4 vs. extinction1) interaction across groups, $F<1$, and equally so in the AAA and ABA groups, given that the Group × CS-type × Trial (acquisition4 vs. extinction1) interaction was non-significant as well, $F(1, 30) = 1.95$, $p = .17$. 

Fig. 3. Mean difference in chocolate craving (+SE) between the CS+ and CS−, for the AAA and ABA group, by trial in Experiment 2.
Extinction. US-expectancies were successfully extinguished and this equally in both groups, CS-type × Trial (extinction1 vs. extinction8) interaction across groups, $F(1, 30) = 28.44, p < .001$ and Group × CS-type × Trial (extinction1 vs. extinction8) interaction, $F < 1$.

Renewal of conditioned responding. A clear difference in renewed differentiation between groups appeared, as confirmed by the significant Group × CS-type × Trial (extinction8 vs. test1) interaction, $F(1, 30) = 17.52, p < .001$. Renewed responding was confirmed by CS-type × Trial interaction in the ABA group, $F(1, 30) = 24.94, p < .001$, but not in the AAA group, $F < 1$.

Session 2
Spontaneous recovery. Both the CS-type × Trial (extinction8 vs. extinction9) and the Group × CS-type × Trial interactions were non-significant, both $F$’s < 1, indicating no spontaneous recovery of conditioned responding after 72 h, and no differences between groups.

Extinction. The difference in responding to the CSs that was significant on the first extinction trial of session 2 in the AAA group, $F(1, 30) = 8.67, p < .01$, and in the ABA group, $F(1, 30) = 13.43, p < .01$, disappeared by the end of the extinction phase, as confirmed by a significant CS-type × Trial (extinction9 vs. extinction16) interaction across groups, $F(1, 30) = 4.02, p = .05$. The non-significant Group × CS-type × Trial (extinction9 vs. extinction16) interaction, $F < 1$, indicates that the groups did not differ in degree of extinction.

Renewal of conditioned responding. Again a difference existed in renewed responding to the CSs between groups as demonstrated by the significant Group × CS-type × Trial (extinction16 vs. test2) interaction, $F(1, 30) = 11.77, p < .01$. The renewal effect could be observed in the ABA group, $F(1, 30) = 16.74, p < .001$, but not in the AAA group, $F < 1$.

Retrospective craving data for the US-expectancy group

Session 1
Acquisition. In both groups an increase in differentiation between the CS+ and CS− ratings from the beginning to the end of the acquisition phase was confirmed by the CS-type × Trial (acquisition1 vs. acquisition4) interaction across groups, $F(1, 30) = 11.23, p < .01$ (see Fig. 5). This acquisition effect did not differ between groups, as reflected by a non-significant Group × CS-type × Trial (acquisition1 vs. acquisition4) interaction, $F(1, 30) = 1.90, p = .18$. 

Fig. 4. Mean difference in US-expectancy ratings (+SE) between the CS+ and CS−, for the AAA and ABA group, by trial in Experiment 2.
Generalization of acquisition. The acquired differentiation generalized well to the first extinction trial, as shown by the non-significant CS-type x Trial (acquisition4 vs. extinction1) interaction across groups, $F(1, 30) = 1.62, p = .21$, and equally so in the AAA and ABA groups, resulting in a non-significant Group x CS-type x Trial (acquisition4 vs. extinction1) interaction, $F < 1$.

Extinction. No evidence for extinction was found, as reflected by the non-significant CS-type x Trial (extinction1 vs. extinction8) interaction across groups, $F < 1$, and the non-significant Group x CS-type x Trial (extinction1 vs. extinction8) interaction, $F(1, 30) = 3.58, p = .07$. However, as can be seen in Fig. 5 and as confirmed by planned comparisons, the difference between CS-types on the last extinction trial was not significant in the AAA group, $F < 1$, but remained significant in the ABA group, $F(1, 30) = 25.62, p < .001$.

