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Altered appetitive conditioning in overweight and obese women

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ABSTRACT

Overweight and obese individuals show increased psychological and physiological reactivity to food cues and many of them have difficulties in achieving long-term weight loss. The current study tests whether abnormalities in the learning and extinction of appetitive responses to food cues might be responsible for this. Overweight/obese and healthy weight women completed a differential appetitive conditioning task using food as rewards, while eating expectancies, eating desires, conditioned stimulus evaluations, salivation, and electrodermal responses were assessed during an acquisition and extinction phase. Results suggested reduced discriminative conditioning in the overweight/obese group, as reflected by a worse acquisition of differential eating desires and no successful acquisition of differential evaluative responses. Some evidence was also found for impaired contingency learning in overweight and obese individuals. No group differences in conditioned salivation and skin conductance responses were found and no compelling evidence for differences in extinction was found as well. In sum, the current findings indicate that overweight and obesity may be characterized by reduced appetitive conditioning. It is suggested that this could be causally related to overeating via stronger context conditioning or a tendency towards overgeneralization in overweight and obese individuals.

1. Introduction

Currently, 2.1 billion individuals worldwide are overweight, including 600 million obese (Ezzati, 2016; Ng et al., 2014). Many overweight individuals attempt to lose weight (Weiss, Galuska, Khan, & Serdula, 2006), but successful long-term weight loss maintenance is rare: only an estimated 20% of dieters are able to lose at least 10% of their weight and maintain the weight loss for at least one year (Wing & Phelan, 2005). The high prevalence of overweight and obesity and the difficulty to lose excess weight has been attributed to the "obesogenic" environment – an environment characterized by an almost constant availability of tasty, inexpensive, and easy-to-get high-calorie foods (King, 2013). Specifically, exposure to the abundant food-associated cues (e.g., the sight and smell of food, food-related contexts such as restaurants, etc.) in this environment elicits food cue reactivity, which consists of psychological (eating desires) and physiological (e.g., salivation) responses (Boswell & Kober, 2016; Jansen, Havermans, & Nederkoorn, 2011; Jansen, Houben, & Roefs, 2015; Nederkoorn, Smulders, & Jansen, 2000). These cue-elicited responses drive overeating and may be stronger (e.g., Boswell & Kober, 2016; Ferriday & Brunstrom, 2011; Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010) and occur more frequently (Chao, Grilo, White, & Sinha, 2014) in overweight and obese individuals. This highlights the importance of studying the mechanisms that may underlie food cue reactivity.

Food cue reactivity is partly learned. After repeated pairings between an initially neutral stimulus and the intake of palatable food (unconditioned stimulus or US), the stimulus (now conditioned stimulus or CS) will become a reliable predictor of intake and elicits conditioned appetitive responses (CRs) such as a heightened desire to eat (Bouton, 2011; Jansen, 1998). Learning theory also predicts that conditioned appetitive responses should diminish when the CS does no longer predict the US (extinction). Indeed, laboratory studies in humans show that after a few pairings between a stimulus (e.g., a tray, box, or vase) and a US (e.g., a piece of chocolate), that stimulus (CS+) generally elicits a range of conditioned responses, including increased eating desires and eating expectancies, more positive evaluations of the stimulus, and physiological and neural reactivity, relative to a stimulus (CS-) that was never paired with food intake (e.g., Andreatta & Pauli,

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2015; Astur, Carew, & Deaton, 2014; Blechert, Testa, Georgii, Klimesch, & Wilhelm, 2016; Bongers, van den Akker, Havermans, & Jansen, 2015; Papachristou, Nederkoorn, Beunen, & Jansen, 2013; van den Akker, Havermans, & Jansen, 2017; van den Akker, Jansen, Frentz, & Havermans, 2013; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008b). These conditioned responses (partly) diminish when the US is no longer provided during extinction (van den Akker, Havermans, Bouton, & Jansen, 2014; van den Akker, Havermans, & Jansen, 2015; van den Akker, van den Broek, Havermans, & Jansen, 2016). Theoretically, a tendency to learn associations more rapidly or strongly between neutral cues and food intake could result in stronger and more frequent cue reactivity (e.g., eating desires), promoting food intake and weight gain while sabotaging successful dieting. Further, a predisposition to extinguish appetitive responses more slowly could also interfere with successful weight loss: when dieting, extinction is presumably practiced as the dieter attempts to restrict eating in response to previously reinforced food cues. If extinction of food cue reactivity is slow, the dieter may experience persistent food cue reactivity even after a prolonged period of successful non-reinforcement of food cues (Jansen et al., 2011; Jansen, Schyns, Bongers, & van den Akker, 2016; van den Akker et al., 2014). Thus, both the increased food cue reactivity in many overweight and obese individuals and a failure to lose weight may be attributable to an abnormal acquisition and extinction of appetitive responses to food-predicting cues.

Only a few studies have examined if and how overweight/obese and healthy weight individuals differ in new appetitive learning involving food rewards. The findings are mixed: one study reports successful acquisition of a conditioned swallowing response (indexing salivation) to a food-associated CS (CS+) in overweight, but not in healthy weight individuals (Meyer, Risbrough, Liang, & Boutelle, 2015), suggesting that overweight individuals may indeed be more prone to forming associations between neutral stimuli and palatable food intake. Unfortunately, in this study, it could not be examined whether overweight and healthy weight individuals differ in extinction due to the group differences in acquisition. A second study found an opposite pattern: obese women did not acquire differential US expectancies to a CS + paired with prospective food rewards vs. a CS-, whereas healthy weight controls showed successful discriminative learning (Zhang, Manson, Schiller, & Levy, 2014). Finally, in a third study, obese (but not healthy weight) individuals showed a preference for a CS *not* consistently associated with food intake (Coppin, Nolan-Poupart, Jones-Gotman, & Small, 2014). These inconsistent findings may be in part explained by the different types of outcome measures used to assess appetitive responding (each study examining only one), as it is known that different response systems are involved in conditioning that may not change in parallel (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Delamater & Oakeshott, 2007). The examination of multiple response systems may therefore aid in determining whether any response dissociations exist that can account for the mixed findings regarding acquisition. Further, whether overweight/obese individuals might (also) show different extinction patterns awaits investigation.

The aim of the present study was to examine whether overweight/obese and healthy weight individuals show differences in the acquisition and extinction of responses to food cues on different outcome measures (US expectancies, US desires, CS evaluations, salivation, and electrodermal responding). Given the associations between obesity, increased food cue reactivity, and a difficulty to lose weight, it was expected that overweight/obese individuals would show a stronger and quicker acquisition and a slower extinction of conditioned appetitive responses.

