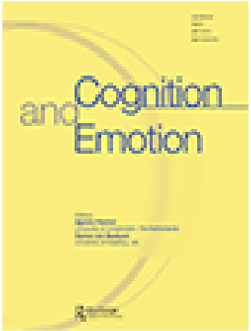

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Emotional eating and Pavlovian learning: evidence for conditioned appetitive responding to negative emotional states

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ABSTRACT
Appetitive learning has been demonstrated several times using neutral cues or contexts as a predictor of food intake and it has been shown that humans easily learn cued desires for foods. It has, however, never been studied whether internal cues are also capable of appetitive conditioning. In this study, we tested whether humans can learn cued eating desires to negative moods as conditioned stimuli (CS), thereby offering a potential explanation of emotional eating (EE). Female participants were randomly presented with 10 different stimuli eliciting either negative or neutral emotional states, with one of these states paired with eating chocolate. Expectancy to eat, desire to eat, salivation, and unpleasantness of experiencing negative emotions were assessed. After conditioning, participants were brought into a negative emotional state and were asked to choose between money and chocolate. Data showed differential conditioned responding on the expectancy and desire measures, but not on salivation. Specific conditioned effects were obtained for participants with a higher BMI (body mass index) on the choice task, and for participants high on EE on the unpleasantness ratings. These findings provide the first experimental evidence for the idea that negative emotions can act as conditioned stimuli, and might suggest that classical conditioning is involved in EE.

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Appetitive conditioning; emotional eating; emotional states; mood; cue reactivity

Palatable high-calorie foods have high potential for conditioning. Every time one eats, there is an opportunity to associate the eating with cues or contexts that are present at the time (Bouton, 2011; Bouton, Woods, Moody, Sunsay, & García-Gutiérrez, 2006). The number of daily possibilities to associate cues and contexts with palatable food intake is almost endless (Bouton, 2011). The place where one eats, food preparing rituals, food smells and tastes, time of the day; they are all potential signals for eating and classical conditioning. Animal studies show that physiological responses to food intake (e.g. insulin release, blood-sugar increase, and salivation) can be elicited by any stimulus predictive of eating (Bouton et al., 2006; Jansen, Havermans, & Nederkoorn, 2011). Context-cues associated with palatable food intake drive overeating in rats, even when they are sated and when the food is less preferred (Boggiano, Dorsey, Thomas, & Murdaugh, 2009; Weingarten, 1983).

In humans, it likewise appears to be relatively easy to learn cued eating desires and cued overeating through classical conditioning. In a series of experimental studies, successful appetitive conditioning to neutral cues like serving trays, vases, and children's jewellery boxes was demonstrated by systematically pairing these neutral cues with the eating of something palatable, like a small piece of chocolate (van den Akker, Havermans, Bouton, & Jansen, 2014; van den Akker, Havermans, & Jansen, 2015; Bongers, van den Akker, Havermans, & Jansen, 2015; Papachristou, Nederkoorn, Beunen, & Jansen, 2013; Van Gucht, Baeyens, Hermans, & Beckers, 2013; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010; Van Gucht, Vansteenwegen, Beckers, & Van Den Bergh, 2008; Van Gucht, Vansteenwegen, Van den

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Bergh, & Beckers, 2008). These studies consistently show that after the learning of a stimulus predicting intake, the mere presence of the food-predictive stimulus is sufficient to elicit eating expectations and eating desires. Also when satiated a signal that predicts consumption is able to elicit food desires; just thinking of how delicious the dessert would taste might make people feel "hungry" and eat, even when they had a large meal. Such cued eating desires increase the risk of overeating (Ferriday & Brunstrom, 2011; Jansen, 1998; Jansen, Havermans, & Nederkoorn, 2011). A mere four cue-intake trials being enough to obtain these effects shows that appetitive learning develops quickly. Appetitive conditioning was also demonstrated with contexts instead of cues. Birch, McPhee, Sullivan, and Johnson (1989) showed contextual conditioning of meal initiation, with pre-school children showing significantly shorter latencies to start eating in an environment previously paired with eating compared to an environment not associated with eating. Van den Akker, Jansen, Frentz, and Havermans (2013) conducted a virtual reality study in which distinct physical environments (contexts) were paired with food intake. As with all kinds of other external cues, contexts easily developed into conditioned signals eliciting increased food expectancies, food craving, salivation, and intake. Though these data show that human appetitive conditioning to external cues and contexts is a quite robust finding, it has never been studied whether internal cues are also capable of appetitive conditioning. Of special interest is whether specific emotional states have the potential to act as conditioned stimuli for overeating. If emotional states are systematically associated with eating they might, in the end, easily trigger eating desires and overeating. Overeating induced by emotions is the hallmark of emotional eating (EE), a term first coined in the 1960s (Bruch, 1964). Although originally introduced as an explanation for obesity and with a focus on merely negative emotions, EE has since evolved into a behaviour also ascribed to other populations (Herman & Mack, 1975; Nisbett, 1968; Van Strien, Frijters, Bergers, & Defares, 1986). In addition, studies have shown that positive emotions are also capable of eliciting overeating in emotional eaters (Bongers, Jansen, Havermans, Roefs, & Nederkoorn, 2013; Bongers, Jansen, Houben, & Roefs, 2013; Evers, Adriaanse, de Ridder, & de Witt Huberts, 2013).

