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The effects of a retrieval cue on renewal of conditioned responses in human appetitive conditioning

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ABSTRACT

Contextual renewal of reward anticipation may be one potential mechanism underlying relapse in eating and substance use disorders. We therefore tested retrieval cues, a method derived from an inhibitory retrieval-based model of extinction learning to attenuate contextual renewal using an appetitive conditioning paradigm. A pilot study was carried out in Experiment 1 to validate a differential chocolate conditioning paradigm, in which a specific tray was set up as a conditioned stimulus (CS) for eating chocolate (unconditioned stimulus, US). Using an ABA renewal design in Experiment 2, half of the participants were presented with a retrieval cue in the acquisition phase (group AC) and the other half in the extinction phase (group EC). Presentation of the retrieval cue in the EC was associated with reduced renewal of US-expectancy, while there was a clear renewal effect for US-expectancy in the AC. One limitation was the difference in cue presentations between both groups due to the number of trials in acquisition and extinction. Experiment 3 therefore aimed at replicating the results of Experiment 2, but with fewer cue presentations for the EC to match the AC. No significant group differences were observed indicating no effect of the retrieval cue. Theoretical and clinical implications in light of the differing results are discussed.

1. Introduction

Basic learning processes are assumed to play an important role in the development and maintenance of disturbed eating behaviour and substance use disorders. For example, previously neutral stimuli (NSs) are thought to have become conditioned stimuli (CSs) predicting reward (the unconditioned stimulus or US) through repeated pairings between CS and US (Berridge & Robinson, 2016; Jansen, 1998; Jansen, Havermans, & Nederkoorn, 2011). As a result, a CS can elicit conditioned appetitive responses (CRs) such as explicit reward expectancies, craving and salivation, which in turn could promote unhealthy overconsumption in susceptible individuals (Boswell & Kober, 2016; Stice & Burger, 2019). Consequently, methods based on learning processes such as extinction or counterconditioning could be used to promote healthier eating or to reduce substance consumption. However, there is a strong need to inform treatment development with basic science, since a) cue exposure training seems to have only limited treatment efficacy (e.g. Loeber, Croissant, Heinz, Mann, & Flor, 2006) and b) many extinction-based treatments still underutilize possible effective strategies (Magson, Handford, & Norberg, 2021). The research suggests that CS-US associations do not get erased via extinction or overwritten via counterconditioning. Rather, these methods tend to inhibit the original behaviour (Bouton, 2014). Importantly, this inhibition seems to be tied specifically to the learning context, which explains, why behaviour change is prone to several lapse and relapse phenomena, e.g., renewal or spontaneous recovery (Bouton, 2014). Renewal can occur, when original learning of a CS-US association takes place in context A while extinction learning of an alternative association (e.g., CS-noUS) takes place in another context B, which then has the potential to inhibit retrieval of the original excitatory memory. Upon returning to context A or upon entering a whole new context C, the CS will elicit the CR again and a relapse of behaviour is more likely. Spontaneous recovery is similar to renewal in that the mere passage of time can bring about a gradual change in context which then leads to a return of the CR (Bouton, 2002). It is therefore of great importance to study ways to effectively tackle renewal and related phenomena, to reduce the risk of relapse for patients prone to overconsumption (Bouton, 2011).

Drawing from the pioneering work by Mark E. Bouton (see Bouton, 1991, 1993 for reviews), Craske et al. (2008, 2014, 2022), derived a wealth of promising strategies out of inhibitory retrieval theory to

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optimize exposure therapy for anxiety disorders. Similar strategies were adapted for the treatment of substance use disorders by Conklin and Tiffany (2002) and for the treatment of eating disorders by Boutelle and Bouton (2015) as well as by Jansen, Schyns, Bongers, and van den Akker (2016). The first main strategy consists of developing alternative associations that compete with the initial excitatory associations. The second main strategy is to provide the augmentation of the retrievability of those alternative associations to increase generalization of extinction learning and therefore attenuate relapse (Craske, Treanor, Zbozinek, & Vervliet, 2022). This could be achieved, for example, by implementing retrieval cues into the exposure rational. In their seminal experiments, Brooks and Bouton (1993, 1994) could show that an extinction cue, a discrete stimulus present during extinction, reduces spontaneous recovery and renewal in rats when present during testing. According to the authors, one of several plausible mechanisms by which extinction cues help to retrieve a memory of extinction could be occasion setting (Fraser & Holland, 2019), a view which was further corroborated in experimental studies with rodents (Brooks & Bowker, 2001), in a human fear conditioning paradigm (Dibbets, Havermans, & Arntz, 2008) and in a human predictive learning paradigm (Bustamante, Uengoer, & Lachnit, 2016).

To date, evidence for the clinical utility of extinction cues in treatments for disorders characterized by overconsumption like binge eating and substance use disorder is almost non-existent. In a classic study with social drinkers, Collins and Brandon (2002) successfully used retrieval cues to attenuate renewal of alcohol cue reactivity. A more recent study on the efficacy of cue exposure therapy for obese adolescents was not able to test the effect of the retrieval cues because compliance to use the cues was too low (Schyns, Roefs, Smulders, & Jansen, 2017). In the anxiety disorder domain, evidence for the clinical utility of retrieval cues is at best mixed. In an experimental study, Vansteenwegen et al. (2006) found weaker renewal of conditioned electro-dermal responding and retrospective expectancy ratings in a group which was presented with an extinction cue compared to a group which was presented with an acquisition cue. Shin and Newman (2018) successfully used retrieval cues to attenuate return of fear for individuals with public speaking anxiety. But there are also a considerable number of null findings (e.g. Culver, Stoyanova, & Craske, 2011; Dibbets, Moor, & Voncken, 2013; Laborda et al., 2016) and concerns regarding the risks of such cues becoming detrimental safety signals (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Dibbets et al., 2008; Weisman & Rodebaugh, 2018), which led some authors to question the clinical relevance of retrieval cues for anxiety disorders (Culver et al., 2011). However, the (absence of a) beneficial effect of retrieval cues may in part depend on cue features like salience, valence, associative history, magnitude, and timing of presentation (Bouton, 1993; Dibbets & Maes, 2011). For example, when participants were explicitly instructed to attend to what they had learned during extinction (i.e. mental reinstatement) more beneficial effects of the retrieval cue were present (Elsesser, Wannemüller, Lohrmann, Jöhren, & Sartory, 2013; Mystkowski, Craske, Echiverri, & Labus, 2006). In addition, Dibbets and Maes (2011) found that an extinction cue with a more positive valence yielded faster extinction, stronger attenuation of renewal, and better transfer of its inhibitory properties to non-extinguished stimuli than a cue which was rated more negatively.

To the best of our knowledge, retrieval cues have never been studied in an appetitive conditioning paradigm like the one developed by van Gucht, Vansteenwegen, Beckers, and van den Bergh (2008). The authors developed a differential chocolate craving conditioning paradigm for humans to better understand appetitive learning processes and to derive better treatment strategies. Recurrent findings are that conditioned differential craving can be acquired relatively quickly after three to five pairings of a cue (CS) with a palatable food like chocolate (US), but only when participants are aware of the CS-US contingency (i.e. they report heightened US-expectancies when presented with the CS at the end of acquisition (e.g. van den Akker, Nederkoorn, & Jansen, 2017; van den Akker, van den Broek, Havermans, & Jansen, 2016; van Gucht, Vansteenwegen, van den Bergh, & Beckers, 2008). Therefore, the development of explicit eating expectancies (US-expectancy) seems to be necessary for successful acquisition of subjective craving. Interestingly, a divergence between conditioned craving and US-expectancy can be observed during a subsequent extinction phase, as extinction consistently falls short in reducing conditioned craving but reduces US-expectancies successfully. As lingering craving could be a potential source of relapse, van Gucht, Baeyens, Vansteenwegen, Hermans, and Beckers (2010) attempted to reduce conditioned craving via counterconditioning, in which a cue is repeatedly paired with consumption of a highly disliked liquid. Counterconditioning was successful in reducing conditioned cravings, CS-evaluations, and US-expectancy, and the obtained changes seemed to be quite robust. No renewal or spontaneous recovery of reduced craving or acquired conditioned evaluations could be detected when counterconditioning and acquisition took place in the same context. However, when acquisition and counterconditioning took place in a different context, renewal of US-expectancy upon returning to the original acquisition context could be observed (van Gucht, Baeyens, Hermans, & Beckers, 2013). These studies suggest that acquired US expectations can return relatively easily after successful extinction, which could increase the risk of relapse (Field, Jedras, & Jones, 2013).

The major aim of the present study was therefore to investigate the effect of a retrieval cue on conditioned expectancy to get a biologically significant and desired outcome (the US: eating chocolate). A pilot study was carried out in Experiment 1 to validate the paradigm developed by van Gucht, Vansteenwegen, Beckers, and van den Bergh (2008) for our lab. Experiment 2 investigated the possible attenuating effect of a retrieval cue on renewal of US-expectancy. Experiment 3 was conducted to test if the effect of the retrieval cue is moderated by the frequency of its presentation.

The ABA-renewal procedure closely resembled van Gucht, Vansteenwegen, Beckers, and van den Bergh (2008), using a differential chocolate craving conditioning paradigm and two different contexts. The use of the retrieval cue was modelled after Vansteenwegen et al. (2006). Two groups were compared, with the extinction-cue group (EC) receiving presentations of the cue during extinction and test and the acquisition-cue group (AC) receiving presentations of the cue during acquisition and test. Since the presentation of any stimulus at the time of testing could attenuate renewal if the stimulus unconditionally interferes with performance by eliciting incompatible responses, or by causing a reduction in generalization, an EC versus AC comparison was chosen to control for possible non-associative effects of the cues (see Brooks & Bouton, 1993, 1994, Experiments 3). We hypothesized that both groups would acquire differential US-expectancies and craving, that only differential US-expectancies would extinguish and that the return of differential US-expectancies during test would be attenuated in the EC compared to AC, with the attenuation being more pronounced in Experiment 2 when presentation frequency of the extinction-cue would be higher.

2. Experiment 1

2.1. Method

2.1.1. Participants

Thirty-two undergraduate psychology students (29 females, mean age = 20.70 years, *SD* = 3.08) took part in the experiment and were randomly assigned to one of two groups: *AAA* ($N = 16$) or *ABA* ($N = 16$). The study adhered to the Declaration of Helsinki. All participants gave written informed consent and received course credits in return for participation (see Table 1, for demographics and test scores).

2.1.2. Settings

The experiment took place in a largely empty room with only one desk in the middle of the room and two seats around it, one for the

Table 1
Means and standard deviations of participant characteristics.

Variable	AAA group ($n = 16$)	ABA group ($n = 16$)	p
Age	21.13 (3.03)	20.31 (3.18)	0.465
BMI	22.26 (2.49)	21.29 (2.52)	0.281
Baseline hunger	49.44 (24.97)	43.88 (31.71)	0.586
Baseline mood	68.38 (12.45)	67.88 (17.97)	0.928
EDE-Q	1.60 (0.91)	1.64 (1.25)	0.910
Restraint	1.38 (0.97)	1.70 (1.78)	0.528
Eating Concern	0.73 (0.64)	0.81 (0.73)	0.719
Weight Concern	1.98 (1.21)	1.89 (1.38)	0.850
Shape Concern	2.32 (1.25)	2.18 (1.60)	0.772
FCQ-T-r	39.13 (11.52)	40.56 (12.43)	0.737

Note. Standard deviations are presented in parentheses. BMI = Body Mass Index (kg/m^2); EDE-Q = Eating Disorder Examination-Questionnaire Global scores; FCQ-T-r = Food Cravings Questionnaire-Trait-reduced scores.

participant and one for the experimenter. The only window was covered by a sliding shutter, so that no natural light could penetrate the room.