2. Methods and materials

2.1. Participants

Eighty individuals took part in the study (overweight/obese or OW: n = 46; healthy weight or HW: n = 34). They were recruited from the community. The sample size of the healthy weight control group was lower due to recruitment difficulties. A power analysis (G*Power 3.1.9.2) showed that using an effect size of d = 0.69 (based on overweight vs. healthy-weight group differences in differential appetitive responding found in a previous study [Meyer et al., 2015]) and an alpha of 0.05, the current study achieved a power of 0.86. The minimum detectable effect size (d) of group differences in responding in the current study was 0.64 (alpha = 0.05; power = 0.80). The inclusion criteria for all participants were: a female gender, age between 18 and 60 years, right-handedness, and a liking for milk chocolate. Exclusion criteria were: an impaired smell, pregnancy, and intolerance or allergy for chocolate. The overweight/obese group consisted of individuals seeking help for successful weight loss, and they completed the current task as part of the baseline assessment for a weight loss intervention (see van den Akker, Schyns, & Jansen, 2016), in which overweight participants were required to have a self-reported Body Mass Index or BMI of at least 27 (calculated by weight in kilograms divided by height in meters squared), needed to be motivated to lose weight, and report a difficulty to refrain from eating high-calorie food. They were excluded from participation if they had previously received, or were about to receive, bariatric surgery. The healthy weight control group was recruited specifically for the present study and participants were required to have a self-reported BMI of 18.5–23.5. The country of birth of most participants was either the Netherlands, Germany, or Belgium (44 OW or 95.65%; 33 HW or 97.06%). The groups were tested in the same time period and by the same team of experimenters. All participants were instructed to have a small meal (e.g., a sandwich) 2 h prior to the conditioning task. The healthy weight participants received a €20,- voucher for participation; the overweight/obese participants received a €25,- voucher for their participation and the completion of some additional measures on a second session that took place on another day (see van den Akker, Schyns, et al., 2016). The study was approved by the local ethical committee, and all participants gave written consent. For participants characteristics, see Table 1.

2.2. Overview of the experimental design

To test for group differences in the acquisition and extinction of appetitive responses to food cues, a differential appetitive conditioning paradigm was used in which two initially neutral geometric shapes functioned as CSs (CS+ and CS-) and chocolate functioned as the US. The experiment included two phases (acquisition and extinction) that ended when a US expectancy performance criterion was reached (see 'conditioning task'). Contingency learning (reaching the performance criterion, and US expectancies), US desires, CS evaluations, electrodermal responses, and salivation in response to the CSs functioned as outcome measures.

2.3. Measures

US expectancies, US desires, and CS evaluations: computerized Visual Analogue Scales (VAS) were used to assess one's expectancy to receive chocolate (*'To what extent do you expect to receive chocolate right now?'*), subjective desire for chocolate (*'When looking at this picture, how strong is your desire for chocolate right now?'*), and evaluations of the CS+ and CS- (*'How pleasant do you find this picture?'*). Ratings were scored from 0 *(certainly not expect to receive*

Table 1
Participants characteristics and baseline measures per group; means with standard deviations in parentheses. OW: overweight/obese group; HW: healthy weight group; BMI: body mass index; US: unconditioned stimulus; EDE-Q: Eating Disorder Examination – Questionnaire.

	HW	OW	*t* or $\chi 2$ (*df*)[a]	*p*
n	46	34		
BMI	22.36 (1.58)	33.78 (4.35)	16.39 (59.98)	<0.001
Age	45.47 (8.28)	41.74 (11.58)	1.60 (78)	0.10
Years of education	15.81 (2.03)	14.35 (2.89)	2.52 (77.93)	0.01
Medication (n)				
Psychotropic	1 (2.94%)	6 (13.04%)	2.50 (1)	0.11
Other	7 (15.22%)	18 (39.13%)	2.49 (1)	0.11
EDE-Q Total	0.83 (0.64)	2.57 (0.98)	9.54 (77.02)	<0.001
Eating concerns	0.29 (0.46)	1.67 (1.22)	7.03 (61.10)	<0.001
Shape concerns	1.19 (0.98)	3.58 (1.23)	9.91 (78)	<0.001
Weight concerns	0.81 (0.83)	3.25 (1.08)	11.03 (78)	<0.001
Restraint	1.04 (0.87)	1.76 (1.29)	2.99 (77.44)	0.004
Baseline hunger	41.21 (29.50)	27.53 (28.04)	2.10 (77)	0.04
Minutes since food intake	139.38 (31.46)	140.68 (34.17)	0.17 (73)	0.86
US liking	68.26 (26.89)	46.78 (30.31)	3.27 (77)	0.002

[a] Degrees of freedom vary across t-tests due to missing data and depending on violation of Levene's test for equality of variances.

chocolate/no desire at all/not pleasant at all) to 100 *(certainly expect to receive chocolate/very strong desire/very pleasant)*.

Skin conductance: electrodermal activity was recorded using Ag/AgCl electrodes (8 mm) which were attached to the volar surfaces of the medial phalanges of the index and middle fingers of the left hand (VAS were completed using the right hand). The electrodes were filled with isotonic electrode paste (0.5% saline in a neutral base). The skin conductance signal was amplified using a BrainAmp ExG device and passed to Brain Vision Recorder 2.0 software (Brain Products, Gilching, Germany). The sampling rate was 500 Hz. Skin conductance provides a nonintrusive measure of arousal that is not specific to appetitive responding (Dawson, Schell, & Filion, 2007). Instead, it might provide a sensitive measure of cognitive contingency learning, and has been frequently used in fear conditioning as well as in some appetitive conditioning studies (e.g., Glautier, Drummond, & Remington, 1994; Klucken et al., 2015; van den Akker, Nederkoorn, & Jansen, 2017; Weike & Hamm, 2005).

Salivation: salivation was measured using two dental roles (Hartmann, nr 2, 10 × 35 mm) which the participant placed and removed herself. The dental roles were placed between the cheek and lower gum on the left and right side, and they were removed after exactly 1 min. The dental roles were kept in sealed plastic bags and were weighed before and after saliva collection using a weighing scale accurate to 0.01 g (Mettler Toledo, PB302).

Hunger and US liking: computerized VAS were used to assess baseline hunger (*'How hungry are you at this moment?'*) and US liking (*'How much did you like the chocolate?'*) ranging from 0 (*not hungry at all/not at all*) to 100 (*very hungry/very much*).

Eating Disorder Examination – Questionnaire (EDE-Q Fairburn & Beglin, 1994): the EDE-Q is a 28-item self-report questionnaire version of the Eating Disorder Examination and measures eating psychopathology. The EDE-Q comprises four subscales (eating concerns, shape concerns, weight concerns, and eating restraint), and a total score can be calculated. Each item is scored on a 7-point scale, with higher scores reflecting greater levels of eating psychopathology.

2.4. Stimuli

CS: two geometric shapes (a blue square and a yellow circle) were used as conditioned stimuli. They were presented on a computer screen in front of the participant. Each shape functioned as CS+ (or CS-) in approximately half of the participants in each group.

US: a small piece of handmade chocolate (approximately 0.9 g, Maison Blanche Dael) was used as US. The US was presented in a small cup.

2.5. Procedure

The overweight/obese group completed some questionnaires and tasks (i.e., a demographic questionnaire, a food cue reactivity test, the Pittsburgh Sleep Quality Index, and a Stop-Signal Task, in this order) prior to the current conditioning task, as part of baseline measures for a weight loss intervention (see van den Akker, Schyns, et al., 2016). The healthy weight participants completed the exact same sequence of measures to hold constant any influences these measures may have had on responding.

Participants were individually tested between 12 p.m. and 7 p.m. Testing took place in a temperature-controlled room. After arrival, the participant was explained how to complete VASs and how to handle the cotton roles. She was informed that electrodes would be attached to her fingers but that these would not be painful. She was then seated at a table in front of a computer screen. Next, the electrodes were attached to her left (i.e., non-dominant) hand and she was instructed to avoid bodily movements and to keep her left hand still during the experiment. She was also instructed that she would sometimes receive something to eat and that she had to use her right hand for picking up the food and for completing the VASs. Then the baseline hunger VAS was filled in. Next, the conditioning task started (see below), after which she completed the US liking VAS, the EDE-Q, and noted the time of pre-experimental food intake. Finally, her height and weight was measured.