If EE is a specific demonstration of appetitive conditioning, two possible pathways through which this could occur are most obvious (Bongers, Akker et al., 2015). The first pathway proposes that EE develops through the facilitating effect a negative mood has on the learning of an association between a neutral cue and food intake. This hypothesis was based on the idea that the eating of highly palatable foods is rewarding and mood-enhancing (see e.g. Coletta et al., 2009; Macht & Dettmer, 2006; Macht & Mueller, 2007; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001), which is especially reinforcing for individuals who are in a negative mood. They would benefit from learning that certain cues predict tasty foods, and thus an alleviation of a negative mood. To test this, half of our participants underwent a differential conditioning procedure while in a negative mood, the other half while in a neutral mood. One distinct vase with flowers was repeatedly paired with food intake, whereas a second distinct vase was not. Expectancy to eat, desire to eat, salivation, and food intake were measured. Though appetitive conditioning was demonstrated, no clear evidence for a facilitating effect of negative mood on appetitive conditioning was found (Bongers, Akker et al., 2015). The second pathway, which is under investigation in the current study, specifies the emotions in itself as conditioned stimuli. If a particular emotional state is (nearly) always followed by the intake of palatable high-calorie foods, the specific emotional state will become a predictor signalling high-calorie food intake. It then follows that the mere experience of such an emotion will automatically elicit food cravings, a salivation response, and ultimately cued consumption. Although never experimentally tested, emotions have been suggested to have the potential to grow into conditioned stimuli (Greeno & Wing, 1994; Jansen, 1998; Jansen, Havermans, & Nederkoorn, 2011; Macht, 2008; Wardle, 1990).

In the present study, we investigate whether, after repeatedly being paired with chocolate (US, or unconditioned stimulus), negative emotional states can act as conditioned appetitive stimuli (CSs) that elicit cue reactivity, like cued eating expectations, cued eating desires, and cued salivation (conditioned responses; CRs). We included expectancy to eat and desire to eat ratings as self-report measures, saliva production as a physiological measure, and a money vs. chocolate choice task during negative mood as a behavioural measure. Because the eating of high-calorie foods is especially rewarding in response to negative emotional states, we expect the appetitive conditioning of negative emotional mood cues to be stronger, quicker, and easier than the appetitive conditioning

of neutral mood cues. We hypothesise differential responding to the CSs (i.e. negative and neutral emotional states) on the self-report and physiological measures. With regard to the behavioural measure, we expect participants conditioned to eat in a negative emotional state to have a stronger preference for chocolate than participants conditioned to eat in a neutral state. Finally, some earlier appetitive conditioning studies show a significant increase in CS+(i.e. the CS paired with food) liking after conditioning (van den Akker et al., 2013, 2014, 2015; Bongers, Akker et al., 2015; Papachristou et al., 2013; Van Gucht et al., 2010). If appetitive conditioning with negative emotions as the CS+is successful, and CS+liking occurs, negative emotions should be evaluated as less negative after conditioning. We therefore predicted that the experienced unpleasantness of negative emotions will reduce in individuals for whom negative emotions were paired with chocolate.

Methods

Participants

Forty-seven female undergraduate students aged 18–30 years old ($M = 20.25$, SD = 2.53) participated in the study in return for course credit or a gift voucher worth €12.50. Sample size was based on previous studies on appetitive conditioning in humans that utilised a similar paradigm (van den Akker et al., 2014; Meyer, Risbrough, Liang, & Boutelle, 2015; Van Gucht et al., 2010; Van Gucht, Vansteenwegen, Beckers, & Van Den Bergh, 2008; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008). Participants were recruited through advertisements which referred to a study on "the influence of concentration and emotions on taste perception". To be eligible for participation, participants had to be female undergraduate students between the ages of 18 and 30, with no food allergies and a liking of chocolate. A single question via email after sign-up assessed chocolate liking on a scale of 1 (does not like chocolate at all) to 5 (likes chocolate very much), and a minimum score of 3 was required. The study was approved by the ethics committee of the Faculty of Psychology and Neuroscience, Maastricht University.

Study design and conditioning procedure

Participants were randomly divided over two conditions: in the FoodNeg condition ($n = 22$) participants were conditioned to eat during negative emotional states (i.e. receiving chocolate when experiencing a negative emotional state (CS+) and no chocolate in a neutral emotional state (CS−)), in the other (FoodNeu condition, $n = 25$) this was reversed (i.e. receiving chocolate in a neutral emotional state (CS+) and no chocolate in a negative emotional state (CS−)). Ten conditioning trials (5 trials with negative mood and 5 trials with neutral mood) were randomly presented, with the restriction that the first two and last two trials consisted of a CS+ and CS− trial, counterbalanced across participants. In addition, there could be no more than two consecutive trials of the same type. After each trial there was a three-minute intertrial interval to return the participants' mood back to its original level.

Stimuli

CSs

Five different stimuli were used to evoke negative or neutral emotional states. All stimuli had a negative and a neutral variety and were presented for three minutes. All stimuli were pilot tested and found to have the desired effect.

Text. The negative text consisted of a 12-year-old girl detailing what happened to her and her family during the Cambodian genocide in the late 1970s. The neutral text was a travel blog of a Dutch girl who visited some well-known Cambodian temples. Both texts consisted of approximately 600 words. Three relevant pictures were added to each text.

Music. For the negative music, participants listened to a song which elicited sad feelings in them. The song of choice was personal and therefore different for each participant. The neutral music was La Traviata (Prelude to Act 1) by Giuseppe Verdi and was the same for each participant. La Traviata was found to be neutral in a previous study (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007).

Film. A scene from the movie The Champ in which a boy watches his father die was used as the negative stimulus. The neutral film explained the making of model train cars.

Memory. To induce a negative mood, participants read and thought about a negative memory. For the neutral mood, participants read and thought about a neutral memory.

Pictures. 18 negative pictures selected from the International Affective Picture System[1] (IAPS; Lang, Bradley, & Cuthbert, 1999) were used to induce a

negative mood; those selected for this study were previously rated high on sadness and low on disgust (Mikels et al., 2005). Each picture was presented for 10 seconds, while Adagio in Sol Minore by Tomaso Albinono played in the background. Adagio in Sol Minore has been found to be an effective inducer of negative mood (Mitterschiffthaler et al., 2007). For the neutral version, 18 neutral IAPS pictures[2] were presented for 10 seconds with Georg Friedrich Haendel's Watermusic Minuet playing in the background. Both the pictures (Lang et al., 1999) and the music (Mitterschiffthaler et al., 2007) were reported as neutral in previous studies.