To create two different contexts, the light in the room was manipulated without giving any cover story. A floor lamp behind the back of the participant served as dark context. For the light context, two central ceiling lights were switched on in addition to the floor lamp. Both the dark and the light context served as contexts A and B, counterbalanced across participants.

2.1.3. Stimuli

Two serving trays served as CSs (one round and green, the other rectangular and white). One tray was used as CS+ while the other one was used as CS–, counterbalanced across participants.

Prior to the experiment, participants were requested to name their favorite kind and brand of chocolate. Based on this information, four pieces (4 g each) of the participants' favored chocolate were individually wrapped in tin foil, which served as USs during the acquisition phase.

2.1.4. Measures

For assessment of the subjective measures (US-expectancy, craving, mood and hunger) computerized versions of a visual analog scale (VAS) were used. The Adaptive Visual Analog Scales (Marsh-Richard, Hatzis, Mathias, Venditti, & Dougherty, 2009) is a freely available computer software package designed to create, administer, and score visual analog scale formats on a laptop or desktop PC. For this experiment, a Dell Latitude E5430 notebook was used. Participants used the touchpad of the notebook during each trial to fill in the VASs. The questionnaires (EDE-Q, FCQ-T-r) were filled out via paper and pencil.

US-expectancy. The participants' expectancy to get to eat chocolate was assessed on a 100-mm VAS stating "How strongly do you now expect to be invited to eat chocolate?" and ranging from 0 = *certainly not* to 100 = *certainly* (the scale did not contain any other marks or labels).

Craving. Participants reported their subjective craving for chocolate on a 100-mm VAS stating "When presented this tray, how strong is your craving for chocolate now?'' and ranging from 0 = *no craving at* all to 100 = *extremely strong craving* (the scale did not contain any other anchors).

Mood and hunger. To control mood and hunger, participants filled in 100-mm VASs ("How is your mood at this moment?"/"How hungry are you at this moment?") ranging from 0 = *very bad/not hungry at all* to 100 = *very good/extremely hungry*. (the scales did not contain any other anchors).

Eating Disorder Examination-Questionnaire. To control for possible group differences in psychopathological symptoms of the eating disorder spectrum, the Eating Disorder Examination-Questionnaire by (Fairburn & Beglin, 1994) was used in its authorized German adaptation (Hilbert & Tuschen-Caffier, 2016). Internal consistency of the Global Score is excellent with Cronbach's α = 0.94 (Hilbert, Zwaan, & Braehler, 2012). In this study the internal consistency was α = 0.94 in the AAA-group and α = 0.96 in the ABA-group.

Food Cravings Questionnaire. As means of control for possible group differences in trait chocolate craving, the chocolate version of the Food Cravings Questionnaire-Trait-reduced (FCQ-T-r) by (Meule & Hormes, 2015) was used. Internal Consistency of the Total scale is excellent with Cronbach's α = 0.94 (Meule & Hormes, 2015). In this study the internal consistency was α = 0.93 in the AAA-group and α = 0.91 in the ABA-group.

2.1.5. Procedure

The experiment approximately lasted 1 h and took place between 9 a.m. and 5 p.m.; all participants were asked to refrain from eating sweets 24 h prior to the experiment. All participants were tested individually. After arrival, participants filled out an informed consent form and rated their mood and hunger. They were then shown the craving and US-expectancy VASs and were explained what the concepts stand for. After that, the experimenter put the trays on the desk and gave the following instruction: "Here you see two different serving trays. I will present you with those trays in a randomized order, determined beforehand on the basis of coin tosses. One tray will sometimes be followed by me asking you to eat something, the other tray not." After the experimenter had ensured that the instruction had been understood, the experimenter put the trays into a large shopping bag behind the chair, so they were kept out of sight of the participants.

Both groups then underwent the same acquisition procedure, consisting of eight trials (four for the CS+ and four for the CS–) which were presented in a randomized order based on the virtual toss of a coin (Haahr, 1998), with the restriction that not more than two consecutive trials were of the same type (CS+ or CS–).

A trial proceeded as follows: the tray was presented to the participants, and they were asked to pay attention to the tray, their thoughts, and their feelings. After 15 s, they were presented with the two scales via notebook on which they were asked to rate their subjective craving for chocolate and their expectancy to get to eat chocolate. The order in which they had to fill out the scales was counterbalanced across participants. The notebook was then turned over until the next trial. In case of a CS+ trial they were then given a piece of chocolate and asked to unwrap and eat it (US). After consumption, the experimenter put the tray back into the shopping bag. In case of a CS– trial the tray was simply removed after filling out the VASs. The intertrial interval (ITI) in this study was 15 s, which was shorter than the ITI used by van Gucht et al. (2013). This was done to avoid boredom of the participants.

After acquisition, the extinction phase started. Depending on the group assignment, the extinction phase was carried out in either the same (A) or a different (B) context. No explanation or cover story was given. The extinction phase consisted of 16 trials (eight for the CS+ and eight for the CS–) randomized as before and with the restriction that no more than two consecutive trials were of the same type. The only difference to acquisition was that now the CS+ was no longer followed by the US (i.e. eating chocolate).

Consecutive to extinction a renewal test phase was carried out in the original acquisition context (A) for both groups. Just as before, no explanation or cover story was given. The renewal phase consisted of four trials (two for the CS+ and two for the CS–). Which trial type (CS+ vs. CS–) came first was counterbalanced across participants. The second trial type was always the opposite of the first one. The third and fourth trial type were randomized as before. As for the extinction phase, no chocolate consumption followed the CS+ presentations.

After completion of the renewal phase, participants filled out the questionnaires (EDE-Q, FCQ-T-r) and were debriefed.

2.1.6. Data reduction and statistical analysis

Seven participants were replaced by additional participants because they did not show awareness of the CS-US contingency (i.e. they did not report clear differential US-expectancies at the last acquisition trial,

indicated by a CS+ vs. CS– difference score smaller than 25). Two participants who initially did not want to eat the chocolate due to dietary concerns were also replaced to ensure full counterbalancing.

All statistical analyses were performed with IBM SPSS 25. The standard rejection criterion was set at $p < .05$ throughout. Effect sizes are reported as Cohen's *d* for *t*-tests and as Partial eta squared (η_p^2) for analyses of variance (ANOVAs). There were no missing data.

To check for possible baseline group differences, demographics and control variables were examined using Chi-squared tests and independent-samples *t*-tests.

Differential acquisition and extinction of craving and US-expectancy over time and across conditions were analyzed using repeated-measures ANOVAS for each of these phases of the experiment (*acquisition* and *extinction*). This resulted in 2 (Group: AAA vs. ABA) × 2 (CS-type: CS+ vs. CS–) × 4/8 (Acquisition Trials/Extinction Trials) repeated measures ANOVAs, with Group as between-subjects factor and CS-type and Trial as within-subjects factors. To check whether differential acquisition *generalized* to the extinction phase, a 2 (Group: AAA vs. ABA) × 2 (CS-type: CS+ vs. CS–) × 2 (Trial: acquisition4 vs. extinction1) repeated-measures ANOVA was calculated. The presence of *renewal* was tested using a 2 (Group: AAA vs. ABA) × 2 (CS-type: CS+ vs. CS–) × 2 (Trial: extinction8 vs. test) repeated-measures ANOVA. If significant, post-hoc t-tests were then conducted. Bonferroni-Holm corrections were used by adjusting the p-values in case of multiple comparisons. Greenhouse-Geisser epsilon corrections are reported for all repeated-measures analyses whenever sphericity was violated.

2.2. Results

2.2.1. Sample characteristics

Participant characteristics did not differ across conditions, highest t (30) = 1.01 (see Table 1).

2.2.2. US-expectancy

Acquisition. The left portion (A) of Fig. 1 shows the expectancy to get to eat chocolate during each trial of acquisition. The ANOVA revealed a clear differentiation of the expectancy to get to eat chocolate from the beginning to the end of the acquisition phase, with an increase in US-expectancy for the CS+ and a decrease for the CS–, as indicated by a significant main effect of CS-type, F (1, 30) = 124.84, $p < 0.001$, η_p^2 = 0.88, 90% CI [0.68, 0.86], and a CS-type × Trial interaction, F (2.16, 65.67) = 20.11, $p < 0.001$, $\eta_p^2 = 0.40$, 90% CI [0.23, 0.51]. Neither the main effect of Group, the main effect of Trial nor any of the other interactions (Group × Trial, Group × CS-type, Group × CS-type × Trial) reached significance, all Fs ≤ 2.30, all ps ≥ 0.094, indicating no difference between the two groups regarding acquisition of differential US-expectancy. Post-hoc tests across groups indicated a significant increase in US-expectancy towards the CS+ in Trial 3, t (31) = 3.17, p = 0.006, d = 0.56, and in Trial 4, t (31) = 2.80, p = 0.008, d = 0.49, compared to Trial 1, but not in Trial 2, t (31) = 0.93, p = 0.179, d = 0.17, and a significant decrease in US-expectancy towards the CS– in all Trials (2 through 4) compared to Trial 1, all ts ≥ 3.28, all ps = 0.006, all ds ≥ 0.58.

Generalization of acquisition. The mean US-expectancy ratings of the CS+ and CS– during the extinction phase are depicted on the right portion (B) of Fig. 1. As can be inferred from Fig. 1, the US-expectancy ratings for both CSs appear to be even higher for the first extinction trial compared to the final acquisition trial. The ANOVA showed a significant main effect of CS-type, F (1, 30) = 164.67, $p < 0.001$, $\eta_p^2 = 0.89$, 90% CI [0.74, 89] and a significant main effect of Trial F (1, 30) = 6.72, p = 0.015, $\eta_p^2 = 0.18$, 90% CI [0.02, 0.37], but no CS-Type × Trial interaction, $F < 1$, nor a main effect of Group or any Group interactions, all Fs ≤ 4.11, all ps ≥ 0.052, indicating a general increase in US-expectancy during the transition from acquisition to extinction phase independent of group or CS-type.

Extinction. The ANOVA showed a significant CS-type × Trial interaction, F (3.84, 115.11) = 8.84, $p < 0.001$, $\eta_p^2 = 0.23$, 90% CI [0.11, 0.31], indicating that differential US-expectancy declined significantly over the course of extinction. Additionally, there was a significant main effect of Trial, F (3.42, 102.65) = 20.22, $p < 0.001$, $\eta_p^2 = 0.40$, 90% CI [0.27, 0.49], and a significant main effect of CS-type, F (1, 30) = 142.36, $p < 0.001$, $\eta_p^2 = 0.83$, 90% CI [0.71, 0.87]. Neither the main effect of Group nor any of the Group interactions (Group × Trial, Group × CS-type, Group × CS-type × Trial) reached significance, all Fs ≤ 1.36, all ps ≥ 0.292, indicating no difference between the two groups regarding extinction of differential US-expectancy. Post-hoc tests across groups comparing responding in Trial 1 to the other trials indicated a significant decrease in US-expectancy towards the CS+ for each trial from Trial 3 through Trial 8, all ts ≥ 3.60, all ps ≤ 0.018, all ds ≥ 0.55, but not for Trial 2, t = 2.08, p = 0.100, d = 0.37, and a significant decrease in US-expectancy towards the CS– in Trial 6 through 8, all ts ≥ 2.84, all ps ≤ 0.024, all ds ≥ 0.50, but not in Trial 2 through 5, all ts ≤ 2.15, all ps = 0.100, all ds ≤ 0.38.