2.6. Conditioning task

In contrast to previous studies (e.g., van den Akker et al., 2015; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008a), no information was provided with regards to a contingency between the stimuli and being allowed to eat chocolate. This was done to minimize possible ceiling effects in overly easy or clear tasks (Beckers et al., 2013; Lissek, Pine, & Grillon, 2006), heightening the chance for individual differences to emerge.

The conditioning task consisted of two phases: acquisition and extinction.

Acquisition. Participants received a partially variable (rather than fixed) number of trials depending on how quickly they learned the CS-US contingencies (see e.g. Bennett, Hermans, Dymond, Vervoort, & Baeyens, 2015; Mutter & Plumlee, 2014). Specifically, participants received a minimum of four trials per trial type and a maximum of fifteen (for trial sequence see below). Acquisition continued until a participant had learned the contingency between the CS+ and the US (acquisition criterion: CS + vs. CS-

differentiation in US expectancies >50 for three consecutive trials). A benefit of this approach is that extinction can be better compared across groups (which might differ in acquisition) because final acquisition levels are more equalized, while still allowing group comparisons in acquisition. A downside of this approach is that the number of CS-US pairings received can differ across groups. After acquisition, salivation was measured on two additional trials: one CS+ and one CS-. Salivation measures started immediately after completion of the VASs. A trial was halted until the measurement was completed, and the following ITI was lengthened by 1 min to allow salivation levels to better return to baseline.

Extinction. No USs were provided during extinction. Extinction continued until an extinction criterion was reached (CS + vs. CS- differentiation in US expectancies <20 for three consecutive trials) and consisted of a minimum of eight trials per trial type and a maximum of fifteen. This approach was used to gain insight into if and when extinction would be achieved if more than 8 trials were required, but to avoid unnecessarily lengthening the procedure. After extinction, two salivation trials (CS+ and CS-) were administered.

A trial proceeded as follows. The CS appeared on the computer screen for 10 s, accompanied by an instruction to look at the picture. Then an expectancy VAS appeared below the CS. After completion, a desire for chocolate VAS was filled in. Next, the VAS disappeared, after which the CS remained visible for three more seconds. For all CS- trials and for non-reinforced CS + trials during extinction, this was immediately followed by an inter-trial interval of 17–23 s (i.e., nothing was given to the participant). In case of a CS + acquisition trial, the experimenter placed the US in front of the participant in the 3-s interval following completion of the desire VAS, and onset of the ITI was delayed until the participant had started eating. Trials were presented in a semi-randomized order, with no more than two consecutive trials being of the same trial type. Finally, to hold constant any trial order/carry-over effects across the OW and HW groups, the type of trial that was received first (CS + or CS-) in extinction and during salivation measures was semi-randomized, approximately half of the participants in each group receiving the CS+ (or CS-) first.

2.7. Data reduction and response definition

Preprocessing and extraction of skin conductance data was done using Ledalab V3.4.8 (Benedek & Kaernbach, 2010). This software has been previously used for analysis of (fear) conditioning data (Cacciaglia et al., 2013; Dibbets, van den Broek, & Evers, 2015; van den Akker, Nederkoorn, & Jansen, 2017). The data were down-sampled to 10 Hz. Artifacts were manually identified and removed using a spline interpolation, and the data were smoothed by means of convolution with a Hanning window. A continuous Decomposition Analysis was run for each participant, in which the skin conductance data is decomposed into its tonic and phasic components resulting in phasic activity with a zero baseline. The sum of amplitudes of skin conductance responses with onsets within a time window (see below) was used as dependent variable (AmpSum). An important benefit of CDA is that it can reduce biases due to overlapping SCRs. A minimum response criterion of 0.01 μS was used. Responses that did not fulfill this criterion were scored as zero and included in the analyses. The skin conductance data were square-root transformed to reduce skewness and kurtosis. First interval responses (FIR; responses in the 1 – 4s time window after CS onset) and second interval responses (SIR; responses in a time window prior to US occurrence spanning from 4 s prior to 1s after VAS offset) were examined (Boucsein, 2012; Prokasy & Kumpfer, 1973).[1]

Due to technical issues, VAS data obtained digitally were missing for one participant (OW group), and for another (OW group), five skin conductance scores were missing (5.43% of all responses for this participant). The missing skin conductance scores were replaced by the overall individual mean. For a third participant (OW group), salivation data for the CS- were not available.

2.8. Statistical analyses

Group differences in the number of acquisition and extinction trials received and whether or not the acquisition/extinction criterions were reached were analyzed using independent samples t-tests and a Pearson's chi-square test. Differential responding of US expectancy, US desire, and skin conductance responses across groups and over the first four acquisition trials and eight extinction trials (which were received by all participants) were analyzed using repeated-measures ANOVAs for each phase of the experiment (acquisition and extinction), and, for skin conductance responses, for each time window (FIR and SIR). This resulted in 2 (CS-type: CS + vs. CS-) x 4/8 (Acquisition Trial/Extinction Trial) x 2 (Group: OW vs. HW) repeated-measures ANOVAs, including CS-type (CS) and Trial (T) as within-subjects factors and Group (G) as between-subjects factor. Differential acquisition and extinction levels of salivation and CS evaluations as well as differential responding on the fourth and last individual acquisition and eighth and last individual extinction trial for US expectancies, US desires, and skin conductance responses was examined by 2 (CS-type: CS + vs. CS-) x 2 (Group: OW vs. HW) repeated-measures ANOVAs. Extinction of conditioned evaluations and salivation was tested using 2 (CS-type: CS + vs. CS-) x 2 (Acquisition/Extinction) x 2 (Group: OW vs. HW) repeated-measures ANOVAs. Greenhouse-Geisser epsilon corrections are reported for repeated measures ANOVAs when sphericity was violated. The significant group differences in education level, EDE-Q scores, baseline hunger, and US liking (see Table 1) were not statistically controlled for because adjustment for variables that share variance with the independent variable in ANCOVAs is not appropriate in case of non-random group assignment: the shared variance is attributed to the covariate, leading to an underestimation of group effects and a heightened chance of spurious findings (see Miller & Chapman, 2001).

3. Results

3.1. Contingency learning

Acquisition/extinction criterion. The groups received a similar number of acquisition trials (i.e., they did not significantly differ in the speed to reach the criterion; OW: M = 10.13; SD = 4.53; HW: M = 8.94; SD = 4.13, t (1, 78) = 1.20, p = 0.23, d = 0.27). However, a lower proportion of participants in the OW vs. HW group reached the acquisition criterion (CS + vs. CS- differentiation in US expectancies >50 on the last three trials; OW: n = 28/46; 60.9%; HW: n = 28/34; 82.4%), χ^2 (1, N = 80) = 4.30, p = 0.038, w = 0.23 (see Fig. 1) – suggesting lower levels of contingency awareness in the OW group.