USs

Small star-shaped chocolates (brand: Maison Blanche Dael) were used as USs. The chocolates were individually presented in a small transparent cup. Participants had a choice between milk and dark chocolate and each chocolate weighed approximately 1.7 grams.

Puzzles

Participants were instructed to work on puzzles during the three-minute intertrial interval. It was stressed to participants that although they should focus only on the puzzles, there was no goal to reach and they could switch between puzzles whenever they wanted. A selection of seven different puzzles (e.g. word finder, Sudoku, crossword, connect-the-dots) was available for participants to choose from. The puzzles were used to keep participants occupied during the intertrial interval and to counteract the possibly ongoing effects of the prior (negative) manipulation. A pilot study with 10 participants showed this to be an effective technique.

Measures

Mood. To take into account the variety of negative emotions that could be induced by our stimuli, and because we were interested in the experience of a negative emotional state in general, and not specific negative feelings, participants received the following instructions before the first mood measurement at baseline:

> During the study you will experience several negative feelings. These can for example be sadness, anger or anxiety, but also other unpleasant or disagreeable feelings. We will not ask about what kind of feelings you experience specifically, but we do want to know how strong these feelings are.

Mood was then rated on a 100 mm visual analogue scale (VAS) which asked "How strong are your negative feelings at this moment?", ranging from "Not strong at all" to "Extremely strong". The VAS scale was presented before and after every stimulus presentation.

Expectancy and desire. Expectancy to receive chocolate and desire to eat chocolate were measured by means of VAS scales after every stimulus presentation. For expectancy, the question was formulated as "Focus on how you feel right now. How strongly do you expect to receive chocolate at this moment?" and the VAS ranged from "Not at all" to "Very much". The question for desire read "Focus on how you feel right now. How much do you desire to eat chocolate at this moment?" and the anchor points on the VAS were identical to those of the expectancy-question.

Emotional valence/CS-liking. At baseline and after conditioning, participants rated on a VAS scale how unpleasant they find it to experience negative emotions. The VAS ranged from "not unpleasant at all" to "very unpleasant".

Imagination. To check whether participants followed instructions and did their best to imagine themselves in the scenes depicted in the stimuli, they were asked how hard they tried to imagine themselves in all situations and how well they managed to do this imagination. Both questions were answered on a VAS ranging from "not hard at all/not well at all" to "very hard/very well".

Contingency awareness. Contingency awareness was measured through two questions, framed in the following way: "You just finished a computer task where you had to empathize with several stimuli. During the task, did you experience a certain feeling or certain feelings which were always followed by eating chocolate?" Answering options were "yes", "no", or "I don't know". If participants answered "yes", they were asked to write down which feelings were always followed by chocolate. An identical question was asked where "feeling(s)" was replaced by "stimulus/stimuli".

Salivation. Salivation was measured at baseline and after trials 9 and 10. Dental cotton rolls (Hartmann Celluron no. 2) were used to assess saliva production. For one minute, participants placed one cotton role in each side of their mouth, between the cheek and lower gum. They placed an additional half role under their tongue. Cotton roles were measured in grams before and after the salivation measurement on a 0.01 gram precision kitchen scale.

Choice task. A wooden tray on which a 2-euro coin and a small bag of the star-shaped chocolates (approximately 90 grams, retail price €2) were presented was put in front of the participants and they were invited to take the item they would most like to have at that moment.

DEBQ. The Emotional Eating (EE) and Dietary Restraint (DR) subscales Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien, 2005) were used to assess emotional eating and dietary restraint. The scales consist of 13 and 10 questions, respectively, and items are answered on a 5-point Likert scale. Higher scores indicate a higher degree of emotional or restrained eating behaviour.

Compliance with eating instructions. Participants were asked to indicate when and what they had last eaten before participating in the experiment. Additionally, they were asked whether they had consumed chocolate in the last 24 hours, and if so, when.

Awareness check. An awareness check was included to assess whether participants were aware of the hypotheses.

Height and weight. Participants' height and weight was measured while wearing street clothes but no shoes.

Procedure

After sign-up, participants received an email with instructions to not consume any chocolate in the 24 hours before the experiment, as well as to eat something small (e.g. an apple or sandwich) 2 hours before participation, but to refrain from eating or drinking (except water) thereafter. They were also asked to send the artists and titles of two songs that made them happy and two songs that made them sad to the experimenter. Finally, they were asked to write down a personal sad memory, a personal happy memory, and a neutral memory (i.e. a description of the route from home to the university library) on three separate sheets of paper and to take those with them to the lab on the testing day. The happy music and happy memory were not used in the experiment, but were included to keep the content of the study obscure. Upon arrival in the lab, participants were asked to put cotton rolls in their mouth for the baseline saliva measurement. They then answered the baseline question for CS liking, and following this received instructions (orally and in writing) with regard to the conditioning part of the experiment:

> Next you will see and hear a number of different stimuli. With stimuli we mean film clips, music, memories, texts and pictures. The film clips, music and pictures will be shown on the screen, the memories and texts are on paper. Some of these stimuli will elicit negative feelings, others will not. After one of the two (so after negative or neutral feelings) you will receive something to eat, after the other you will not. So, after every stimulus, you can predict whether or not you will receive something to eat.