Renewal. The renewal test trial is depicted in Fig. 2. As hypothesized, the ANOVA revealed a significant Group × CS-type × Trial interaction, F (1, 30) = 17.51, $p < 0.001$, $\eta_p^2 = 0.37$, 90% CI [0.14, 0.53], indicating a difference in renewal of differential US-expectancy between the two groups. Post-hoc tests, comparing responding towards the CS+ on the last extinction trial versus the renewal test trial within each group confirmed, that renewal of US-expectancy was clearly present in the ABA, t (15) = 4.26, p = 0.004, d = 1.07, but absent in the AAA, t (15) = 1.57, p = 0.308, d = 0.26. A parallel comparison for the CS– revealed no change in US-expectancy, both ts ≤ 1.57, both ps ≥ 0.207, both ds ≤

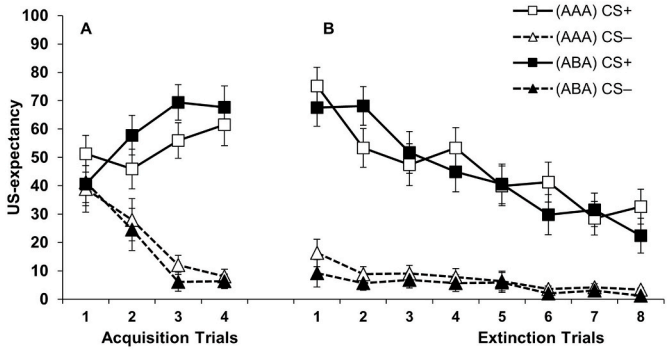

Fig. 1. Mean reported US-expectancy (±SE) on a VAS-scale ranging from 0 (*certainly not*) to 100 (*certainly*) across the different learning phases of Experiment 1 for the AAA-group and ABA-group, by CS-type and trial. (A) Mean US-expectancy produced by CS+ and CS– during the acquisition phase. (B) Mean US-expectancy produced by CS+ and CS– during the extinction phase.

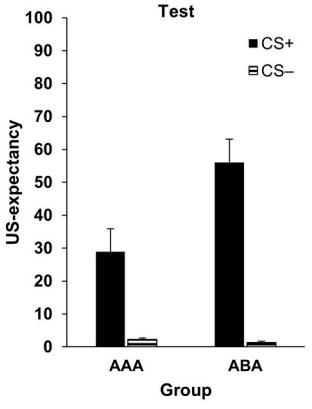

Fig. 2. Mean reported US-expectancy (+SE) of CS+ and CS– on the first renewal test trial of Experiment 1 for the AAA-group and ABA-group.

0.39. Additionally, there was a significant main effect of Trial, F (1, 30) = 10.93, p = 0.002, η_p^2 = 0.27, 90% CI [0.06, 0.44], a significant main effect of CS-type, F (1, 30) = 62.63, p < 0.001, η_p^2 = 0.68, 90% CI [0.49, 0.77], a significant Group × Trial interaction, F (1, 30) = 19.56, p < 0.001, η_p^2 = 0.40, 90% CI [0.16, 0.55] and a significant CS-type × Trial interaction, F (1, 30) = 12.81, p = 0.001, η_p^2 = 0.30, 90% CI [0.09, 0.47]. The Group × CS-type interaction did not reach significance, F (1, 30) = 1.46, p = 0.237, η_p^2 = 0.05, 90% CI [0.00, 0.20].

2.2.3. Self-reported craving ratings

Acquisition. Mean subjective craving ratings are depicted at the left portion (A) of Fig. 3. The ANOVA showed a significant main effect of Trial, F (3, 90) = 2.81, p = 0.044, η_p^2 = 0.09, 90% CI [0.01, 0.16], a significant main effect of CS-type, F (1, 30) = 13.83, p < 0.001, η_p^2 = 0.32, 90% CI [0.78, 0.91], and a significant CS-type × Trial interaction, F (1.88, 56.35) = 6.27, p = 0.004, η_p^2 = 0.17, 90% CI [0.04, 0.30], indicating that subjects learned to crave chocolate more in the presence of the CS+ compared to the CS– from the beginning to the end of the acquisition phase, with no differences between groups, as reflected by a non-significant Group × CS-type × Trial interaction, F (1.88, 56.35) = 1.03, p = 0.360, η_p^2 = 0.03, 90% CI [0.00, 0.11]. The main effect of Group, the Group × CS-type interaction as well as the Group × Trial interaction did not reach significance, all Fs < 1. Post-hoc tests revealed that compared to Trial 1, subjective craving towards the CS+ was significantly higher in Trial 2, t (31) = 3.32, p = 0.006, d = 0.59, in Trial 3, t (31) = 3.75, p = 0.006, d = 0.66, and in Trial 4, t (31) = 2.90, p = 0.012, d = 0.51. A parallel comparison for the CS– revealed no significant change for each Trial of acquisition (2 through 4), all ts ≤ 0.98, all ps ≥ 0.501, all ds ≤ 0.17.

Generalization of acquisition. The ANOVA revealed a significant main effect of CS-type, F (1, 30) = 22.21, p < 0.001, η_p^2 = 0.43, 90% CI [0.19, 0.58]. No other significant main effect or interaction effect emerged, Fs ≤ 1.29, p ≥ 0.264, indicating that differential subjective craving generalized well from the last acquisition to the first extinction trial.

Extinction and renewal. Mean subjective craving ratings during the extinction phase are depicted at the right portion (B) of Fig. 3. The ANOVA revealed a significant main effect of Trial, F (3.79, 113.65) = 3.76, p = 0.008, η_p^2 = 0.11, 90% CI [0.02, 0.18], indicating a small general decrement in subjective craving for both CSs. However, the acquired differentiation in craving between CS+ and CS– was not extinguished, as indicated by a significant main effect of CS-type, F (1, 30) = 39.18, p < 0.001, η_p^2 = 0.57, 90% CI [0.35, 0.68] and a non-significant CS-type × Trial interaction, F < 1. Hence, renewal of differential conditioned craving could not be assessed. Additionally, no significant main effect of Group or any Group interactions were observed, all Fs ≤ 1.26, all ps ≥ 0.271.

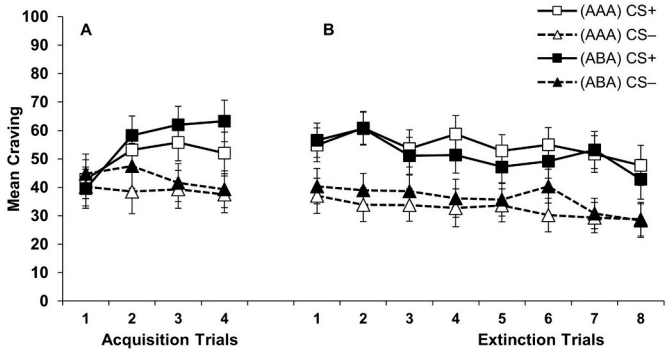

Fig. 3. Mean reported chocolate craving (±SE) on a VAS-scale ranging from 0 (*no craving at all*) to 100 (*extremely strong craving*) across the different learning phases of Experiment 1 for the AAA-group and ABA-group, by CS-type and trial. (A) Mean craving produced by CS+ and CS– during the acquisition phase. (B) Mean craving produced by CS+ and CS– during the extinction phase.

2.3. Discussion

The aim of Experiment 1 was to validate the appetitive conditioning paradigm developed by van Gucht, Vansteenwegen, Beckers, and van den Bergh (2008) for our lab. Our results are well in line with those authors works. Using an ABA renewal design, the paradigm produced reliable acquisition of differential chocolate craving, but craving did not extinguish and hence no renewal could be assessed.

Most importantly, for differential US-expectancy we found reliable acquisition, extinction, and renewal. These results are in line with previous research, which implicated that conditioned US-expectancy and craving seem to stem from loosely coupled response systems, which behave in concordance during acquisition but diverge during extinction (Baeyens, Crombez, van den Bergh, & Eelen, 1988; van den Akker et al., 2016; van Gucht, Vansteenwegen, Beckers, & van den Bergh, 2008). Because renewal of US-expectancy can be a considered a potential cause of relapse after exposure treatment, Experiment 2 was conducted in which we aimed to test a method to attenuate renewal of US-expectancy.

3. Experiment 2

3.1. Method

3.1.1. Participants

Thirty-two undergraduate psychology students (24 females, mean age = 20.91, *SD* = 2.31) were randomly assigned to two groups: *Acquisition cue* (AC, N = 16) or *Extinction cue* (EC, N = 16). The study adhered to the Declaration of Helsinki. All participants gave written informed consent and received course credits in return for participation (see Table 2, for demographics and test scores).

3.1.2. Settings

Experiment 2 took place under the same settings as in Experiment 1. For further details please see above.

3.1.3. Stimuli

The same stimuli as in Experiment 1 were used as CSs and USs. Additionally, a small pale blue magnet shaped as a seashell (diameter approx. 2 cm) was used as retrieval cue. The magnet was chosen because of its associative distinctiveness to food.

3.1.4. Measures

The same measures and questionnaires as in Experiment 1 were used. We only report Cronbach's alpha in the sample of Experiment 2 here. For further details on measures and questionnaires please see above.

Cronbach's alpha for the EDE-Q (Hilbert & Tuschen-Caffier, 2016) was 0.95 for the total scale for the EC and 0.96 for the AC.

For the FCQ-T-r (Meule & Hormes, 2015) Cronbach's alpha was 0.96 for the AC and 0.77 for the EC.

Table 2
Means and standard deviations of participant characteristics.

Variable	AC group (n = 16)	EC group (n = 16)	p
Age	21.00 (2.23)	20.81 (2.40)	0.822
BMI	22.13 (2.52)	21.58 (2.05)	0.504
Baseline hunger	32.75 (22.01)	32.06 (28.98)	0.940
Baseline mood	75.44 (12.17)	76.31 (12.99)	0.845
EDE-Q	1.03 (0.98)	1.46 (1.17)	0.266
Restraint	0.80 (1.12)	1.24 (1.08)	0.271
Eating Concern	0.45 (0.51)	0.90 (0.70)	0.046
Weight Concern	1.35 (1.40)	1.75 (1.63)	0.464
Shape Concern	1.50 (1.29)	1.95 (1.57)	0.388
FCQ-T-r	37.25 (14.20)	32.06 (28.98)	0.493

Note. Standard deviations are presented in parentheses. BMI = Body Mass Index (kg/m^2); EDE-Q = Eating Disorder Examination-Questionnaire Global scores; FCQ-T-r = Food Cravings Questionnaire-Trait-reduced scores.