The number of extinction trials did not differ across groups, t (78) = 0.85, p = 0.40, d = 0.19 (OW: M = 8.35; SD = 1.01; HW: M = 8.62; SD = 1.74). However, most participants received the

[1] We additionally analyzed the third interval omission response or TOR (measured in the 1 – 5s window after CS offset; Boucsein, 2012; Prokasy & Kumpfer, 1973; Spoormaker et al., 2011). These analyses revealed similar group differences in non-differential skin conductance responses. No evidence for differential responding was found.

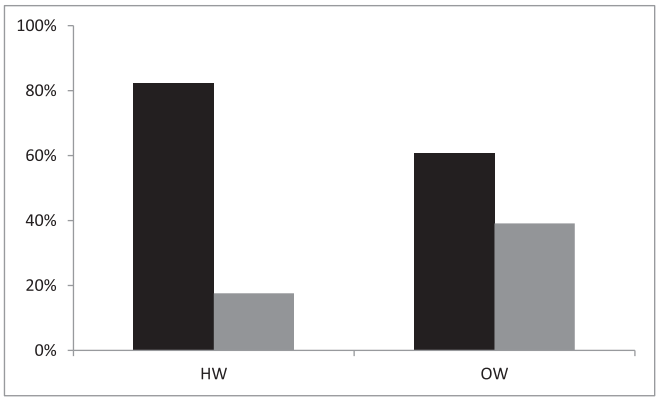

Fig. 1. Percentage of participants in each group who have reached (dark bars) vs. not reached (light bars) the acquisition criterion (CS + vs. CS- differentiation in US expectancies >50 on at least three trials) by the end of acquisition, separated by group (healthy weight [HW], overweight/obese [OW]).

minimum of 8 trials (n = 68) because they reached the extinction criterion relatively early. Additional analyses on the trial at which the extinction criterion was actually first reached (CS + vs. CS- differentiation <20 on three consecutive trials; not reaching the criterion was scored as 15 [n = 2; NW group]) showed no group differences either, $t(78) = 0.86$, $p = 0.40$, $d = 0.19$ (criterion reached at: OW: M = 5.54 trials, SD = 2.43; HW: M = 6.06 trials, SD = 2.95).

US expectancies. Overall, differential US expectancies were successfully acquired over the first four acquisition trials, as indicated by a significant CS × T interaction, $F(2.15, 165.73) = 27.79$, $p < 0.001$, $\eta_p^2 = 0.27$, with no differences across the groups (CS x T x G), $F < 1$ (see Fig. 2). This resulted in a significant CS + vs. CS- differentiation on the fourth trial, $F(1, 77) = 52.89$, $p < 0.001$, $\eta_p^2 = 0.41$, and the last individual trial, $F(1, 77) = 224.63$, $p < 0.001$, $\eta_p^2 = 0.75$. Group differences in differential US expectancies were not statistically significant on the fourth trial (CS x G), $F < 1$, nor on the last trial, $F(1, 77) = 3.28$, $p = 0.07$, $\eta_p^2 = 0.04$.

US expectancies extinguished over the first eight extinction trials (CS x T), $F(3.44, 264.49) = 61.84$, $p < 0.001$, $\eta_p^2 = 0.45$, though on trial 8, a differentiation between the CS+ and CS- was still present, $F(1, 77) = 5.44$, $p = 0.02$, $\eta_p^2 = 0.07$. This differentiation was non-significant by the last extinction trial, $F = 1.22$, *ns*. No significant group differences were found in initial extinction levels, F < 1, the course of extinction, F < 1, the differentiation on trial 8, F < 1, or on the last extinction trial, $F(1, 77) = 2.93$, $p = 0.09$.

In sum, these data provide partial evidence for worse contingency learning in the OW vs. HW group: fewer participants in the OW group reached our acquisition criterion, but they did not receive fewer acquisition trials nor differed significantly on the acquisition of US expectancies. No significant group differences in extinction were found.

3.2. US desires

A differential desire for chocolate was successfully acquired (CS x T), $F(2.59, 199.24) = 9.23$, $p < 0.001$, $\eta_p^2 = 0.11$ [CS + vs. CS- differentiation on trial 4: $F(1, 77) = 8.95$, $p = 0.004$, $\eta_p^2 = 0.10$; last trial: $F(1, 77) = 25.89$, $p < 0.001$, $\eta_p^2 = 0.25$, see Fig. 2]. Although the CS x T × G interaction was non-significant, $F < 1$, the OW (vs. HW) group showed lower overall desires to the CS + vs. CS- over the first four acquisition trials (CS x G), $F(1, 77) = 5.63$, $p = 0.02$, $\eta_p^2 = 0.07$, and smaller differentiations on the fourth and the last acquisition trials, $F(1, 77) = 4.31$, $p = 0.041$, $\eta_p^2 = 0.05$, $F(1, 77) = 7.86$, $p = 0.006$, $\eta_p^2 = 0.09$. Follow-up analyses showed elevated desires in the HW group to the CS + vs. CS- over the first four trials (main effect of CS), $F(1, 33) = 7.02$, $p = 0.01$, $\eta_p^2 = 0.18$, as well as a significant differentiation on trial 4, $F(1, 33) = 9.96$, $p = 0.003$, $\eta_p^2 = 0.23$. In contrast, these CS + vs. CS- differentiations were not significant in the OW group, *F*s < 1. On the last acquisition trial, a differentiation (i.e., a successful acquisition) was also present in the OW group, $F(1, 44) = 4.05$, $p = 0.050$, $\eta_p^2 = 0.08$ [HW: $F(1, 33) = 20.47$, $p < 0.001$, $\eta_p^2 = 0.38$]. To gain insight into whether this worse acquisition of desires might be characterized by elevated responding to the CS- (resulting e.g. from an overgeneralization from the CS + to the CS-), or a worse conditioning to the CS+ (Lissek et al., 2005), follow-up analyses were conducted on each CS-type. Responses on the first acquisition trial were taken into account to control for group differences in baseline responding. These analyses revealed no group differences in responding to the individual CSs (acq1 − acq4; acq1 vs. acqlast), $F < 1$. Overall US desires were non-significantly lower in the OW group during acquisition [acq1 − acq4; main effect of Group: $F(1, 77) = 3.49$, $p = 0.07$, $\eta_p^2 = 0.04$].

On the first extinction trial the groups no longer differed significantly in differential desires, $F(1, 77) = 1.95$, $p = 0.17$, $\eta_p^2 = 0.03$ (overall CS + vs. CS- differentiation: $F(1, 77) = 25.41$, $p < 0.001$, $\eta_p^2 = 0.25$). Conditioned desires partly extinguished (ext1 − ext8, CS x T), $F(3.84, 296.01) = 5.73$, $p < 0.001$, $\eta_p^2 = 0.07$, and similarly across the conditions (CS x T x G), $F < 1$ [CS x G: $F(1, 77) = 3.66$, $p = 0.06$, $\eta_p^2 = 0.05$]. On the eighth extinction trial, the OW group showed a smaller differentiation, $F(1, 77) = 4.05$, $p = 0.048$, $\eta_p^2 = 0.05$ [last trial CS x G: $F(1, 77) = 3.92$, $p = 0.051$, $\eta_p^2 = 0.05$; overall CS + vs CS- differentiation on trial 8: $F(1, 77) = 5.95$, $p = 0.02$, $\eta_p^2 = 0.07$; last trial: $F(1, 77) = 3.30$, $p = 0.07$, $\eta_p^2 = 0.04$]. Follow-up tests suggested a complete extinction in the OW group, $F < 1$, but not in the HW group, $F(1, 33) = 8.88$, $p = 0.005$, $\eta_p^2 = 0.21$. However, interpretation of this finding is complicated by the worse acquisition of desires in the OW group.