The next screen contained the explanation of the mood measurements, and subsequently the first trial started with a mood VAS. Before presentation of every stimulus, the following information appeared on the participants' screen: "You are about to see a stimulus. We want you to fully focus on this stimulus and concentrate on the feelings the stimulus elicits in you. You should really experience the feelings." After three minutes stimulus presentation was stopped, and the mood VAS was administered again, followed by the expectancy and desire measures. The experimenter then approached the participant with either an empty cup or a cup with a chocolate in it, dependent on the trial type. Participants were instructed to eat (or not) the chocolate, and following this, the computer screen showed the puzzle instructions. This trial procedure was repeated nine more times. During trial 9 and 10, the expectancy and desire ratings were followed by a second and third saliva measurement. After trial 10 the participant answered the second VAS to measure CS-liking. Finally, all participants listened to their second sad song. After three minutes the music stopped and the experimenter approached the participant and told her that she would get the standard reward for participating, but that the research team would like to give her something extra as a token of appreciation because of the considerable length and negative stimuli in the experiment. After the participants made their choice of either chocolate or money, they were asked to fill out a few more questionnaires, including the DEBQ, and the questions regarding contingency awareness, empathising, US liking, and compliance with eating instructions. They were measured and weighed, received their reward, and thanked for participation. The total duration of the experiment was 90 minutes. Timelines of both the whole experimental procedure and one single conditioning trial are provided in Figure 1(a) and 1(b), respectively. Participants

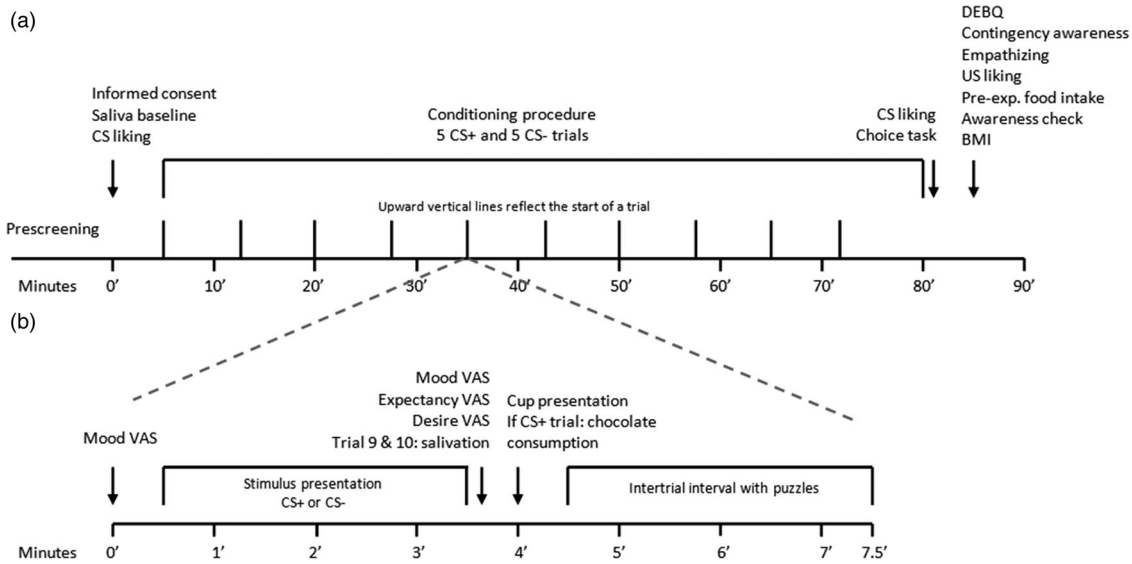

Figure 1. Timelines of the full experimental procedure (a) and a single conditioning trial (b).

received a debriefing via email after all data collection was completed.

Statistical analyses

Thirty-one participants (18 in the FoodNeg condition) reported contingency awareness on the self-report measure, whereas 16 participants did not or were unclear in their answers (6 in the FoodNeg condition). Closer inspection of expectancy graphs of these 16 participants revealed that 9 of the 16 did show conditioned expectancies in their responses. Analyses were run with and without these nine participants and revealed a similar pattern of results, and were therefore included in the analysis. The seven participants who did not report contingency awareness, neither in self-report nor in the expectancy graphs, were all in the FoodNeu condition and were not included in the analyses. The final sample consisted of 40 participants (22 in the FoodNeg condition, 18 in the FoodNeu condition).

A one-way ANOVA was carried out to check for pre-existing baseline differences between the two conditions. To investigate the effectiveness of our mood stimuli, we conducted a 2 (time: pre vs. post) × 2 (stimulus: negative vs. neutral) Repeated Measures ANOVA for each of the five stimuli. In case of a significant Time × Stimulus interaction, paired-sample *t*-tests were carried out to examine simple effects.

In all analyses on our main outcome variables (expectancy, desire, salivation, CS liking, and the choice task), centred body mass index (BMI) and DEBQ EE scores were included as covariates. Because Pearson's correlations revealed a moderate correlation between BMI and DEBQ-DR, $r = .38$, $p = .017$, only BMI was included as a covariate. Given that there were no a priori hypotheses regarding the covariates, α were adjusted to .008 (for expectancy and desire analyses), .016 (for salivation analysis) or .025 (for CS liking analysis) to correct for the number of factor and covariate interactions tested among these variables. Acquisition of expectancy and desire to eat was analysed in a mixed 2 (Condition: FoodNeg vs. FoodNeu) × 2 (CS-type: CS+ vs. CS−) × 5 (Trial: 1, 2, 3, 4, 5) ANOVA. Salivary responding was analysed in a mixed 2 (Condition: FoodNeg vs. FoodNeu) × 2 (CS-type: CS+ vs. CS−) × 3 (Time: baseline, CS+, CS−) ANOVA. A 2 (Condition: FoodNeg vs. FoodNeu) × 2 (Time: pre-conditioning vs. post-conditioning) mixed ANOVA was used to assess changes in CS liking. Additional analyses were performed in the case of significant interactions. When sphericity was violated, Greenhouse–Geisser corrections are reported. A logistic regression (method = Enter) with choice (chocolate vs. money) as the dependent variable, condition (FoodNeg vs. FoodNeu) as the main predictor variable (Block 1), BMI and DEBQ EE scores (Block 2) and their interactions with Condition (Block 3) as covariates was conducted to investigate

the effect of condition on reward choice. Reported effect sizes are eta-squared.

Results

Participant characteristics

As shown in Table 1, participants did not differ on age, imagination, emotional valence, DEBQ EE, or minutes since last eaten. There were significant condition differences on BMI (Cohen's $d = 0.75$) and DEBQ-DR (Cohen's $d = 0.49$). None of the participants were aware of the hypotheses of the study.