3.1.5. Procedure

Experiment 2 closely resembled the procedure of Experiment 1, with some important differences: a) Now both groups (AC-group and EC-group) were subjected to a context switch to extinction (context B) and back to the original acquisition context (context A) for the renewal test. b) For the AC-group, during acquisition, two out of four presentations of the CS+ and two out of four presentations of the CS– were accompanied by the retrieval cue. For the EC-group, during extinction, four out of eight presentations of the CS+ and four out of eight presentations of the CS– were accompanied by the retrieval cue. The decision to incorporate the retrieval cues in only 50% of the trials deviates from previous work, where retrieval cues are usually more present (e.g. Brooks & Bouton, 1993, 1994; Bustamante et al., 2016; Dibbets et al., 2008). This decision was made based on the following reasons. On the one hand, it might be more valid from a clinical perspective to present the cue throughout a trial (rather than presenting it only briefly at the beginning of a trial). This may be more representative of what clinicians do during exposure sessions or during exposure processing discussion sessions. On the other hand, there is then more of a risk that the cue will take on the characteristics of a conditioned inhibitor or safety signal and that a patient will become dependent on it. Following the recommendations by Craske et al. (2022), the compromise was that the cue should be visible throughout a trial, but that it should be used only on a small percentage of trials and as variably as possible. The cue was therefore placed in a random position around the tray by the experimenter where it stayed until the trial ended. This procedure was thought to discourage configural learning and to enhance the salience of the cue. In case of a CS+ trial for the AC-group, the experimenter put the tray as well as the retrieval cue back into the shopping bag after consumption of the US during acquisition. In case of a CS– trial, the tray and the retrieval cue were simply removed after participants had filled out the VASs. In case of a CS+ or a CS– trial for the EC-group, the experimenter put the tray as well as the retrieval cue back into the shopping bag after participants had filled out the VASs during extinction. Analogous to Experiment 1, both the trays and the retrieval cue remained out of the participants sight until the next scheduled trial. c) During renewal test, the retrieval cue was present on every trial for both groups.

3.1.6. Data reduction and statistical analysis

Fourteen participants (ten in AC, four in EC) were replaced by additional participants because they did not show awareness of the CS-US contingency.

Statistical analyses were identical to those of Experiment 1, except that for all repeated measures ANOVAS the between group factor now comprised the AC and the EC.

3.2. Results

3.2.1. Sample characteristics

Participant characteristics did not differ across conditions, highest t (30) = 2.08 (see Table 2).

3.2.2. US-expectancy

Acquisition. The left portion (A) of Fig. 4 shows the expectancy to get to eat chocolate during each trial of acquisition. As was expected because of our exclusion criterion, participants acquired differential expectancy to get to eat chocolate from the beginning to the end of the acquisition phase, with an increase in US-expectancy for the CS+ and a decrease for the CS–. This was confirmed by the ANOVA, which showed a significant main effect of CS-type, F (1, 30) = 211.09, $p < 0.001$, $\eta_p^2 = 0.88$, 90% CI [0.79, 0.91] and a significant CS-type × Trial interaction, F (2.3, 67.6) = 24.40, $p < 0.001$, $\eta_p^2 = 0.45$, 90% CI [0.29, 0.55]. Neither the main effect of Trial, the main effect of Group nor any of the other interactions (Group × Trial, Group × CS-type, Group × CS-type × Trial) reached significance, indicating no difference between the two groups regarding acquisition of differential US-expectancy. Post-hoc tests across groups indicated a significant increase in US-expectancy towards the CS+ in Trial 3, t (31) = 4.43, $p = 0.01$, $d = 0.78$, and in Trial 4, t (31) = 2.50, $p = 0.01$, $d = 1.10$, compared to Trial 1, but not in Trial 2, t (31) = 1.73, $p = 0.072$, $d = 0.31$, and a significant decrease in US-expectancy towards the CS– in all Trials (2 through 4), all $ts \geq 2.45$, all $ps \leq 0.03$, all $ds \geq 0.43$.

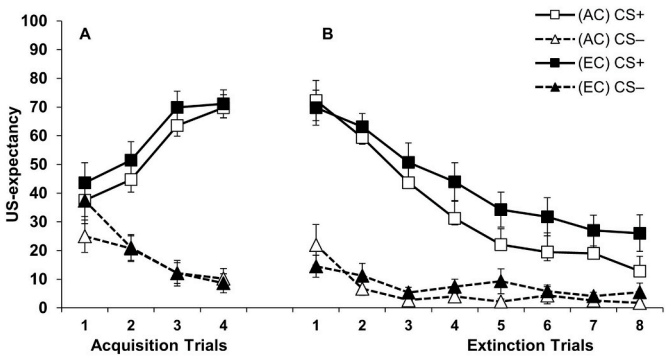

Fig. 4. Mean reported US-expectancy (±SE) on a VAS-scale ranging from 0 (*certainly not*) to 100 (*certainly*) across the different learning phases of Experiment 2 for the AC-group and EC-group, by CS-type and trial. (A) Mean US-expectancy produced by CS+ and CS– during the acquisition phase. (B) Mean US-expectancy produced by CS+ and CS– during the extinction phase.

Generalization of acquisition. The ANOVA revealed a significant main effect of CS-type, F (1, 30) = 233.92, $p < 0.001$, $\eta_p^2 = 0.87$, 90% CI [0.81, 0.92]. No other significant main effect or interaction effect emerged, $Fs < 2.73$, $p \geq 0.109$, indicating that differential US-expectancy generalized well from the last acquisition to the first extinction trial.

Extinction. The right portion (B) of Fig. 4 shows the expectancy to get to eat chocolate during each trial of extinction. The ANOVA showed a significant CS-type × Trial interaction, F (3.2, 94.5) = 12.26, $p < 0.001$, $\eta_p^2 = 0.29$, 90% CI [0.15, 0.39], indicating that differential US-expectancy declined significantly over the course of extinction. In addition, there was a significant main effect of Trial, F (2.9, 87.7) = 27.72, $p < 0.001$, $\eta_p^2 = 0.48$, 90% CI [0.34, 0.56], and a significant main effect of CS-type, F (1, 30) = 141.13, $p < 0.001$, $\eta_p^2 = 0.83$, 90% CI [0.71, 0.87]. Unexpectedly, there was also a significant main effect of Group, F (1, 30) = 4.72, $p = 0.038$, $\eta_p^2 = 0.14$, 90% CI [0.01, 0.32], but no significant Group interactions emerged (Group × Trial, Group × CS-type, Group × CS-type × Trial), all $Fs < 1$. Post-hoc tests across groups indicated a significant decrease in US-expectancy towards the CS+ for each trial from Trial 3 onwards (3 through 8) compared to Trial 1, all $ts \geq 3.35$, all $ps \leq 0.013$, all $ds \geq 0.59$, but not for Trial 2, t (31) = 1.56, $p = 0.062$, $d = 0.28$ and a significant decrease in US-expectancy towards the CS– for each trial (2 through 8) compared to Trial 1, all $ts \geq 2.41$, all ps

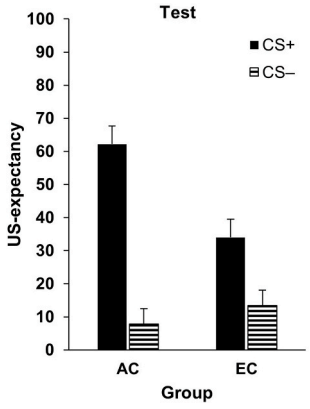

Fig. 5. Mean reported US-expectancy (+SE) of CS+ and CS– on the first renewal test trial of Experiment 2 for the AC-group and EC-group.

≤ 0.022, all *ds* ≥ 0.42.

Renewal. The renewal test is depicted in Fig. 5. As hypothesized, the ANOVA revealed a significant Group × CS-type × Trial interaction, F (1, 30) = 21.85, p < 0.001, η_p^2 = 0.42, 90% CI [0.18, 0.57], indicating a difference in renewal of differential US-expectancy after the context switch between the two groups. Post-hoc tests comparing US-expectancy towards the CS+ on the last extinction trial versus the renewal test trial within each group confirmed, that renewal was clearly present in the AC, t (15) = 7.24, p = 0.008, d = 1.81, but absent in the EC, t (15) = 1.11, p = .143, d = 0.28. A parallel comparison for the CS– revealed no change in US-expectancy, both *ts* ≤ 1.91, both *ps* ≥ 0.112, both *ds* ≤ 0.48. Additionally, there was a significant main effect of Trial, F (1, 30) = 30.25, p < 0.001, η_p^2 = 0.50, 90% CI [0.27, 0.64], a significant main effect of CS-type, F (1, 30) = 49.70, p < 0.001, η_p^2 = 0.62, 90% CI [0.42, 0.73], a significant Group × Trial interaction, F (1, 30) = 9.30, p = 0.005, η_p^2 = 0.24, 90% CI [0.05, 0.42] and a significant CS-type × Trial interaction, F (1, 30) = 21.97, p < 0.001, η_p^2 = 0.42, 90% CI [0.19, 0.57]. The Group × CS-type interaction did not reach significance, F (1, 30) = 2.59, p = .118, η_p^2 = 0.08, 90% CI [0.00, 0.25].

3.2.3. Self-reported craving ratings

Acquisition. The left portion (A) of Fig. 6 shows the subjective craving ratings during each trial of acquisition. From the beginning to the end of the acquisition phase, subjects learned to crave chocolate more in the presence of the CS+ compared to the CS–, as indicated by a significant CS-type × Trial interaction, F (3, 90) = 3.83, p = 0.019, η_p^2 = 0.11, 90% CI [0.02, 0.20]. In addition, the ANOVA revealed a significant main effect of CS-type, F (1, 30) = 13.25, p = 0.001, η_p^2 = 0.31, 90% CI [0.09, 0.48], a significant main effect of Trial, F (2.04, 61.31) = 5.85, p = 0.004, η_p^2 = 0.16, 90% CI [0.03, 0.28] and a significant CS-type × Group interaction, F (1, 30) = 4.57, p = 0.041, η_p^2 = 0.13, 90% CI [0.01, 0.31], indicating a difference in differential responding between the groups. Post hoc tests within the groups revealed that the differentiation between the CS+ and CS– was significant for the EC in Trial 3, t = 3.42, p = 0.02, d = 0.86, and in Trial 4, t = 3.05, p = 0.036, d = 0.76, but not in Trial 1 and 2, both *ts* ≤ 1.83, both *ps* ≥ 0.798, both *ds* ≤ 0.46, while at the same time no differentiation could be detected for the AC in any of the acquisition trials (1 through 4), all *ts* ≤ 1.54, all *ps* ≥ 0.576, all *ds* ≤ 0.39, indicating that only the EC acquired differential subjective craving in the acquisition phase. In addition, for the EC there was a significant increase in subjective craving towards the CS+ in Trial 2 compared to Trial 1, t (15) = 2.97, p = 0.04, d = 0.74, but not in Trial 3 and 4, *ts* ≤ 1.94, p ≥ 0.216, *ds* ≤ 0.49, and no change towards the CS– in any of the acquisition trials (2 through 4), all *ts* ≤ 2.18, all *ps* ≥ 0.161, all *ds* ≤ 0.54. For the AC, there was no change in subjective craving towards the CS+ in any of the acquisition trials (2 through 4) compared to Trial 1, *ts* ≤ 0.54, p > 0.999, *ds* ≤ 0.14, but a significant decrease in subjective craving towards the CS– in Trial 3 compared to Trial 1, t (15) = 3.15, p = 0.03, d = 0.78, and no change in the other trials (2 and 4), *ts* ≤ 2.05, p ≥ 0.261, *ds* ≤ 0.51. For completeness, the main effect of Group, the Group × Trial interaction and the Group × CS-type × Trial interaction did not reach significance, all *Fs* < 1.83, all *ps* ≥ 0.169.

Generalization of acquisition. Because of the failed acquisition of differential subjective craving for the AC, further analyses are reported for the EC only. The acquired differentiation generalized to the first extinction trial, as indicated by a significant main effect of CS-type, F (1, 15) = 16.99, p < 0.001, η_p^2 = 0.53, 90% CI [0.19, 0.69], a non-significant main effect of Trial, F < 1, and a non-significant CS-type × Trial interaction, F < 1.