In sum, the OW group showed a reduced acquisition of differential US desires: although eventually, this group successfully acquired desires, this acquisition occurred less quickly, and final differential US desires were smaller compared with the HW group. The reduced differential learning was not specifically driven by increased CS- or decreased CS + responding. Further, the OW group also demonstrated a better extinction, but interpretation of this finding is difficult due to group differences in acquisition.

3.3. CS evaluations

The groups differed in the acquisition of conditioned evaluations, $F(1, 77) = 5.37$, $p = 0.02$, $\eta_p^2 = 0.07$ [overall differentiation: $F(1, 77) = 5.51$, $p = 0.02$, $\eta_p^2 = 0.07$]: participants in the HW group acquired a liking for the CS + over the CS-, $F(1, 33) = 10.97$, $p = 0.002$, $\eta_p^2 = 0.25$, whereas participants in the OW group did not, $F < 1$ (see Fig. 3), indicating an absence of evaluative learning in overweight/obese individuals. The OW group's absent differential responding seemed not specifically driven by elevated evaluative responses to the CS-, $F(1, 77) = 3.32$, $p = 0.07$, $\eta_p^2 = 0.04$, nor by reduced responses to the CS+: $F(1, 77) = 1.74$, $p = 0.19$, $\eta_p^2 = 0.02$. The HW group's conditioned evaluations did not extinguish, $F(1, 33) = 1.41$, $p = 0.24$, $\eta_p^2 = 0.04$, still evaluating the CS + more positively after extinction, $F(1, 33) = 7.88$, $p = 0.008$, $\eta_p^2 = 0.19$.

Thus, these findings suggest an absence of differential evaluative conditioning in overweight and obese individuals.

3.4. Salivation

No acquisition of a conditioned salivary response was found, $F(1, 77) = 1.34$, $p = 0.25$, $\eta_p^2 = 0.02$ (CS x G: $F < 1$; see Fig. 4). Although differential responding changed over the course of extinction, $F(1,$

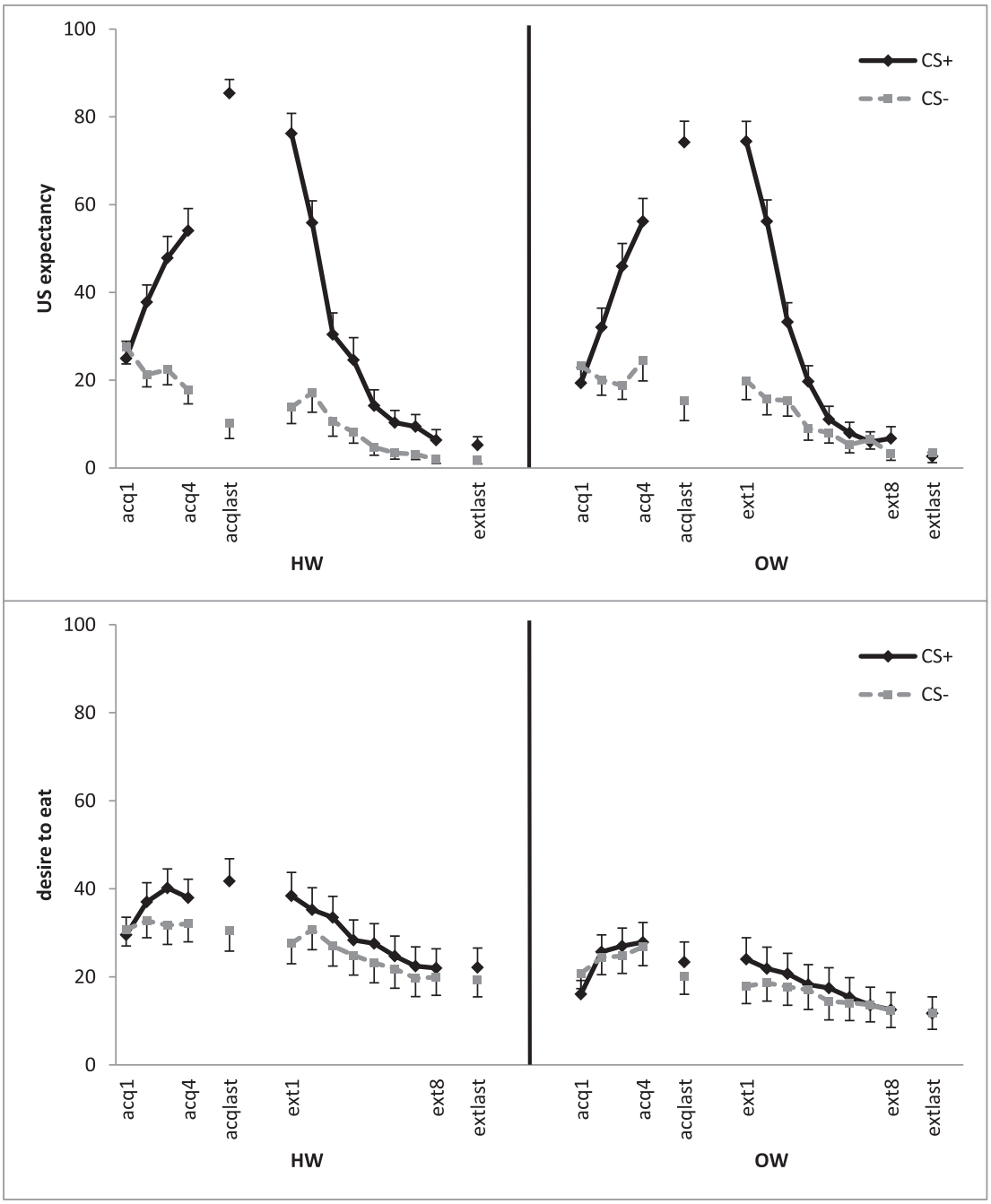

Fig. 2. Mean US expectancies and US desires (±SEM) across groups, phases of the experiment, trials, and CS-types. CS: conditioned stimulus; HW: healthy weight; OW: overweight/obese.

77) = 4.29, $p = 0.04$, $\eta_p^2 = 0.05$ (CS x T), salivation to the CS + vs. the CS- was still not significantly different after extinction, F (1, 77) = 2.88, $p = 0.09$, $\eta_p^2 = 0.04$ [CS x G: F (1, 77) = 1.45, $p = 0.23$, $\eta_p^2 = 0.02$]. Interestingly, groups differed in the overall change in salivation from acquisition to extinction (T x G), F (1, 77) = 6.20, $p = 0.015$, $\eta_p^2 = 0.08$. Follow-up analyses showed no overall decrease in salivation in the OW group from acquisition to extinction, $F = 1.07$, *ns,* but a significant decrease in the HW group, F (1, 33) = 32.10, $p < 0.001$, $\eta_p^2 = 0.49$. However, group differences in overall salivation levels after extinction did not reach significance, F (1, 77) = 2.56, $p = 0.11$, $\eta_p^2 = 0.03$ (acquisition: $F < 1$).