Emotional states manipulation

Pre- and post-mood scores per stimulus are displayed in Table 2. The Time × Stimulus interactions were significant for all five mood stimuli (all F's > 128.41, all p's < .000). Follow-up paired-sample t-tests to test for simple effects revealed a significant increase in negative feelings for all five negative stimuli. With regard to the neutral stimuli, there was a slight but significant decrease in negative feelings for the film, memory, and text manipulations. Together, these results show successful mood manipulations.

Conditioning effects

US Expectancy

US Expectancy ratings for participants in both conditions are shown in Figure 2. A significant Trial × CS-Type × Condition interaction, $F(3.39, 115.38) = 7.84$, $p < .001$, $\eta^2 = .11$, indicated differences between the FoodNeu and FoodNeg condition in expectancy learning. There was no effect of BMI or EE (all Fs < 1.51, all ps > .20. Follow-up analyses of Trial × CS-Type interactions per condition revealed that

Table 1. Means and standard deviations of participant characteristics per condition.

	FoodNeg ($n = 22$)		FoodNeu ($n = 18$)			
	M	SD	*M*	SD	*F*	*p*
Age	19.86	2.64	20.72	2.37	1.15	.29
BMI	21.59	1.97	24.94	5.97	6.15	.02
Imagination (effort)	80.59	9.26	84.50	8.63	1.88	.18
Imagination (success)	75.00	10.07	77.56	13.40	0.47	.50
Emotional valence (baseline)	64.41	21.12	68.06	22.91	0.27	.60
DEBQ-EE	3.01	0.53	2.72	0.64	2.57	.12
DEBQ-DR	2.62	0.66	3.05	0.54	4.87	.03
Minutes since last eaten	188.77	176.90	145.56	30.19	1.05	.31

DEBQ-EE, emotional eating scale of the DEBQ; DEBQ-DR, dietary restraint scale of the DEBQ.

Table 2. Means and standard deviations of pre- and post-mood score (on a scale from 0 to 100 with higher scores indicating higher negative feelings) per stimulus type.

	Pre ($n = 40$)		Post ($n = 40$)				
	M	SD	*M*	SD	*t*	*p*	Cohen's *d*
Film							
Negative	8.88	10.40	68.55	20.39	16.71	<.001	2.64
Neutral	18.43	16.90	10.50	13.42	4.34	< .001	0.69
Memory							
Negative	12.30	14.45	68.78	18.09	16.65	<.001	2.63
Neutral	18.58	18.44	11.68	14.69	3.04	.004	0.48
Pictures							
Negative	12.78	14.81	61.03	20.13	14.21	<.001	2.25
Neutral	15.28	15.86	12.05	13.43	1.30	.203	–
Text							
Negative	11.60	14.25	63.73	19.28	13.35	<.001	2.11
Neutral	18.85	16.63	9.70	13.96	4.12	<.001	0.66
Music							
Negative	12.08	14.10	65.20	21.06	14.07	<.001	2.22
Neutral	15.88	16.22	20.53	18.98	1.24	.118	–
Music II[a]							
Negative	19.90	18.31	63.60	20.76	13.04	<.001	2.06

[a]The second music manipulation, at the end of the conditioning procedure, consisted of a negative version only.

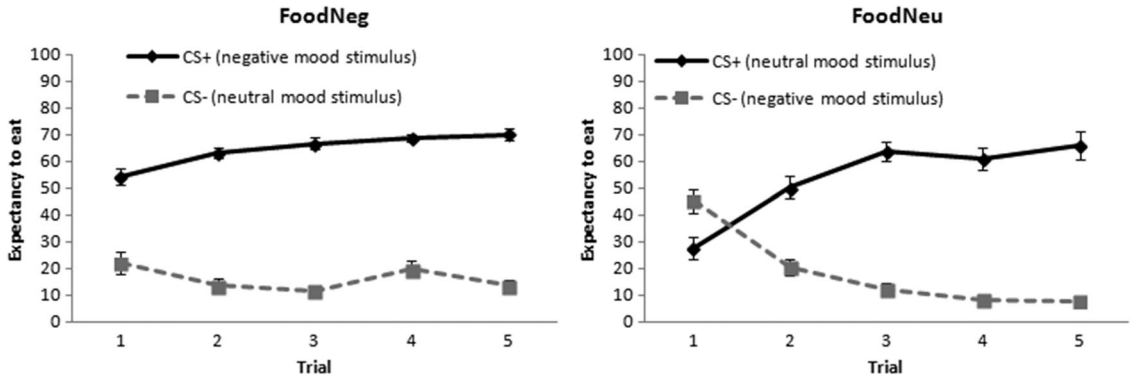

Figure 2. Mean US expectancy scores (+SEM) by CS-type and trial, for the FoodNeg and FoodNeu conditions separately.

acquisition was successful in both conditions (Negative: $F(2.42, 46.02) = 3.47$, $p = .031$, $\eta^2 = .14$; Neutral: $F(4, 60) = 25.40$, $p < .001$, $\eta^2 = .59$). Closer inspection of expectancy scores on Trial 1 showed a significant CS-Type × Condition interaction on this trial, $F(1, 34) = 20.37$,
$p < .001$, $\eta^2 = .33$, indicating a larger baseline difference between CS+ and CS− for the FoodNeg compared to the FoodNeu condition, although baseline differences on Trial 1 were present in both conditions (Negative: CS+ $M = 57.73$, SD = 21.06; CS− $M = 25.45$, SD = 24.12, $F(1, 21) = 23.37$, $p < .001$, $\eta^2 = .53$; Neutral: CS+ $M = 31.28$, SD = 27.05; CS− $M = 45.83$, SD = 23.50, $F(1, 17) = 4.94$, $p = .04$, $\eta^2 = .23$). There was a significant differentiation between CS+ and CS− trials on Trial 5, $F(1, 34) = 115.09$, $p < .001$, $\eta^2 = .76$, with no differences between conditions, $F(1, 34) = .02$, $p = .88$.