Extinction and renewal. The right portion (B) of Fig. 6 shows the subjective craving ratings during each trial of extinction. The acquired differentiation in craving was not extinguished, as indicated by a significant main effect of CS-type, F (1, 15) = 11.34, p = 0.004, η_p^2 = 0.43, 90% CI [0.10, 0.62], a non-significant main effect of Trial, F < 1, and a non-significant CS-type × Trial interaction, F < 1. Hence, renewal of conditioned craving could not be assessed.

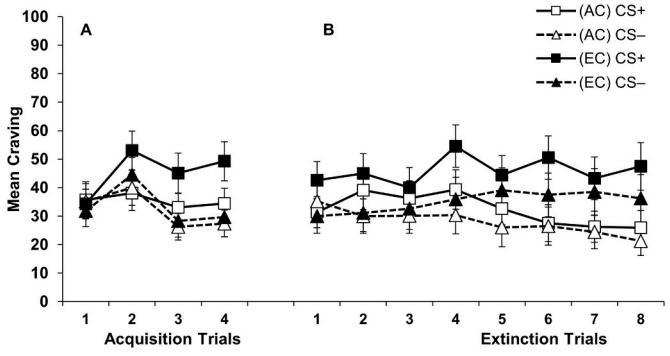

Fig. 6. Mean reported chocolate craving (±SE) on a VAS-scale ranging from 0 (*no craving at all*) to 100 (*extremely strong craving*) across the different learning phases of Experiment 2 for the AC-group and EC-group, by CS-type and trial. (A) Mean craving produced by CS+ and CS– during the acquisition phase. (B) Mean craving produced by CS+ and CS– during the extinction phase.

3.3. Discussion

The aim of Experiment 2 was to test the effect of a retrieval cue on renewal of US-expectancy. The paradigm reliably produced differential acquisition and extinction of expectancies to get to eat chocolate in both groups. Most importantly, whilst there was a clear renewal of US-expectancy upon returning to the original acquisition context in the group, where a retrieval cue had been presented during acquisition (group AC), this renewal effect was absent in the group where the cue had been presented during extinction (group EC).

Unexpectedly, a group difference regarding US-expectancy emerged between the AC and the EC in the extinction phase, with the EC showing a generally higher US-expectancy independent of CS-type or trial. This result could be due to the introduction of the extinction cue in this phase. However, this finding reinforces the significance of the extinction cue in terms of attenuating the renewal effect. This is because it could be argued that a generally higher US-expectancy is also more susceptible to renewal. And if renewal is nevertheless attenuated by the presentation of the extinction cue during test, this could reinforce the significance of the extinction cues' effect.

Another unexpected result was that differential conditioning of self-reported craving could not be achieved in the AC. One explanation may be the simultaneous assessment of craving and US-expectancy (van Gucht, Vansteenwegen, van den Bergh, & Beckers, 2008). Additionally, participants overall hunger was relatively low. This could have resulted in satiation by the end of the acquisition phase, leading to a reduction of self-reported craving. Reents, Seidel, Wiesner, and Pedersen (2020) found, that self-reported craving was significantly higher in hungry compared to sated states and Dicker-Oren, Gelkopf, and Greene (2022) found, that hunger predicted food craving in daily life. As stated in the methods section, we instructed our participants to refrain from eating sweets 24 h prior to the experiment but gave no specific instructions with regards to regular meals and satiety. Future appetitive conditioning experiments which leverage actual food intake as US should ensure moderate to high levels of participants hunger to avoid failure of acquisition of differential craving. However, the results of Experiment 1 and the successful acquisition of differential subjective craving in the EC render this explanation insufficient. Maybe the presentation of the additional retrieval cue during acquisition distracted the participants. This interpretation fits with the unequal distribution of replaced participants (10 in AC versus 4 in EC) who displayed no contingency awareness at the end of the acquisition phase. Besides, due to the cravings lingering nature and resistance to extinction in the EC, no conclusions can be drawn regarding an effect of the cue on renewal of conditioned self-reported craving.

The findings of Experiment 2 indicate that a retrieval cue presented during extinction can have an attenuating effect on renewal of US-expectancy. However, whilst promising, our findings are limited in the sense that the EC was exposed to the cue more often than the AC (eight versus four times respectively). This was due to the design of the conditioning paradigm, where usually four acquisition trials are enough to ensure learning and at the same time do not oversaturate participants with the appetitive US, while at least eight extinction trials are necessary for US-expectancy to reliably decrease. This difference in number of acquisition versus extinction trials led to a different frequency of cue presentations for both groups respectively, which in turn could have impacted the results due to greater familiarity with the cue for the EC during test (Vansteenwegen et al., 2006). On the one hand, the acquisition cue could have disrupted responding on the test trial because it was less familiar compared to the extinction cue, which is unlikely because there was a clear renewal effect in the AC, which was comparable to Experiment 1, where no cue was present in any of the phases. On the other hand, the acquisition cue could have had an excitatory effect due to its relative novelty compared to the extinction cue, which may have strengthened responding at test. This is more plausible, because the EC also showed a significant general increase in US-expectancy during the extinction phase, which could have been a consequence of the novelty of the extinction cue. However, the interpretation that the difference in responding at test was due to the novelty of the acquisition cue is contradicted by the fact that the extent of the renewal effect in the AC in Experiment 2 was comparable to the renewal effect in Experiment 1, in which no reminder cues were used. To overcome this limitation, we set up Experiment 3, where we aimed at replicating the results of Experiment 2, but with an equal cue presentation frequency for both groups. In addition, Experiment 3 provided the opportunity to investigate whether the attenuating effect of the retrieval cue on renewal of US-expectancy was influenced by the frequency of its presentation during extinction learning. Demonstrating that a lower number of cue presentations than in Experiment 2 can have an attenuating effect on renewal would be useful in terms of clinical applications, as it would then be even less likely that the cue would take on the deleterious properties of a conditioned inhibitor or safety signal.

4. Experiment 3

4.1. Method

4.1.1. Participants

Thirty-two undergraduate psychology students (26 females, mean age = 20.84, SD = 2.70) were randomly assigned to two groups: *Acquisition cue* (AC, $N = 16$) or *Extinction cue* (EC, $N = 16$). The study adhered to the Declaration of Helsinki. All participants gave written informed consent and received course credits in return for participation (see Table 3, for demographics and test scores).

Table 3
Means and standard deviations of participant characteristics.

Variable	AC group ($n = 16$)	EC group ($n = 16$)	p
Age	21.31 (3.05)	20.38 (2.31)	0.334
BMI	21.88 (2.27)	21.23 (2.50)	0.448
Baseline hunger	39.63 (25.62)	31.31 (22.76)	0.340
Baseline mood	75.88 (16.68)	63.25 (20.60)	0.066
EDE-Q (Global)	1.79 (1.10)	1.90 (1.07)	0.067
Restraint	2.25 (1.57)	2.54 (1.67)	0.783
Eating Concern	1.19 (0.74)	1.12 (0.78)	0.619
Weight Concern	1.59 (1.34)	1.74 (1.07)	0.781
Shape Concern	2.13 (1.49)	2.20 (1.12)	0.894
FCQ-T-r	40.63 (12.36)	36.57 (11.51)	0.344

Note. Standard deviations are presented in parentheses. BMI = Body Mass Index (kg/m^2); EDE-Q = Eating Disorder Examination-Questionnaire Global scores; FCQ-T-r = Food Cravings Questionnaire-Trait-reduced scores.

4.1.2. Settings and stimuli

Experiment 3 took place under the same settings as in Experiment 2 and the same stimuli were used. For further details please see above.

4.1.3. Procedure

Experiment 3 closely resembled the procedure of Experiment 2, with the only difference that the retrieval cue was now presented equally often in both groups. This change of the presentation frequency resulted in two out of four presentations of the CS+ and two out of four presentations of the CS– for the AC, (i.e. in 50% of the trials which was the same as in Experiment 2), and in two out of eight presentation of the CS+ and two out of eight presentations of the CS– for the EC (i.e. in only 25% of the trials which was half as often as in Experiment 2).

4.1.4. Measures

The same measures and questionnaires as in Experiments 1 and 2 were used. We only report Cronbach's alpha in the sample of Experiment 3 here. For further details on measures and questionnaires please see above.

Cronbach's alpha for the EDE-Q (Hilbert & Tuschen-Caffier, 2016) was 0.88 for the total scale for the EC and 0.92 for the AC.

For the FCQ-T-r (Meule & Hormes, 2015), Cronbach's alpha was 0.90 for both the AC and the EC.

4.1.5. Data reduction and statistical analysis

Eight participants (four in AC, four in EC) were replaced by additional participants because they did not show awareness of the CS-US contingency. All statistical analyses were identical to those of Experiment 2.

4.2. Results

4.2.1. Sample characteristics

Participant characteristics did not differ across conditions, highest $t(30) = 1.91$ (see Table 3).

4.2.2. US-expectancy

Acquisition. The left portion (A) of Fig. 7 shows the expectancy to get to eat chocolate during each trial of acquisition. As was expected because of our exclusion criterion, participants acquired differential expectancy to get to eat chocolate from the beginning to the end of the acquisition phase, with an increase in US-expectancy for the CS+ and a decrease for the CS–. This was confirmed by the ANOVA, which showed a significant main effect of CS-type, $F(1, 30) = 107.75$, $p < 0.001$, $\eta_p^2 = 0.78$, 90% CI [0.64, 0.84] and a significant CS-type × Trial interaction, $F(2.35, 70.72) = 39.08$, $p < 0.001$, $\eta_p^2 = 0.57$, 90% CI [0.42, 0.65].

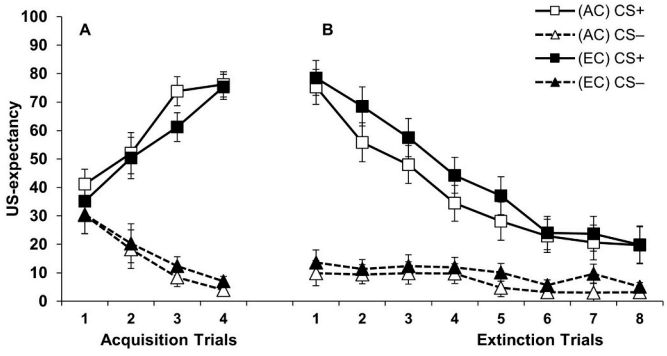

Fig. 7. Mean reported US-expectancy (±SE) on a VAS-scale ranging from 0 (*certainly not*) to 100 (*certainly*) across the different learning phases of Experiment 3 for the AC-group and EC-group, by CS-type and trial. (A) Mean US-expectancy produced by CS+ and CS– during the acquisition phase. (B) Mean US-expectancy produced by CS+ and CS– during the extinction phase.

Neither the main effect of Group, the main effect of Trial nor any of the other interactions (Group × Trial, Group × CS-type, Group × CS-type × Trial) reached significance, all *F*s < 1, indicating no difference between the two groups regarding acquisition of differential US-expectancy. Post-hoc tests across groups indicated a significant increase in US-expectancy towards the CS+ in each Trial (2 through 4) compared to Trial 1, all *t*s ≥ 2.31, all *p*s ≤ 0.028, all *d*s ≥ 0.41, and a significant decrease in US-expectancy towards the CS– in each Trial (2 through 4) compared to Trial 1, all *t*s ≥ 2.48, all *p*s ≤ 0.027, all *d*s ≥ 0.44.