Renewal of conditioned responding. No difference between groups in terms of renewed differential responding was present, Group x CS-type x Trial (extinction8 vs. test1) interaction, $F < 1$. There was no return of (or increase in) differentiation on the test trial as assessed by CS-type x Trial (extinction8 vs. test1) interactions in either of both groups, both $F's < 1$.

Session 2
Spontaneous recovery. Both the CS-type x Trial (extinction8 vs. extinction9) interaction, $F(1, 30) = 2.66, p = .11$, and the Group x CS-type x Trial (extinction8 vs. extinction9) interaction, $F(1, 30) = 1.16, p = .29$, were non-significant, indicating no spontaneous recovery of conditioned responding after 72 h, and no differences between groups.

Extinction. No evidence for extinction was found and no differences in terms of extinction between groups, as reflected by the non-significant CS-type x Trial (extinction9 vs. extinction16) and Group x CS-type x Trial (extinction9 vs. extinction16) interactions, both $F's < 1$.

Renewal of conditioned responding. The non-significant Group x CS-type x Trial (extinction16 vs. test2) interaction, $F(1, 30) = 1.08, p = .31$, demonstrated no between-groups difference in renewed responding to the CSs. CS-type x Trial (extinction16 vs. test2) interactions within each group showed no renewal effect in either the ABA group, $F(1, 30) = 2.39, p = .13$, or the AAA group, $F < 1$.

![Fig. 5. Mean difference in retrospective chocolate craving (+ SE) between the CS+ and CS-, for the AAA and ABA group, by trial in Experiment 2 (expectancy group).](image-url)
Discussion

In the second experiment, we again obtained evidence for a differential acquisition effect in online self-reported craving for chocolate and for the insensitivity of craving to our extinction manipulation. No evidence was obtained for a spontaneous recovery effect, but analyses did indicate that the difference in responding on the first trial of the second session completely disappeared by the end of this second extinction phase. No evidence was found for renewal of the craving responses.

On the other hand, the online US-expectancy data revealed the expected pattern of results: Strong differential acquisition which generalized well to the first extinction trial and which was extinguished by the end of the extinction phase. In the ABA group, renewed responding was observed when presented with the CS+ in the original acquisition context. Although participants expected to be able to eat chocolate more when presented with the CS+ than when presented with the CS− at the beginning of the second session, spontaneous recovery was not reliable. However, expectancies were further extinguished by the end of the second extinction phase. In the ABA group, we again saw a renewed differentiation in expectancy upon return to the acquisition context. The participants who were instructed to report their US-expectancies online were also asked to retrospectively report their craving throughout the experiment (i.e., the reverse of Experiment 1, in which participants reported their craving online and were retrospectively asked for their US-expectancies). Interestingly, these retrospective craving data did not follow the online US-expectancy data, but strongly resembled the online craving data of Experiments 1 and 2: craving analyses revealed a differential acquisition effect, but no evidence was found for extinction or renewal.

General discussion

The differential conditioning paradigm that we developed is clearly valid. For one thing, it produces reliable acquisition of craving: participants reported stronger craving to an initially neutral cue that had been paired with eating chocolate (the US) than to a cue that had not been paired with eating chocolate. Moreover, for US-expectancy, both when assessed online or retrospectively, the paradigm replicated typical effects demonstrated in other paradigms such as differential acquisition, generalization of acquisition and subsequent extinction of the acquired differentiation, and renewal upon a return to the original acquisition context in the ABA group. A renewal effect was even observed after two extinction sessions (Experiment 2). These results are important, because so far, context dependency of extinction in the appetitive domain has not been studied extensively in human laboratory studies; our experiments provide evidence for ABA renewal in human appetitive learning in terms of US expectancy.

However, no clear evidence for extinction was found for subjective craving, partly due to the fact that generalization of acquired craving was not easily obtained, but even when it was, no clear evidence for extinction was found. As a result, renewal was not amenable to testing.