3.5. Skin conductance

Regarding the FIR, the CS × T interaction over the first four trials was non-significant, $F(3, 234) = 1.75$, $p = 0.16$, $\eta_p^2 = 0.02$ (see Fig. 5). On the fourth and last acquisition trials, the CS + vs. CS- differentiation did not reach significance as well, $F(1, 78) = 3.69$, $p = 0.058$, $\eta_p^2 = 0.05$; F < 1. When disregarding the orienting response present on the first acquisition trial, the CS x T (acq2 − acq4) interaction was also not significant, F (2, 156) = 2.71, $p = 0.07$, $\eta_p^2 = 0.03$. Regarding the SIR, no significant CS × T interaction was found, F (2.60, 202.84) = 2.47, $p = 0.07$, $\eta_p^2 = 0.03$, and no differentiation was

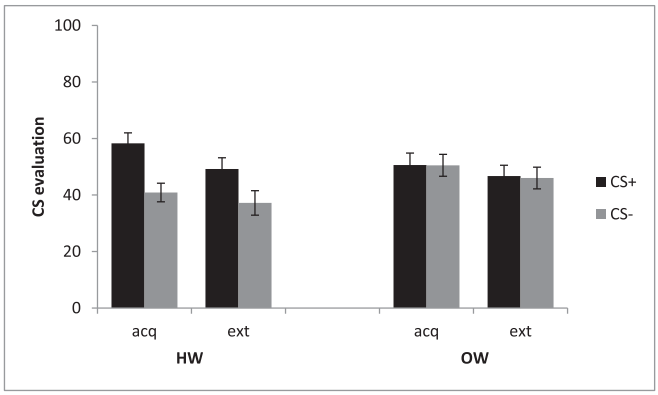

Fig. 3. Mean subjective CS evaluations across groups (±SEM), phases of the experiment, and CS-types. CS: conditioned stimulus; HW: healthy weight; OW: overweight/obese.

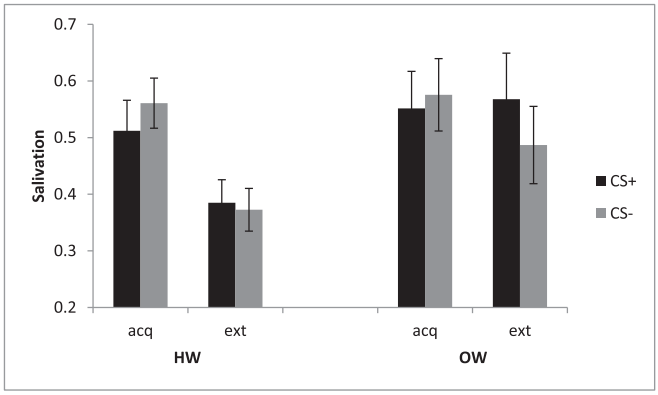

Fig. 4. Mean salivation across groups (±SEM), phases of the experiment, and CS-types. CS: conditioned stimulus; HW: healthy weight; OW: overweight/obese.

present on the fourth or the last acquisition trials, largest $F = 1.99$, smallest $p = 0.16$ (see Fig. 5). No interactions with Group were found, largest $F = 1.64$, smallest $p = 0.20$. In sum, no convincing evidence for differential skin conductance responding was found, suggesting skin conductance was not a very sensitive measure of differential responding in the present study.

Analyses on overall (changes in) skin conductance responding showed that FIR magnitudes were overall heightened in the OW vs. HW group during acquisition [main effect of Group acq1 − acq4: FIR: F (1, 78) = 4.89, $p = 0.03$, $\eta_p^2 = 0.06$; SIR: F (1, 78) = 3.87, $p = 0.053$, $\eta_p^2 = 0.05$]. Group differences in changes in FIR and SIR magnitudes from the first to the last acquisition trial did not reach significance [SIR: acq1 vs. acqlast: F (1, 78) = 3.89, $p = 0.052$, $\eta_p^2 = 0.05$; acq1 − acq4: $F = 1.36$, *ns;* FIR: Fs < 1). Finally, groups did not differ in overall changes in skin conductance responses during extinction (T x G; ext1 − ext8, ext1 vs. extlast), largest $F = 2.72$, smallest $p = 0.10$, but the OW group still showed heightened overall responding (ext1 − ext8), FIR: $F(1, 78) = 8.85$, $p = 0.004$, $\eta_p^2 = 0.10$, SIR: $F(1, 78) = 7.20$, $p = 0.009$, $\eta_p^2 = 0.09$, suggesting a heightened arousal in the OW group throughout the experiment.

3.6. Contingency awareness and BMI

Because we were interested in group differences in (e.g., contingency) learning, participants who did not reach the acquisition criterion were not initially excluded from analyses. Secondary analyses on group differences in differential acquisition only including participants who reached the criterion revealed results that were generally comparable but did not always reach significance, [i.e., reduced differential acquisition of US desires and CS evaluations in the OW vs. NW group: US desires: CS x G: F (1, 53) = 3.96, $p = 0.05$, $\eta_p^2 = 0.07$, acq4: $F = 1.82$, *ns*, acqlast: F (1, 53) = 3.68, $p = 0.06$, $\eta_p^2 = 0.07$; evaluations: CS x G: $F(1, 53) = 3.78$, $p = 0.057$, $\eta_p^2 = 0.07$]. Overall, this suggests that the reduced discriminative acquisition of US desires and evaluations may have largely occurred independent of the contingency learning impairments in the OW group.

Finally, to check whether the reduced differential responding in the OW group increased as a function of BMI, correlations between BMI and differential responding (CS + minus CS-) were calculated within the OW group on the trials where group differences were found. Whether the acquisition criterion was reached less frequently as a function of BMI was examined in a one-way ANOVA. None of these analyses reached significance, smallest $p = 0.28$.

4. Discussion

The current study aimed to examine whether overweight/obese and healthy weight individuals differ in the acquisition and extinction of appetitive responses to food cues. Contrary to expectations, overweight/obese (vs. healthy weight) individuals showed less discriminative appetitive learning: they demonstrated a reduced acquisition of differential US desires, and did not acquire more positive evaluations for the CS + vs. CS-. Overweight/obese individuals were also less likely to reach our acquisition criterion, but they did not receive more acquisition trials nor reported significantly lower differential US expectancies − providing partial evidence for worse contingency learning in overweight and obesity. Further, the reduced acquisition of differential US desires and CS evaluations was not specifically driven by increased responding to the CS- nor by decreased responding to the CS+. The extinction of desires appeared worse in healthy weight individuals, though this might have been due to the group differences in acquisition. No convincing evidence for a successful acquisition and extinction of differential skin conductance and salivary responses was found, nor for group differences herein. However, overweight/obese individuals showed overall greater skin conductance responses to the CSs over the course of the experiment, and no overall decline in salivation during extinction.