Generalization of acquisition. The ANOVA revealed a significant main effect of CS-type, $F(1, 30) = 253.93$, $p < 0.001$, $\eta_p^2 = 0.89$, 90% CI [0.82, 92]. No other significant main effect or interaction effect emerged, *F*s < 2.33, p ≥ 0.138, indicating that differential US-expectancy generalized well from the last acquisition to the first extinction trial.

Extinction. The right portion (B) of Fig. 7 shows the expectancy to get to eat chocolate during each trial of extinction. The ANOVA revealed a significant main effect of CS-type, $F(1,30) = 77.70$, $p < 0.001$, $\eta_p^2 = 0.72$, 90% CI [0.55, 0.80], a significant main effect of Trial, $F(3.54, 106.14) = 46.01$, $p < 0.001$, $\eta_p^2 = 0.61$, 90% CI [0.50, 0.66], but no main effect of Group or Group interactions were detected, all *F*s < 1. Furthermore, a significant CS-type × Trial interaction emerged, $F(2.48, 74.36) = 23.96$, $p < 0.001$, $\eta_p^2 = 0.44$, 90% CI [0.29, 0.54], indicating that differential US-expectancy declined significantly over the course of extinction. Post-hoc tests across groups indicated a significant decrease in US-expectancy towards the CS+ in each trial (2 through 8) compared to Trial 1, all *t*s ≥ 3.78, all *p*s ≤ 0.013, all *d*s ≥ 0.67, and no significant change in US-expectancy towards the CS– in all Trials (2 through 8) compared to Trial 1, all *t*s ≤ 2.37, all *p*s ≥ 0.072, all *d*s ≤ 0.42.

Renewal. The renewal test is depicted in Fig. 8. A significant main effect of CS-type emerged, $F(1, 30) = 47.19$, $p < 0.001$, $\eta_p^2 = 0.61$, 90% CI [0.40, 0.72], as well as a significant main effect of Trial, $F(1, 30) = 26.03$, $p < 0.001$, $\eta_p^2 = 0.46$, 90% CI [0.23, 0.61]. Furthermore, a significant CS-type × Trial interaction emerged, $F(1, 30) = 13.48$, $p < 0.001$, $\eta_p^2 = 0.31$, 90% CI [0.09, 0.48], indicating renewal of differential US-expectancy, but no main effect of Group or Group interactions (Group × Trial, Group × CS-type, Group × CS-type × Trial) were detected, all *F*s < 1, indicating no differences in renewal between the groups. Post-hoc tests across groups showed a significant increase in US-expectancy towards the CS+ on the renewal test trial compared to the last extinction trial, $t(31) = 4.91$, $p = 0.004$, $d = 0.87$. A parallel comparison for the CS– revealed no significant change, $t(31) = 1.81$, $p = .16$, $d = 0.32$.

4.2.3. Self-reported craving ratings

Acquisition. The ANOVA revealed a significant main effect of CS-type, $F(1, 30) = 8.91$, $p = 0.006$, $\eta_p^2 = 0.23$, 90% CI [0.04, 0.41], as well as a significant CS-type × Trial interaction, $F(2.28, 68.41) = 4.19$, $p = 0.015$, $\eta_p^2 = 0.12$, 90% CI [0.01, 0.23]. The main effect of Trial, the main effect of Group and the Group interactions did not reach significance, all *F*s ≤ 1.38, all *p*s ≥ 0.193, indicating no differences between groups in acquisition of differential subjective craving. However, because visual inspection of the data appeared to somewhat contradict this result, suggesting a possible lack of statistical power to detect group differences, and because of the failed acquisition of subjective craving in the AC in Experiment 2, the ANOVA was repeated for each group separately. This resulted in a non-significant CS-type × Trial interaction for the AC, $F(1, 15) = 1.05$, $p = 0.380$, $\eta_p^2 = 0.07$, 90% CI [0.00, 0.30] and a significant CS-type × Trial interaction for the EC, $F(1, 15) = 5.30$, $p = 0.003$, $\eta_p^2 = 0.26$, 90% CI [0.01, 0.49]. Post-hoc tests within the groups did not show significant increases or decreases in subjective craving in any of the trials (2 through 4) compared to the first trial, neither for the CS+ nor for the CS– and this in both groups. AC, all *t*s ≤ 1.37, all *p*s ≥ 0.728, all *d*s ≤ 0.33. EC, all *t*s ≤ 2.14, all *p*s ≥ 0.21, all *d*s ≤ 0.53. However, while there was no significant differentiation between CS+ and CS– in any of the trials (1 through 4) for the AC, all *t*s ≤ 2.45, all *p*s ≥ 0.13, all *d*s ≤ 0.61, and no significant differentiation in Trial 1 through 3 for the EC, all *t*s ≤ 2.34, all *p*s ≥ 0.21, all *d*s ≤ 0.59, the differentiation between CS+ and CS– was significant for the EC in the last acquisition Trial 4, $t(15) = 3.62$, $p = 0.01$, $d = 0.90$. Taken together, the results again suggest that only the EC acquired differential craving at the end of the acquisition phase. Hence, further analyses are reported for the EC only.

Generalization of acquisition. The ANOVA revealed a significant main effect of CS-type, $F(1, 15) = 9.89$, $p = 0.007$, $\eta_p^2 = 0.40$, 90% CI [0.08, 0.59] as well as a significant CS-type × Trial interaction, $F(1, 30) = 4.97$, $p = 0.042$, $\eta_p^2 = 0.25$, 90% CI [0.01, 0.48], indicating a loss of differential responding from the last acquisition to the first extinction Trial. Post-hoc tests showed that although there was no significant change in subjective craving between the last acquisition and the first extinction trial towards both the CS+, $t(15) = 1.60$, $p = 0.13$, $d = 0.40$, and the CS–, $t(15) = 0.86$, $p = 0.195$, $d = 0.22$, the differentiation between the CS+ and the CS– was no longer significant at the first extinction trial, $t(15) = 1.83$, $p = 0.12$, $d = 0.47$, indicating that differential subjective craving was already extinct at the beginning of the extinction phase. Hence, no further analyses regarding subjective craving were carried out.

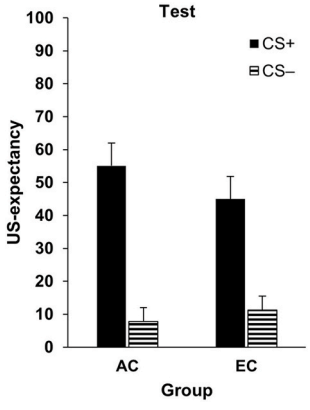

Fig. 8. Mean reported US-expectancy (+SE) of CS+ and CS– on the first renewal test trial of Experiment 3 for the AC-group and EC-group.

4.3. Discussion

Experiment 3 aimed at replicating the results of Experiment 2, where a cue presented during extinction attenuated renewal of conditioned expectancies to get to eat chocolate, but with the difference that now the cue was presented less often in the EC to match the frequency of the cue presentations for the AC. Reliable acquisition, extinction and renewal of US-expectancy was found in both groups, indicating that the cue presented during extinction did not attenuate renewal of US-expectancy upon returning to the original acquisition context. It seems, that the presentation of the cue during only four out of 16 extinction trials is not enough for the cue to exert an attenuating effect on renewal of US-expectancy.

Regarding self-reported craving, the data unexpectedly showed no reliable acquisition for the AC again, probably for the same reasons as in Experiment 2. Similarly, no reliable generalization of acquisition to the extinction context for the EC was achieved, indicating a loss of differential conditioning of subjective craving already at the beginning of extinction, which prevented further analyses. At this point one might question the usefulness of the paradigm to investigate retrieval cues in the context of conditioned craving responses. But it is important to keep in mind that US-expectancy was the main variable of interest, because based on previous research with the paradigm conditioned craving was hypothesized to not extinguish easily anyway. We discuss the clinical implications of the differing findings on US-expectancy and craving in more detail in the general discussion. In addition, subjective craving

could probably be conditioned much more reliably if certain preconditions were considered to a greater extent than was the case in this study. First, as in Experiment 2, subjects overall hunger again was very low, which might have led to saturation at the end of the acquisition phase. We would therefore like to reiterate our recommendation, to ensure that subjects participate in experiments using the differential chocolate conditioning paradigm only when at least moderately hungry, if possible, and to limit testing to late morning or afternoon hours, for example. Second, the use of an alternative control condition might be more appropriate in this context. An EC versus AC comparison was chosen to control for possible non-associative effects of the cues during test. However, a similar comparison could have been achieved with neutral or pre-exposed cues, with the advantage that the reduced novelty of the cue in the case of a pre-exposed cue or its complete absence during acquisition in the case of a neutral cue would have been particularly helpful to not distract participants attention while they focused on the trays and their inner reactions during acquisition. Participants could therefore be pre-exposed to the retrieval cues and continuously instructed to focus on the tray during acquisition trials to avoid orientation and distraction, which may better enable differential craving to emerge. Finally, it is important to mention that the failed acquisition in the AC was almost not detected because statistical power was probably too low. As is shown by Experiments 1 and 2, the sample size which was based on previous experiments with the paradigm should have been appropriate to detect a possible clinically meaningful effect of the retrieval cues, but with regards to the failed acquisition of differential craving a larger sample would have been preferable.

Further implications derived from these results regarding the clinical usefulness of retrieval cues are discussed below.

5. General discussion

The purpose of the research presented here was to test the possible effect of a retrieval cue on renewal of US-expectancy. Three experiments were conducted. Experiment 1 successfully validated the appetitive conditioning paradigm developed by van Gucht, Vansteenwegen, Beckers, and van den Bergh (2008) for our lab. The paradigm reliably produced differential acquisition, extinction, and renewal of craving and expectancy to get to eat chocolate (the US). Experiments 2 and 3 were therefore conducted to test, if a cue presented during extinction can attenuate this renewal of US-expectancy. Our results support this hypothesis, but also demonstrate limitations of this approach. Thus, when the retrieval cue was presented during half of the extinction trials, renewal was clearly reduced compared to a group where the retrieval cue had been presented during acquisition (Experiment 2). When the number of presentations was reduced to match the control group, no attenuating effect of the cue was observable (Experiment 3).

This pattern of results is consistent with the previous literature on retrieval cues. The strongest evidence for the clinical utility comes from studies where the salience of the cue was particularly high (Shin & Newman, 2018) and in which participants were explicitly instructed to attend to what they had learned during extinction (Elsesser et al., 2013; Mystkowski et al., 2006). Fearful individuals may tend to attend more to the threating information of the environment compared to the non-threatening information value of retrieval cues and therefore need to be reminded of attending to the retrieval cues, either via instruction to engage in mental reinstatement or via raising the salience of the cue (Culver et al., 2011; Mogg & Bradley, 2016). The same could apply to individuals who are prone to overconsumption and who may exhibit attentional biases towards reward-related stimuli (Field et al., 2016; Stojek et al., 2018). At the same time, one must be careful to prevent the retrieval cues from acquiring inhibitory properties and therefore becoming counter-therapeutic safety signals. To find the right balance between a retrieval cue acquiring sufficient extinction-reminder value without becoming a safety signal might propose a challenge for clinicians (Dibbets & Maes, 2011). Our experiments underscore this important constraint by showing, that renewal of expectancy to get to eat chocolate was attenuated but only when the extinction cue was presented often enough during extinction (i.e. in at least half of the trials). Unfortunately, the design of our experiments does not allow to make any secure claim regarding the associative mechanism underlying the effect of the extinction cue. However, based on important previous work it seems plausible to assume, that the retrieval cue did not become a safety signal but functioned as an occasion setter aiding in retrieving the memory-representation of the extinction context (Brooks & Bouton, 1994; Bustamante et al., 2016; Dibbets et al., 2008). The retrieval cues were only presented on a limited percentage of trials, during both CS+ trials and CS– trials, and at random locations around the CSs to prevent any kind of configural learning. But to make a definite claim, one would have to implement a more sophisticated procedure allowing for summation or retardation tests to check for conditioned inhibition (Rescorla, 1969). From a clinical point, Craske et al. (2022) suggested to introduce retrieval cues only during exposure session processing discussions, which would prevent the cues from influencing outcome expectations but still allow them to become a reminder of what was learned during exposure.