Desire to eat

Figure 3 displays desire ratings in both conditions. The participants showed a conditioned desire to eat, $F(3.2, 108.85) = 5.1$, $p = .002$, $\eta^2 = .09$, which did not differ between the two conditions, $F(3.2, 108.85) = .60$, $p = .63$. BMI and EE did not have a significant effect (all $Fs < 3.67$, all $ps < .013$). Differential desire to eat was present on Trial 5, $F(1, 34) = 13.64$, $p = .001$, $\eta^2 = .27$, with no differences between conditions, $F(1, 34) = 1.17$, $p = .29$.

Salivation

Salivation data of one participant in the neutral condition was missing. There was a main effect of time, $F(1.70, 56.00) = 3.72$, $p = .037$, $\eta^2 = .09$, indicating a difference in salivation across the three measurements (Negative: baseline $M = .80$, SD = .38; CS+ $M = 1.18$, SD = .82; CS− $M = 1.26$, SD = .76; Neutral: baseline $M = .88$, SD = .58; CS+ $M = 1.19$, SD = .64; CS− $M = 1.03$, SD = .55. Pairwise comparisons showed an increase of salivation from baseline to CS+ ($p = .04$), from baseline to CS− ($p = .01$), but no differences in salivation between CS+ and CS− ($p = .75$). BMI and EE did not exert any influence, all $Fs < 1.27$, all $ps > .29$.

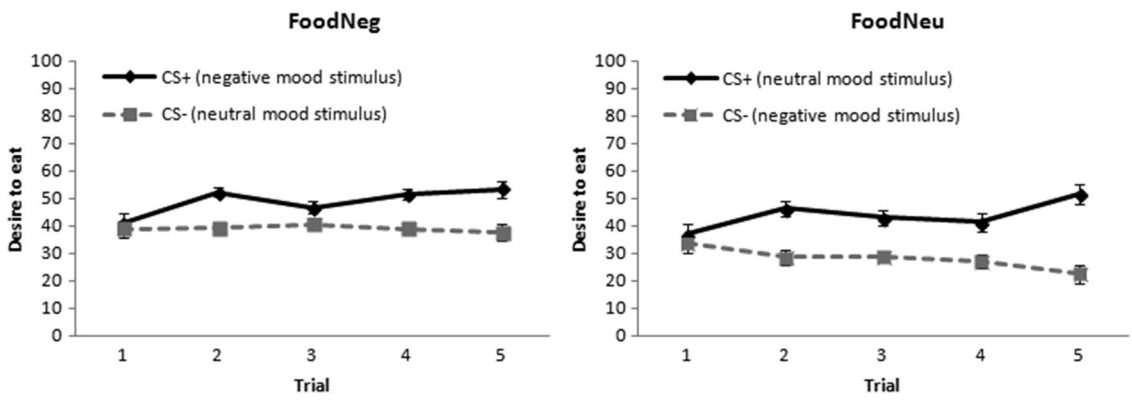

Figure 3. Mean US desire scores (+SEM) by CS-type and trial, for the FoodNeg and FoodNeu conditions separately.

Choice task

In the FoodNeg condition, 19 out of 22 (86%) participants chose chocolate over money. In the FoodNeu condition, this was 10 out of 18 participants (56%), $X^2(1) = 4.71$, $p = .03$, OR = 5.07. However, after controlling for BMI and EE in a logistic regression, the predictive effect of condition was no longer significant. EE × Condition ($B = 1.09$, SE = 1.81, $p = .55$) and the main effect of EE ($B = 1.42$, SE = .87, $p = .10$) were not significant and removed from the model. The final model with BMI and BMI × Condition as covariates showed a significant contribution of the interaction to the model (Block $X^2(1) = 3.96$, $p = .047$; Model $X^2(3) = 11.98$, $p = .007$, Nagelkerke $R^2 = .37$. B(SE) for all variables in this model were 2.37 (1.43), $p = .097$ for condition, −.32 (.20), $p = .12$ for BMI, and .84 (.50), $p = .09$ for BMI × Condition. To further investigate the BMI × Condition interaction a spotlight-analysis at one standard deviation above and below mean BMI was conducted. The results of this analysis are depicted in Figure 4. At low levels of BMI (−1 SD), participants in the FoodNeu and FoodNeg conditions did not differ in their probability of choosing chocolate (FoodNeu = .99, FoodNeg = .95, $B = -1.43$, SE = 1.16, $p = .37$). At high levels of BMI, there was a trend-significant effect indicating a higher probability of choosing chocolate for those in the FoodNeg (1.0) compared to the FoodNeu condition (.82), $B = 6.18$, SE = 3.4, $p = .07$. These results suggest a conditioned behavioural effect for participants with higher levels of BMI.

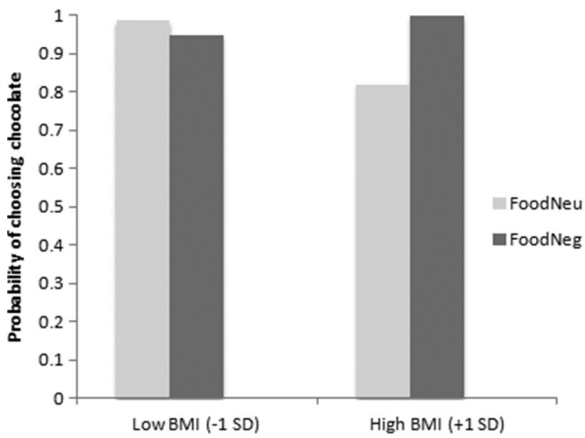

Figure 4. Probability of choosing chocolate as a function of condition and BMI (−1 SD and +1 SD from the mean BMI score).