The current findings indicate that the heightened food cue reactivity in overweight and obesity might not be the result of a predisposition to form associations more strongly or quickly between neutral stimuli and food intake. Instead, the current findings indicate that overweight and obesity could be characterized by *reduced* appetitive learning − evidence for this being strongest for US desires and CS evaluations in the current study. Overall, the data seem consistent with, and extend, findings of a previous appetitive conditioning study using food as reward showing reduced acquisition of differential US expectancies in obese women (Zhang et al., 2014). One could speculate about how such reduced discriminatory learning might be related to overeating. One possibility is that overweight individuals form stronger associations between the context and the US: lower levels of contingency awareness in the overweight group could result in perceived unpredictability of the US which promotes the formation of context-US associations (Grillon & Davis, 1997). This might lead to more sustained/generalized contextual appetitive responding rather than strong cue-elicited appetitive reactivity to discrete cues. Alternatively, some of the findings could point towards overgeneralization (i.e., an increased tendency to react to stimuli perceptually or symbolically/conceptually similar to the CS + but that were never paired with a US), since an impaired ability to distinguish between predictive and

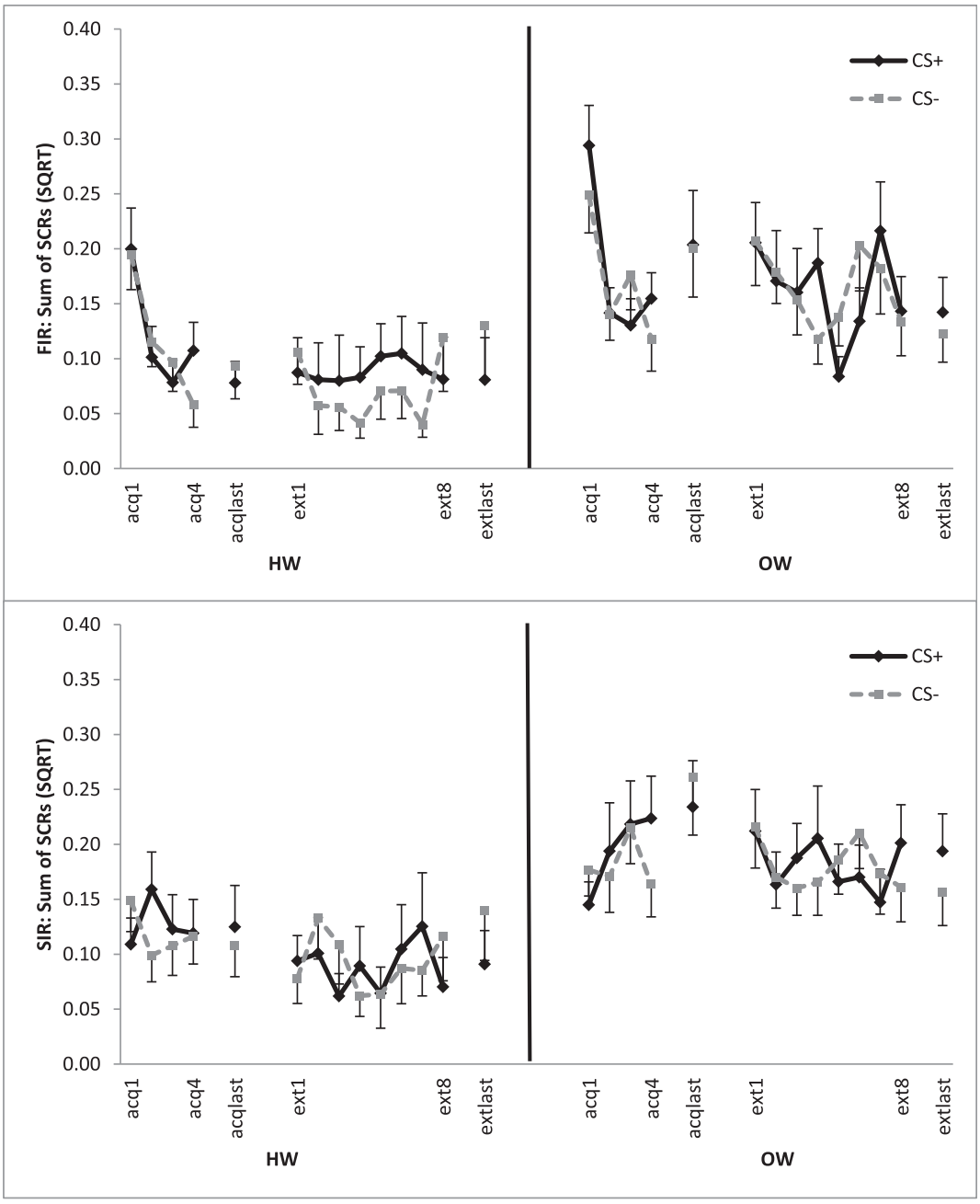

Fig. 5. Mean FIR and SIR magnitudes across groups (±SEM), phases of the experiment, and CS-types. CS: conditioned stimulus; HW: healthy weight; OW: overweight/obese; SCR: skin conductance response; FIR: first interval response; SIR: second interval response.

non-predictive cues is thought to be a core feature of (over) generalization (Dibbets et al., 2015; Hermans, Baeyens, & Vervliet, 2013; Lissek et al., 2010; Pearce, 1987). The implications for real-life eating behaviour are interesting: greater contextual and/or generalized appetitive responding might translate to an increased frequency or duration of food cue reactivity – which could be in line with correlational evidence suggesting obese individuals experience more frequent appetitive reactivity (Chao et al., 2014). The exact processes underlying the reduced discriminative conditioning in overweight and obese individuals and their consequences for real-life eating behaviour remain speculative, however. Nevertheless, the current data suggest that overweight and obesity are characterized by reduced discriminative appetitive conditioning, potentially pointing towards a novel mechanism underlying overeating and obesity (see also Davidson & Martin, 2014; Kroemer & Small, 2016).

Our overweight and obese participants also exhibited stronger skin conductance responses to *both* CSs during acquisition and extinction. However, responding to the CS + vs. CS- was not significantly larger in any of the groups, suggesting that skin conductance responses did not sufficiently track (changes in) associative value of the CSs. It therefore seems likely that the group differences in skin conductance responses primarily reflected differences in nonassociative processes – for instance, a heightened sensitivity to appetitive contexts in overweight and obese individuals causing sustained arousal and interfering with habituation (see Orr et al., 2000). Future studies should aim to include psychophysiological measures that may be more sensitive to

conditioning effects, and ideally measure baseline responding in inter-trial intervals (using measures suitable for this; e.g., Mallan & Lipp, 2007; Sandt, Sloan, & Johnson, 2009), allowing for correction of group differences in non-associative processes (Lissek et al., 2005).

The groups also showed some differences in the extinction of differential desires: healthy weight (but not overweight/obese) individuals showed an incomplete extinction of US desires. This could suggest that some appetitive responses in overweight/obese individuals extinguish quicker after repeated non-reinforced presentations of food cues. However, the larger post-acquisition differentiations in these measures in healthy weight individuals can account for these findings as well. Further, and possibly in contrast to the extinction patterns of US desires, both skin conductance responses and salivation remained heightened to both CSs in the overweight/obese group during extinction. This might either represent a failure to extinguish acquired responses – which could be similar to worse fear extinction observed in anxiety disorder patients (see e.g. Duits et al., 2015) – or, again (and perhaps more likely), a heightened sensitivity to appetitive contexts in the overweight/obese group that might increase arousal and interfere with habituation. In line with the latter explanation, not only skin conductance but also salivation has been shown to habituate more slowly when arousal is higher (Epstein, Mitchell, & Caggiula, 1993). Further, there is evidence for less salivary habituation in obese (vs. nonobese) individuals to the repeated taste of palatable food (Epstein, Paluch, & Coleman, 1996). More studies are clearly needed to determine whether and how the extinction of appetitive responses differs as a function of weight status.