There are several limitations concerning the results of this study. First, the relatively small sample size, the studied population of psychology students and the use of an ABA design make it difficult to draw any strong generalizable conclusions. Further, it is possible that the observed renewal effect was due to a summation of the associate strength of the context and the CS, as was pointed out by Vervliet, Baeyens, van den Bergh, and Hermans (2013). Future studies could therefore implement an ABC design and run appropriate tests to check for renewal. An ABC design presumably reflects a more adequate model of the real world where individuals also encounter novel contexts after exposure treatment. Possible attenuating effects of retrieval cues on recovery of craving responses in novel contexts would further warrant their examination as a useful treatment supporting strategy. Another potential limitation is the difference in number of retrieval cue presentations between both groups in Experiment 2, which may have influenced the results due to greater familiarity with the cue in the EC. We cannot rule out the possibility that the acquisition cue had an additional excitatory effect due to its relative novelty compared to the extinction cue, which could have strengthened responding at test and as a result led to a difference in responding between the groups. Experiment 3 was therefore conducted in which an attempt was made to keep familiarity with the cues constant between the groups. Unfortunately, the extinction cue showed no attenuating effect on renewal, possibly because the presentation of the cue was too infrequent to be linked to the extinction context which may have prevented retrieval of the inhibitory association. In this regard Experiment 3 failed to overcome the methodological limitation of Experiment 2. Further, we cannot make definite claims with regards to the direction of the effect. It is possible that the difference between the AC and the EC at renewal test in Experiment 2 was due to a) a disrupting effect of the cue in the EC, b) a heightened renewal effect in the AC, or c) both. However, the results of Experiment 1, where a contextual renewal effect was observed in the ABA group in the absence of any acquisition retrieval cue, suggest a similar interpretation as was made by Vansteenwegen et al. (2006). Hence, it seems more plausible to assume that the difference in responding at test was due to a disrupting effect of the cue in the EC. However, this interpretation is based only on indirect evidence and future research is needed to directly test this interpretation.

Another important limitation to consider is that the retrieval cue seemed to have interfered with acquisition of conditioned craving in Experiments 2 and 3. Contrary to the results of Experiment 1 and to previous research with the paradigm, no reliable acquisition of differential conditioned craving could be achieved in the AC in Experiments 2 and 3 and for the EC it was already abolished at the first extinction trial in Experiment 3. As we were mostly interested in the acquisition, extinction and most importantly renewal of US-expectancies, the failure

to achieve reliable differential conditioned craving in Experiments 2 and 3 may be considered not too much of a limitation for the present study but should be considered in future experiments. Although speculative, we cannot rule out that the course of US-expectancy would have been different if reliable differential craving would have been achieved in both groups. Participants could therefore be pre-exposed to the retrieval cues to reduce possible non-associative effects of the cues and instructed to constantly focus on the tray during acquisition trials to avoid orientation and distraction, which may better enable differential craving to emerge. However, based on previous research with the chocolate conditioning paradigm, subjective craving and US-expectancy seem to stem from only loosely related response systems, which behave in concordance during acquisition but diverge during extinction (van Gucht, Vansteenwegen, Beckers, & van den Bergh, 2008). Interestingly and contrary to findings in the broader addiction literature, explicit disconfirmation of eating expectancies did not abolish conditioned desire or craving for chocolate in an experimental study, questioning the mediating role of eating expectancies in the short-term extinction of conditioned eating desires (van den Akker et al., 2016). The authors argue that the representation of the US may get activated in memory upon encountering the CS even in the absence of any actual eating expectancies. This activation could be sufficient for experiencing an increase in craving. From an evolutionary perspective, the triggering of appetitive responses regardless of immediate availability information could serve the purpose of motivating an organism to actively seek out food sources which could have been essential for survival but may pose a threat for durable abstinence in our western abundant environment. Clearly, targeting craving specifically seems to be important in the treatment of eating and substance use disorders (van Gucht et al., 2010; Wolz, Nannt, & Svaldi, 2020) So which purpose could retrieval cues serve regarding relapse prevention of eating and substance use disorders? It can be hypothesized, that expectancy of a reward outcome associated with a stimulus might be a crucial aspect that triggers relapse to overconsummatory behaviour. In line with this hypothesis, previous work in our lab evidenced that the strength of acquired reward expectancy significantly predicted the impact of conditioned cues on instrumental responding for the corresponding reward (i.e. gaming-related rewards) in a Pavlovian-to-instrumental transfer (PIT)-paradigm (Vogel et al., 2018). Based on these considerations, retrieval cues may best serve as an intervention to influence psychological representations of reward availability. For example, susceptible individuals could probably purchase high-calorie foods and drugs almost whenever they want to (Field et al., 2013). A retrieval cue may prevent an individual from surrendering to short-term temptations not by abolishing subjective craving or eating desires, but by reinstating the psychological context of intentionally refraining from consumption, hence rendering the reward unavailable in one's mind and strengthen self-efficacy regarding abstinence. One could also aim at not only changing the availability information but also the (often unrealistic and exaggerated) expectations of the immediate outcome of a reward as is done in cognitive behavioural therapy (Field et al., 2013). In a naturalistic study with forty woman who reported binge eating, a combination of negative affect and higher cognitive eating expectancies (i.e. the belief, that eating would improve one's mood) increased the likelihood of subsequent binge eating (Smith et al., 2020). This means that changing specific eating expectancies may also prove useful and retrieval cues could aid in retrieving the newer and more realistic expectations from memory. Of course, one intervention alone most likely will not be sufficient for every patient and a combination of multiple strategies will be necessary for sustainable recovery (Craske et al., 2022). Assuming retrieval cues are integrated into treatment based on the recommendations by Craske et al. (2022), implementation seems relatively effortless especially when considering the potential benefits in the appetitive domain. However, tangible evidence for the effects of retrieval cues on desired behavioural outcomes has yet to be established. Future experimental studies ideally should test, if retrieval cues can exert an influence on recovery of instrumental responding after extinction using for example a PIT-paradigm or instrumental discrimination training (Bezzina, Lee, Lovibond, & Colagiuri, 2016; Steins-Loeber et al., 2019).

To summarize, our study provides - at an analogue level – further evidence for the potential utility of retrieval cues in the appetitive domain. We demonstrated that a retrieval cue can attenuate renewal of US-expectancy towards a naturalistic and biologically significant stimulus under conditions of ecological validity. This may prove useful for aiding patients in keeping long-term abstinence from unhealthy overconsumption via building a psychological bridge to what they have learned during therapy. However, serious methodological limitations are restricting any generalizable implications and more sophisticated research is clearly needed to shed light on the underlying mechanisms and ideal properties of retrieval cues. Only then will we be able to warrant the use of retrieval cues in the treatment of eating and substance use disorders.

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CRediT authorship contribution statement

Frank Lörsch: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ines Kollei:** Validation, Supervision. **Sabine Steins-Loeber:** Writing – review & editing, Supervision, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Baeyens, F., Crombez, G., van den Bergh, O., & Eelen, P. (1988). Once in contact always in contact: Evaluative conditioning is resistant to extinction. *Advances in Behaviour Research and Therapy, 10*(4), 179–199. https://doi.org/10.1016/0146-6402(88)90014-8

Berridge, K. C., & Robinson, T. E. (2016). Liking, wanting, and the incentive-sensitization theory of addiction. *American Psychologist, 71*(8), 670–679. https://doi.org/10.1037/amp0000059

Bezzina, L., Lee, J. C., Lovibond, P. F., & Colagiuri, B. (2016). Extinction and renewal of cue-elicited reward-seeking. *Behaviour Research and Therapy, 87*, 162–169. https://doi.org/10.1016/j.brat.2016.09.009

Boswell, R. G., & Kober, H. (2016). Food cue reactivity and craving predict eating and weight gain: A meta-analytic review. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity, 17*(2), 159–177. https://doi.org/10.1111/obr.12354

Boutelle, K. N., & Bouton, M. E. (2015). Implications of learning theory for developing programs to decrease overeating. *Appetite, 93*, 62–74. https://doi.org/10.1016/j.appet.2015.05.013

Bouton, M. E. (1991). Context and retrieval in extinction and in other examples of interference in simple associative learning. In *Current topics in animal learning: Brain, emotion, and cognition* (pp. 25–53). Lawrence Erlbaum Associates, Inc.

Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin, 114*(1), 80–99. https://doi.org/10.1037/0033-2909.114.1.80

Bouton, M. E. (2002). Context, ambiguity, and unlearning: Sources of relapse after behavioral extinction. *Biological Psychiatry, 52*(10), 976–986. https://doi.org/10.1016/S0006-3223(02)01546-9

Bouton, M. E. (2011). Learning and the persistence of appetite: Extinction and the motivation to eat and overeat. *Physiology & Behavior, 103*(1), 51–58. https://doi.org/10.1016/j.physbeh.2010.11.025

Bouton, M. E. (2014). Why behavior change is difficult to sustain. *Preventive Medicine, 68*, 29–36. https://doi.org/10.1016/j.ypmed.2014.06.010

Brooks, D. C., & Bouton, M. E. (1993). A retrieval cue for extinction attenuates spontaneous recovery. *Journal of Experimental Psychology: Animal Behavior Processes, 19*(1), 77–89. https://doi.org/10.1037/0097-7403.19.1.77

Brooks, D. C., & Bouton, M. E. (1994). A retrieval cue for extinction attenuates response recovery (renewal) caused by a return to the conditioning context. *Journal of Experimental Psychology: Animal Behavior Processes, 20*(4), 366–379. https://doi.org/10.1037//0097-7403.20.4.366

Brooks, D. C., & Bowker, J. L. (2001). Further evidence that conditioned inhibition is not the mechanism of an extinction cue's effect: A reinforced cue prevents spontaneous recovery. *Animal Learning & Behavior, 29*(4), 381–388. https://doi.org/10.3758/BF03192903

Bustamante, J., Uengoer, M., & Lachnit, H. (2016). Reminder cues modulate the renewal effect in human predictive learning. *Frontiers in Psychology, 7*, 1968. https://doi.org/10.3389/fpsyg.2016.01968

Collins, B. N., & Brandon, T. H. (2002). Effects of extinction context and retrieval cues on alcohol cue reactivity among nonalcoholic drinkers. *Journal of Consulting and Clinical Psychology, 70*(2), 390–397. https://doi.org/10.1037//0022-006X.70.2.390

Conklin, C. A., & Tiffany, S. T. (2002). Applying extinction research and theory to cue-exposure addiction treatments. *Addiction, 97*(2), 155–167. https://doi.org/10.1046/j.1360-0443.2002.00014.x