Our extinction data suggest that online conditioned craving differs from online conditioned US expectancy. In addition, participants who reported their US expectancies online, retrospectively reported their craving differently and in line with the online craving reported in the experiments. Conversely, participants who reported their craving online and their expectancies retrospectively differed on both measures as well. These data strongly suggest that craving and US expectancy are only loosely related. On the one hand, the lack of extinction in subjective craving could be due to specific factors related to chocolate craving. One of those specific factors that could come to mind is that after tasting chocolate, small particles of chocolate or mere aftertaste sensations could remain during the extinction trials, preventing the reduction of craving. However, the fact that differential acquisition was obtained effectively counters this argument. One could also argue that the consumption of four pieces of chocolate during acquisition caused saturation, but the data showed no general decline in the reported craving.

This suggests that the divergence between craving and US expectancy reflects a more fundamental difference, which raises the question of whether there is evidence for similar discrepancies between such measures in other appetitive or non-appetitive (e.g., fear conditioning) paradigms.

In the appetitive domain, the limited evidence seems to point to a concordance of craving and explicit US expectancy or contingency knowledge, and to a causal role of explicit US expectancies in the generation of
craving responses. For instance, in a recent review on the role of contingency knowledge in human nicotine conditioning, Hogarth and Duka (2006) cite three studies in which evidence was found that subjective craving reflects drug expectancy. Carter and Tiffany (2001) showed that with increasing instructed probability of smoking (0% vs. 50% vs. 100%), craving, skin conductance as well as instrumental tobacco-seeking behavior increased. Dols, Willems, van den Hout, and Bittoun (2000), using a differential conditioning paradigm with explicit instructions, found evidence that a neutral CS that was paired with the opportunity to smoke (CS+) elicited more subjective craving than a CS that was not paired with smoking (CS−), and this already on the first “conditioning trial”. Finally, Field and Duka (2001), also using a differential conditioning paradigm, found that there was an acquired differentiation between CS-types in US expectancies in the contingency aware group (US expectancies were not measured in the unaware group). In addition, in the aware group only, there was more craving on the last CS+ trial compared with the last CS− trial in the acquisition phase. The acquired differentiation in craving was abolished after the explicit instruction was given that smoking would no longer be possible (instructed extinction). However, the instructed extinction seemed not to reduce craving to the CS+ but rather increased craving to the CS−. Moreover, no extinction data for the US-expectancy measure were available, because the ‘expectancy of smoking’ question was removed in the ‘instructed extinction’ session. Therefore, it is hard to draw conclusions concerning the role of US expectancy in the extinction of craving from this study (note that extinction was not addressed in the other studies).

Human aversive Pavlovian conditioning studies have found evidence for the role of explicit contingency knowledge in generating fear (as for instance measured through skin conductance responding). Moreover, when expectancies are explicitly disconfirmed, extinction of US-expectancy goes hand in hand with reduction of conditioned skin conductance responding (Lovibond, 2003, 2004).

From the evidence on aversive conditioning and nicotine addiction, we can conclude that contingency knowledge (and thus, explicit US expectancy) seems to play a role in generating responses like fear and craving. This does not conflict with our data as far as acquisition is concerned. However, our data do seem to call for an important qualification of the role of explicit US expectancy in acquired craving: although US expectancy may be necessary to generate cue-induced craving, it seems that subsequent disconfirmation of US expectancy does not necessarily lead to a parallel reduction in cue-induced craving.