CS liking—emotional valence

The Condition × Time interaction was not significant, $F(1, 34) = .46$, $p = .50$, but a significant Condition × Time × EE interaction, $F(1, 34) = 6.06$, $p = .019$, $\eta^2 = .14$, indicated that EE scores influence the change in emotional valence over time differently for each condition. A subsequent moderated regression and spotlight-analysis with simple slope testing at one standard deviation below or above the mean EE-score was conducted on the emotional valence difference score (baseline—post-conditioning) and is plotted in Figure 5. Centred Condition and EE scores were entered in Block 1 ($R^2 = .027$, $p = .61$), and their interaction was added in Block 2 ($R^2 = .238$, $p = .003$). This analysis revealed a significant Condition × EE interaction, B(SE) = 33.52 (10.60), $\beta = .69$, $t(39) = 3.16$, $p = .003$. More specifically, low emotional eaters (−1 SD) in both conditions did not differ on the

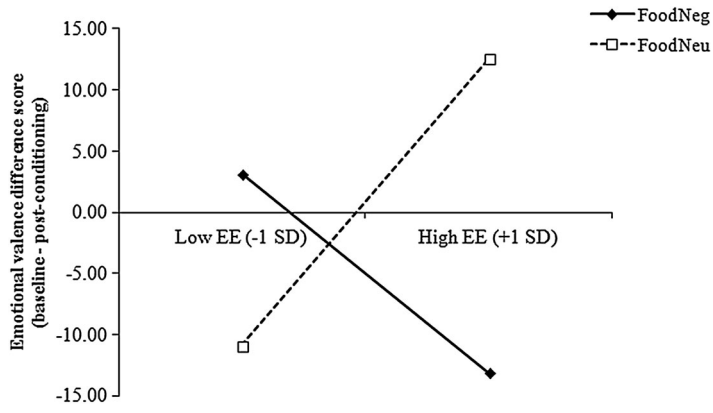

Figure 5. Emotional valence difference scores as a function of condition and low and high EE scores (−1 SD and +1 SD from the mean). Positive scores indicate an increase in unpleasantness of experiencing negative emotions from baseline to post-conditioning, while negative scores reflect a decrease in unpleasantness.

change in unpleasantness ratings after experiencing negative emotions, $B(SE) = -14.04$ (8.82), $t(39) = -1.59$, $p = .12$. On the other hand, participants scoring high on EE (+1 SD) responded differently to the experience of negative emotions, depending on condition, $B(SE) = 25.69$ (8.85), $t(39) = 2.90$, $p = .006$: when negative emotions were not accompanied by eating chocolate, high emotional eaters rated experiencing negative emotions as more unpleasant, and significantly more so than low emotional eaters, $B(SE) = 19.80$ (7.17), $t(39) = 2.76$, $p = .009$. When negative emotions were paired with eating chocolate, however, the unpleasantness ratings decreased, and were marginally lower than those of low emotional eaters, $B(SE) = -13.71$ (7.80), $t(39) = -1.76$, $p = .089$.

Discussion

We investigated whether negative emotional states can act as conditioned appetitive stimuli that elicit cue reactivity, and we expected the appetitive conditioning of emotional mood cues to be stronger than the appetitive conditioning of neutral mood cues. We found clear evidence of appetitive conditioning: in both conditions, participants successfully learned to expect and desire foods when confronted with a CS+ while they did not expect and desire foods while confronted with the CS−. This study again shows how relatively easy it is to learn cued desires to eat. However, contrary to expectations, this effect on expectations and desires was not more pronounced in the FoodNeg condition, meaning that the appetitive conditioning using emotional mood cues as CS+ was not stronger, quicker, or easier than the conditioning using neutral mood cues as CS+. Though both the negative and the neutral emotional states rather easily elicited cued expectations and desires, such an effect was not found for salivation: significant differences in salivation in response to the CS+ and CS− were not found. The behavioural data, the choice task, did, however, show the predicted effect, with participants in the FoodNeg condition being more inclined to choose chocolate than participants in the FoodNeu condition. A closer look at these data revealed that while at low levels of BMI the probability of choosing chocolate was equal in both conditions, participants higher in BMI chose the chocolate reward more frequently than the monetary reward compared to participants lower in BMI and to the condition in which neutral emotions were associated with the eating. Of note is that in the current design, participants in both conditions experienced only a negative stimulus before the choice task, limiting interpretation of the choice-effect. Adjusting the design so that half of the participants in both conditions are presented with a negative stimulus and the other half with a neutral stimulus could reveal whether the conditioned effect of choosing chocolate is as strong for the FoodNeu as for the FoodNeg condition. Differences in the emotional valence of emotions in the FoodNeg condition were also predicted: if appetitive conditioning with negative emotional states as the CS+ is successful, and CS+ liking occurs, negative emotions should be evaluated as less negative after conditioning. We found that self-reported EE scores significantly influenced the emotional valence of negative emotions after appetitive conditioning: high emotional eaters reported a decrease in experienced unpleasantness of negative emotions after repeated exposure to negative emotions when these emotions were followed by the eating of chocolate.

When examining the expectancy ratings, it is interesting to note that expectancies to receive food differ at the first trial. This might be due to the awareness of EE in the general public: the coverage of EE in the media means that most people will be familiar with the topic and endorse the idea that an association between negative emotions and eating exists, which translated to specific expectancies during the first conditioning trial. The data on salivation are in line with some other studies from our lab that assessed salivary responses in appetitive conditioning (van den Akker et al., 2013, 2014; Bongers, Akker et al., 2015). None of these studies found clear evidence for a conditioned salivation response. Possibly salivation responses are vulnerable to cross-over effects when measuring responses to CS+ and CS− within subjects and using cotton dental rolls. A recent study by Meyer et al. (2015) measured swallow responses according to the method of Nederkoorn, Smulders, and Jansen (1999) instead of using cotton rolls. They found conditioned responding (increased swallowing in response to the CS+) but only in obese and not healthy-weight participants. Together with our findings of an increased preference of chocolate over money which was present in the sample with higher BMI, these results might suggest that obese individuals are more susceptible to cue-induced responding than their healthy-weight counterparts. This idea fits with numerous previous studies that have demonstrated an association between weight status and food cue

reactivity, in which higher BMI is related to increased food cue reactivity like a stronger attention bias for food (Bongers, Giessen et al., 2015; Castellanos et al., 2009; Nijs, Muris, Euser, & Franken, 2010; Werthmann et al., 2011), stronger desire to eat after exposure to the sight or smell of food (Ferriday & Brunstrom, 2011; Tetley, Brunstrom, & Griffiths, 2009), more salivation (Epstein, Paluch, & Coleman, 1996), increased brain reward activity (Pursey et al., 2014) and increased cued intake (Jansen et al., 2003, 2008).