Craske, M. G., Kircanski, K., Zelikowsky, M., Mystkowski, J., Chowdhury, N., & Baker, A. (2008). Optimizing inhibitory learning during exposure therapy. *Behaviour Research and Therapy, 46*(1), 5–27. https://doi.org/10.1016/j.brat.2007.10.003

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy, 58*, 10–23. https://doi.org/10.1016/j.brat.2014.04.006

Craske, M. G., Treanor, M., Zbozinek, T. D., & Vervliet, B. (2022). Optimizing exposure therapy with an inhibitory retrieval approach and the OptEx Nexus. *Behaviour Research and Therapy, 152*, Article 104069. https://doi.org/10.1016/j.brat.2022.104069

Culver, N. C., Stoyanova, M., & Craske, M. G. (2011). Clinical relevance of retrieval cues for attenuating context renewal of fear. *Journal of Anxiety Disorders, 25*(2), 284–292. https://doi.org/10.1016/j.janxdis.2010.10.002

Dibbets, P., Havermans, R., & Arntz, A. (2008). All we need is a cue to remember: The effect of an extinction cue on renewal. *Behaviour Research and Therapy, 46*(9), 1070–1077. https://doi.org/10.1016/j.brat.2008.05.007

Dibbets, P., & Maes, J. H. (2011). The effect of an extinction cue on ABA-renewal: Does valence matter? *Learning and Motivation, 42*(2), 133–144. https://doi.org/10.1016/j.lmot.2010.12.003

Dibbets, P., Moor, C., & Voncken, M. J. (2013). The effect of a retrieval cue on the return of spider fear. *Journal of Behavior Therapy and Experimental Psychiatry, 44*(4), 361–367. https://doi.org/10.1016/j.jbtep.2013.03.005

Dicker-Oren, S. D., Gelkopf, M., & Greene, T. (2022). The dynamic network associations of food craving, restrained eating, hunger and negative emotions. *Appetite, 175*, Article 106019. https://doi.org/10.1016/j.appet.2022.106019

Elsesser, K., Wannemüller, A., Lohrmann, T., Jöhren, P., & Sartory, G. (2013). Mental retrieval of treatment context in dental phobia. *Behavioural and Cognitive Psychotherapy, 41*(2), 173–187. https://doi.org/10.1017/S1352465812000318

Fairburn, C. G., & Beglin, S. J. (1994). Assessment of eating disorders: Interview or self-report questionnaire? *International Journal of Eating Disorders, 16*(4), 363–370.

Field, M., Jedras, P., & Jones, A. (2013). The role of anticipation in drug addiction and reward. *Neuroscience and Neuroeconomics, 1*. https://doi.org/10.2147/NAN.S35917

Field, M., Werthmann, J., Franken, I., Hofmann, W., Hogarth, L., & Roefs, A. (2016). The role of attentional bias in obesity and addiction. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association, 35*(8), 767–780. https://doi.org/10.1037/hea0000405

Fraser, K. M., & Holland, P. C. (2019). Occasion setting. *Behavioral Neuroscience, 133*(2), 145–175. https://doi.org/10.1037/bne0000306

Haahr, M. (1998). Coin flipper [Computer software] https://www.random.org/coins/.

Hilbert, A., & Tuschen-Caffier. (2016). *Eating disorder examination-questionnaire: Deutschsprachige übersetzung (bd. 02, 2. Auflage)*. dgvt-Verlag. https://doi.org/10.1026/0012-1924.53.3.144

Hilbert, A., Zwaan, M.de, & Braehler, E. (2012). How frequent are eating disturbances in the population? Norms of the eating disorder examination-questionnaire. *PLoS One, 7*(1), Article e29125. https://doi.org/10.1371/journal.pone.0029125

Jansen, A. (1998). A learning model of binge eating: Cue reactivity and cue exposure. *Behaviour Research and Therapy, 36*(3), 257–272. https://doi.org/10.1016/S0005-7967(98)00055-2

Jansen, A., Havermans, R. C., & Nederkoorn, C. (2011). Cued overeating. In V. R. Preedy, R. R. Watson, & C. R. Martin (Eds.), *Handbook of behavior, food and nutrition* (pp. 1431–1443). New York: Springer. https://doi.org/10.1007/978-0-387-92271-3_92.

Jansen, A., Schyns, G., Bongers, P., & van den Akker, K. (2016). *From lab to clinic: Extinction of cued cravings to reduce overeating. Physiology & Behavior*. Advance online publication. https://doi.org/10.1016/j.physbeh.2016.03.018

Laborda, M. A., Schofield, C. A., Johnson, E. M., Schubert, J. R., George-Denn, D., Coles, M. E., et al. (2016). The extinction and return of fear of public speaking. *Behavior Modification, 40*(6), 901–921. https://doi.org/10.1177/0145445516645766

Loeber, S., Croissant, B., Heinz, A., Mann, K., & Flor, H. (2006). Cue exposure in the treatment of alcohol dependence: Effects on drinking outcome, craving and self-efficacy. *British Journal of Clinical Psychology, 45*(Pt 4), 515–529. https://doi.org/10.1348/014466505X82586

Magson, N. R., Handford, C. M., & Norberg, M. M. (2021). The empirical status of cue exposure and response prevention treatment for binge eating: A systematic review. *Behavior Therapy, 52*(2), 442–454. https://doi.org/10.1016/j.beth.2020.06.005

Marsh-Richard, D. M., Hatzis, E. S., Mathias, C. W., Venditti, N., & Dougherty, D. M. (2009). Adaptive visual analog scales (avas): A modifiable software program for the creation, administration, and scoring of visual analog scales. *Behavior Research Methods, 41*(1), 99–106. https://doi.org/10.3758/BRM.41.1.99

Meule, A., & Hormes, J. M. (2015). Chocolate versions of the Food Cravings Questionnaires. Associations with chocolate exposure-induced salivary flow and ad libitum chocolate consumption. *Appetite, 91*, 256–265. https://doi.org/10.1016/j.appet.2015.04.054

Mogg, K., & Bradley, B. P. (2016). Anxiety and attention to threat: Cognitive mechanisms and treatment with attention bias modification. *Behaviour Research and Therapy, 87*, 76–108. https://doi.org/10.1016/j.brat.2016.08.001

Mystkowski, J. L., Craske, M. G., Echiverri, A. M., & Labus, J. S. (2006). Mental reinstatement of context and return of fear in spider-fearful participants. *Behavior Therapy, 37*(1), 49–60. https://doi.org/10.1016/j.beth.2005.04.001

Reents, J., Seidel, A.-K., Wiesner, C. D., & Pedersen, A. (2020). The effect of hunger and satiety on mood-related food craving. *Frontiers in Psychology, 11*, Article 568908. https://doi.org/10.3389/fpsyg.2020.568908

Rescorla, R. A. (1969). Pavlovian conditioned inhibition. *Psychological Bulletin, 72*(2), 77–94. https://doi.org/10.1037/h0027760

Schyns, G., Roefs, A., Smulders, F. T. Y., & Jansen, A. (2017). Cue exposure therapy reduces overeating of exposed and non-exposed foods in obese adolescents. *Journal of Behavior Therapy and Experimental Psychiatry, 58*, 68–77. https://doi.org/10.1016/j.jbtep.2017.09.002

Shin, K. E., & Newman, M. G. (2018). Using retrieval cues to attenuate return of fear in individuals with public speaking anxiety. *Behavior Therapy, 49*(2), 212–224. https://doi.org/10.1016/j.beth.2017.07.011

Smith, K. E., Mason, T. B., Juarascio, A., Weinbach, N., Dvorak, R., Crosby, R. D., et al. (2020). The momentary interplay of affect, attention bias, and expectancies as predictors of binge eating in the natural environment. *International Journal of Eating Disorders, 53*(4), 586–594. https://doi.org/10.1002/eat.23235

Steins-Loeber, S., Madjarova, R., Lörsch, F., Herpertz, S. C., Flor, H., & Duka, T. (2019). An experimental study on spontaneous recovery of conditioned reward expectancies and instrumental responding in humans. *Behaviour Research and Therapy, 118*, 54–64. https://doi.org/10.1016/j.brat.2019.03.010

Stice, E., & Burger, K. (2019). Neural vulnerability factors for obesity. *Clinical Psychology Review, 68*, 38–53. https://doi.org/10.1016/j.cpr.2018.12.002

Stojek, M., Shank, L. M., Vannucci, A., Bongiorno, D. M., Nelson, E. E., Waters, A. J., et al. (2018). A systematic review of attentional biases in disorders involving binge eating. *Appetite, 123*, 367–389. https://doi.org/10.1016/j.appet.2018.01.019

van den Akker, K., Nederkoorn, C., & Jansen, A. (2017). Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology, 118*, 40–47. https://doi.org/10.1016/j.ijpsycho.2017.06.004

van den Akker, K., van den Broek, M., Havermans, R. C., & Jansen, A. (2016). Violation of eating expectancies does not reduce conditioned desires for chocolate. *Appetite, 100*, 10–17. https://doi.org/10.1016/j.appet.2016.02.004

van Gucht, D., Baeyens, F., Hermans, D., & Beckers, T. (2013). The inertia of conditioned craving. Does context modulate the effect of counterconditioning? *Appetite, 65*, 51–57. https://doi.org/10.1016/j.appet.2013.01.019

van Gucht, D., Baeyens, F., Vansteenwegen, D., Hermans, D., & Beckers, T. (2010). Counterconditioning reduces cue-induced craving and actual cue-elicited consumption. *Emotion, 10*(5), 688–695. https://doi.org/10.1037/a0019463

van Gucht, D., Vansteenwegen, D., Beckers, T., & van den Bergh, O. (2008). Return of experimentally induced chocolate craving after extinction in a different context: Divergence between craving for and expecting to eat chocolate. *Behaviour Research and Therapy, 46*(3), 375–391. https://doi.org/10.1016/j.brat.2008.01.003

van Gucht, D., Vansteenwegen, D., van den Bergh, O., & Beckers, T. (2008). Conditioned craving cues elicit an automatic approach tendency. *Behaviour Research and Therapy, 46*(10), 1160–1169. https://doi.org/10.1016/j.brat.2008.05.010

Vansteenwegen, D., Vervliet, B., Hermans, D., Beckers, T., Baeyens, F., & Eelen, P. (2006). Stronger renewal in human fear conditioning when tested with an acquisition retrieval cue than with an extinction retrieval cue. *Behaviour Research and Therapy, 44*(12), 1717–1725. https://doi.org/10.1016/j.brat.2005.10.014

Vervliet, B., Baeyens, F., van den Bergh, O., & Hermans, D. (2013). Extinction, generalization, and return of fear: A critical review of renewal research in humans. *Biological Psychology, 92*(1), 51–58. https://doi.org/10.1016/j.biopsycho.2012.01.006

Vogel, V., Kollei, I., Duka, T., Snagowski, J., Brand, M., Müller, A., et al. (2018). Pavlovian-to-instrumental transfer: A new paradigm to assess pathological

mechanisms with regard to the use of internet applications. *Behavioural Brain Research, 347*, 8–16. https://doi.org/10.1016/j.bbr.2018.03.009

Weisman, J. S., & Rodebaugh, T. L. (2018). Exposure therapy augmentation: A review and extension of techniques informed by an inhibitory learning approach. *Clinical Psychology Review, 59*, 41–51. https://doi.org/10.1016/j.cpr.2017.10.010

Wolz, I., Nannt, J., & Svaldi, J. (2020). Laboratory-based interventions targeting food craving: A systematic review and meta-analysis. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity, 21*(5), Article e12996. https://doi.org/10.1111/obr.12996