There are other instances of acquired responding that are relatively insensitive to disruption of CS–US contingencies. For instance, evaluative conditioning research has shown that acquired likes and dislikes are quite resistant to extinction (De Houwer et al., 2001). Also in a fear-conditioning procedure, acquired disliking of a stimulus remains unaffected, even when US expectancy ratings and non-evaluative behavioral measures of fear show complete extinction (Hermans, Crombez, Vansteenwegen, Baeyens, & Eelen, 2002; Vansteenwegen, Crombez, Baeyens, & Eelen, 1998; Vansteenwegen, Francken et al., 2006). This suggests that different response systems do not always behave in synchrony with each other in different phases of a conditioning procedure: craving and US expectancy may go hand in hand during the process of acquisition and contingency knowledge might be important for both response systems underlying these variables. However, subsequent disconfirmation of expectancies may impact more upon response systems related to preparing the organism to process a stimulus than upon response systems underlying its evaluative value.

The idea that in addictive behavior different response systems have different sensitivities to extinction may have implications for clinical practice. For one, it suggests that it is important to determine what exactly causes relapse: is lingering craving responsible or rather the return of preparatory reactions due to a context switch after extinction (such as the renewal effects observed in expectancies), or both? In what follows, we will offer some suggestions for clinical practice, both to counter the renewal effect we observed in the US-expectancy data and to improve manipulations to reduce craving.

The renewal effect we observed in our US-expectancy data in this appetitive paradigm corroborates the evidence found in animal and human fear-conditioning studies. As already mentioned, research on context dependency of extinction in these latter domains has suggested ways to counter renewal, such as increasing the number of extinction trials (Denniston et al., 2003), conducting exposure in multiple contexts (Chelonis et al., 1999; Gunther et al., 1998; Vansteenwegen et al., 2007), and reminding the subjects of the extinction context by means of retrieval cues (Brooks & Bouton, 1994; Vansteenwegen, Francken et al., 2006; Vansteenwegen, Vervliet et al., 2006). It would therefore be worthwhile to pay attention to the potential success of such techniques in an appetitive paradigm in reducing renewal of US expectancies.
Second, some evidence suggests that craving and liking play a role in relapse (see prediction studies on relapse of ex-smokers, e.g., Killen & Fortmann, 1997; Shiffman et al., 1997). Therefore, simply disconfirming expectancies, even if in the original acquisition context, may not suffice. Moreover, because craving and liking appear to be relatively unaffected by an extinction procedure, it may be worthwhile to try reducing them through a different procedure. In evaluative conditioning research, some evidence has been found for the effectiveness of counterconditioning in changing the valence of a stimulus (Baeyens, Eelen, Van den Bergh, & Crombez, 1989). In a counterconditioning procedure, after the acquisition phase, the CS is presented with a US of a valence opposite to that of the US that was used for acquisition. In an appetitive paradigm, a CS that has repeatedly been paired with a liked or craved US, such as eating a piece of chocolate, would afterwards be coupled with a new and disliked US, such as the consumption of a highly sour and bitter liquid.

Although counterconditioning has not proven successful so far in the treatment of fear (e.g., de Jong, Vorage, & van den Hout, 2000), it may bear more promise for the treatment of unwanted behavior in the appetitive domain, as it is much easier to change evaluations from positive to negative than from negative to positive (positive–negative asymmetry or negative learning bias, see Lewicka, Czapinski, & Peeters, 1992; Rozin & Royzman, 2001). However, we should keep in mind that even if counterconditioning would prove to decrease subjective craving, the context dependency of such counterconditioning effects should carefully be considered as well.

In summary, the present set of studies has documented that—at an analog level—chocolate craving can be easily acquired in a laboratory paradigm. However, these acquired craving responses seem to behave differently compared to other conditioned responses with regard to extinction and sensitivity to context changes. Future research might focus on the similarity of acquired craving responses to acquired preferences, the learning of which has been proposed to reflect principles different from those governing preparatory associative learning (De Houwer et al., 2001). Research along these lines may help to identify interventions that are more successful in reducing acquired craving. Finally, given that research about renewal in animals and in human fear conditioning has yielded interesting suggestions with regard to the possible impact of context changes on relapse, and given the clinical relevance of renewal for understanding relapse in addiction, more research about context dependency of extinction (and counterconditioning) in human appetitive learning is worthwhile and even timely.

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