Of interest is our finding that, after being followed by the eating of chocolate, negative emotions were rated as less unpleasant (i.e. "liked" more) by emotional eaters only. This finding seems to be in line with affect regulation (Ganley, 1989) and escape theories (Heatherton & Baumeister, 1991), which propose that food intake can serve to improve mood, either by reducing negative feelings (affect regulation) or by creating a distraction from aversive self-awareness (escape theory). However, the current design withholds us from drawing any conclusions regarding eating-induced changes in mood. Inclusion of a third mood assessment after chocolate consumption could provide more insight into the mood-improving effects of food intake. Also, though affect regulation and escape theory do predict a change in mood, they do not necessarily predict changes in the experienced valence of negative emotions. A more parsimonious explanation for the demonstrated change in the valence of negative emotions is the occurrence of evaluative conditioning. Evaluative conditioning refers to a valence change of the conditioned stimulus, that is, mood in the current study, due to its co-occurrence with the US, that is, the tasting of pleasant foods. The current findings are in line with previous studies demonstrating increased liking of a neutral cue (CS) after it was repeatedly paired with palatable foods (van den Akker et al., 2013, 2014, 2015; Bongers, Akker et al., 2015; Papachristou et al., 2013; Van Gucht et al., 2010). Similar to the increased liking of vases, trays, or jewellery boxes in those earlier studies, the increased liking (or lower disliking) of negative emotions (CS) as observed in the current study could be explained in terms of evaluative conditioning. Remarkably, this change in emotional valence of negative emotions was only observed in participants scoring high on self-reported EE. Why this change is specific to this group is a question for future research. EE questionnaires should be interpreted with some caution. Although the data clearly show an effect of DEBQ-EE scores on change in unpleasantness ratings, high scorers on EE scales do not necessarily represent true emotional eaters. Recent studies have cast doubt on this assumption (Adriaanse, de Ridder, & Evers, 2011; Bongers, Jansen, Havermans, et al., 2013; Bongers, Jansen, Houben, & Roefs, 2013; Bongers, de Graaff, & Jansen, 2015; Brogan & Hevey, 2013; Conner, Fitter, & Fletcher, 1999), and it has been proposed that high-scoring individuals are instead characterised by a more general eating concern or constant worrying about eating (Adriaanse et al., 2011; Jansen, Nederkoorn, et al., 2011).

One question the current design cannot account for is whether it is truly a *feeling* that has become a conditioned stimulus or whether it is the *knowledge* that something sad is about to occur that elicited conditioned responding. In the design of the study, we focused strongly on feelings. Participants were instructed before every stimulus to concentrate on how the stimulus would make them feel, and when rating their expectancy and desire, the question was framed in such a way that participants had to focus on how they felt and answer the questions depending on this feeling. However, for all of the stimuli it was most likely clear from early on whether they were negative or neutral (e.g. the first image of the film clip being of a man dying, or being given the instructions to read the sad memory). Thus, after some pairings, participants might have been able to know a stimulus would be sad at first sight, leading immediately to the knowledge that chocolate would (or would not) follow, without actually having experienced feelings of sadness (which would develop during the three minutes of experiencing the stimulus). Although it would be interesting to design a future study in such a way that conditioned responding to knowledge can be separated from responding to feelings, for example, by adding expectancy and desire ratings soon after stimulus onset, both types of responding could be involved in EE. In real life, it is likely that emotional eaters initiate food intake when they experience negative feelings, which trigger CRs. On the other hand, it is also conceivable that the knowledge that something aversive is about to occur is enough to elicit these responses. It might be that the knowledge in itself induces apprehension—a negative feeling—and thus leads to craving and food consumption. An alternative is that conditioned responding occurs in such situations to "soften the blow" of what is coming; eating palatable food could have a protective effect, and could be a learned precautionary measure.

The current findings have implications for combating EE. Based on the classical conditioning principle of extinction, individuals should form a CS (i.e. negative feeling)—no US (i.e. eating) contingency, in which the CS does no longer predict the US. The new contingency should become stronger and more prominent than the original CS–US relationship. This can be obtained by repeatedly presenting the CS without it being followed by the US. Cue exposure with response prevention therapies (CERP), in which sight and smell of food are CSs, have proven fruitful in reducing CS–US contingencies in people diagnosed with bulimia nervosa (Jansen, Broekmate, & Heymans, 1992; Martinez-Mallén et al., 2007; Toro et al., 2003), overweight children (Boutelle et al., 2011), and overweight adults (Schyns, Roefs, Mulkens, & Jansen, 2015). It would be worthwhile to investigate whether CERP is also effective with negative emotional states as CSs.

Finally, a limitation of the study is that only healthy young women were included in the sample. Although this enabled us to study appetitive conditioning on emotional states in a homogenous group and made it possible to compare our results directly to the results of previous studies, generalisation of the findings to other populations is limited.

To conclude, it appears that negative emotional states do not differ from other stimuli in terms of learning potential, and can thus easily become conditioned stimuli for the intake of high-calorie snack foods. Although this has been theorised before, the current study is the first to experimentally show appetitive conditioned responding to negative emotional states and provides exciting evidence for emotional devaluation of the conditioned stimuli, that is, negative emotions, in emotional eaters.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Notes

1. IAPS pictures used for the negative version were 2053, 2141, 2205, 2800, 2900, 3230, 3350, 6570, 6838, 9000, 9041, 9050, 9415, 9421, 9520, 9530, 9611, 9910. IAPS pictures used for the neutral version were 1670, 2191, 2393, 2410, 2487, 2514, 2518, 5390, 5395, 5520, 7002, 7004, 7039, 7041, 7090, 7150, 8211, 8311.
2. See note 1 above.

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