It is important to note that our specific overweight/obese sample (i.e., individuals recruited for weight loss therapy) comprised concerned eaters who might have had a strong ambivalence towards the US (Urland & Ito, 2005). It is possible that this US ambivalence led to the reduced acquisition of differential US desires and CS evaluations in the overweight group, and hence, it could be that the findings are specific to this population. Further, since we could base our current conclusions only on self-report (but not the arguably more objective psychophysiological) measures, it remains a possibility that the observed group differences in the acquisition of US desires and CS evaluations may be explained by the overweight/obese individuals being more reluctant to admit experiencing strong eating desires in response to the CS+ (Roefs et al., 2006), or to evaluate the CS + as more positively after acquisition, perhaps due to fears of confirming stereotypes associated with obesity. The lower levels of self-reported baseline hunger (and liking of the US) in the overweight group found in the current study might be in line with this. However, since the main analyses were based on within-subject comparisons (i.e., CS + vs. CS-), such non-associative processes might be controlled for. Still, future studies should aim at ruling out this alternative explanation (e.g., by including sensitive psychophysiological measures), further investigate the possible influence of ambivalence on appetitive conditioning, and examine appetitive learning in overweight populations not specifically recruited for weight loss.

The study has some other limitations. First, although it provided initial insight into differences in appetitive learning between overweight and healthy weight individuals, we limited our investigation to group differences in acquisition and extinction, and instrumental learning (which also plays an important role in real-life eating behaviour) has not been specifically examined. The use of instrumental procedures and additional and/or more complex paradigms (e.g., blocking, renewal phenomena, pavlovian-instrumental transfer) might bring to light other interesting differences in appetitive learning and responding (Beckers et al., 2013; Watson, Wiers, Hommel, Gerdes, & de Wit, 2017). Second, the group differences in acquisition complicated analyses and interpretations regarding group differences in extinction, and hence, this awaits further investigation. Third, for some of the analyses, we may have lacked power to detect significant differences in responding. Finally, the groups differed in variables associated with overweight and obesity (e.g., fewer years of education). It is possible that some of these variables (including those not specifically assessed in the current study, such as psychological disorders) contributed to the observed differences between overweight and healthy weight individuals.

In sum, and although further research is needed, the present findings suggest that in adult women, overweight and obesity are characterized by reduced discriminatory learning in an appetitive conditioning task involving food rewards. This may be related to an overgeneralization of appetitive responding and/or more contextual conditioning in overweight/obese women, and hence, a new causal or maintaining mechanism underlying obesity that operates via promoting more frequent/sustained appetitive reactivity. Future studies could aim to more specifically examine the potential consequences of reduced appetitive learning for eating behaviour and obesity (e.g., whether this indeed translates to an overgeneralization of appetitive responses).

Conflict of interest

The authors declare no conflict of interest.

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References

Andreatta, M., & Pauli, P. (2015). Appetitive vs. Aversive conditioning in humans. *Frontiers in Behavioral Neuroscience, 9*, 128. https://doi.org/10.3389/fnbeh.2015.00128.

Astur, R. S., Carew, A. W., & Deaton, B. E. (2014). Conditioned place preferences in humans using virtual reality. *Behavioural Brain Research, 267*, 173–177. https://doi.org/10.1016/j.bbr.2014.03.018.

Beckers, T., Krypotos, A.-M., Boddez, Y., Effting, M., & Kindt, M. (2013). What's wrong with fear conditioning? *Biological Psychology, 92*(1), 90–96. https://doi.org/10.1016/j.biopsycho.2011.12.015.

Benedek, M., & Kaernbach, C. (2010). A continuous measure of phasic electrodermal activity. *Journal of Neuroscience Methods, 190*(1), 80–91. https://doi.org/10.1016/j.jneumeth.2010.04.028.

Bennett, M., Hermans, D., Dymond, S., Vervoort, E., & Baeyens, F. (2015). From bad to worse: Symbolic equivalence and opposition in fear generalisation. *Cognition and Emotion, 29*, 1137–1145. https://doi.org/10.1080/02699931.2014.973833.

Blechert, J., Testa, G., Georgii, C., Klimesch, W., & Wilhelm, F. H. (2016). The Pavlovian craver: Neural and experiential correlates of single trial naturalistic food conditioning in humans. *Physiology & Behavior, 158*, 18–25. https://doi.org/10.1016/j.physbeh.2016.02.028.

Bongers, P., van den Akker, K., Havermans, R., & Jansen, A. (2015). Emotional eating and Pavlovian learning: Does negative mood facilitate appetitive conditioning? *Appetite, 89*, 226–236. https://doi.org/10.1016/j.appet.2015.02.018.

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

Boucsein, W. (2012). *Electrodermal Activity*. Springer Science & Business Media.

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.

Cacciaglia, R., Nees, F., Pohlack, S. T., Ruttorf, M., Winkelmann, T., Witt, S. H., et al. (2013). A risk variant for alcoholism in the NMDA receptor affects amygdala activity during fear conditioning in humans. *Biological Psychology, 94*(1), 74–81. https://doi.org/10.1016/j.biopsycho.2013.05.006.

Chao, A., Grilo, C. M., White, M. A., & Sinha, R. (2014). Food cravings, food intake, and weight status in a community-based sample. *Eating Behaviors, 15*(3), 478–482.

https://doi.org/10.1016/j.eatbeh.2014.06.003.
Coppin, G., Nolan-Poupart, S., Jones-Gotman, M., & Small, D. M. (2014). Working memory and reward association learning impairments in obesity. *Neuropsychologia, 65*, 146–155. https://doi.org/10.1016/j.neuropsychologia.2014.10.004.
Davidson, T. L., & Martin, A. A. (2014). Obesity: Cognitive impairment and the failure to 'eat right'. *Current Biology, 24*(15), R685–R687. https://doi.org/10.1016/j.cub.2014.06.031.
Dawson, M. E., Schell, A. M., & Filion, D. (2007). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology*. Cambridge University Press.
Delamater, A. R., & Oakeshott, S. (2007). Learning about multiple attributes of reward in pavlovian conditioning. *Annals of the New York Academy of Sciences, 1104*(1), 1–20. https://doi.org/10.1196/annals.1390.008.
Dibbets, P., van den Broek, A., & Evers, E. A. (2015). Fear conditioning and extinction in anxiety-and depression-prone persons. *Memory, 23*(3), 350–364. https://doi.org/10.1080/09658211.2014.886704.
Duits, P., Cath, D. C., Lissek, S., Hox, J. J., Hamm, A. O., Engelhard, I. M., et al. (2015). Updated meta-analyses of classical fear conditioning in the anxiety disorders. *Depression and Anxiety, 32*(4), 239–253. https://doi.org/10.1002/da.22353.
Epstein, L. H., Mitchell, S. L., & Caggiula, A. R. (1993). The effect of subjective and physiological arousal on dishabituation of salivation. *Physiology & Behavior, 53*(3), 593–597. https://doi.org/10.1016/0031-9384(93)90158-C.
Epstein, L. H., Paluch, R., & Coleman, K. J. (1996). Differences in salivation to repeated food cues in obese and nonobese women. *Psychosomatic Medicine, 58*(2), 160–164.
Ezzati, M. (2016). Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *The Lancet, 387*(10026), 1377–1396. https://doi.org/10.1016/S0140-6736(16)30054-X.
Fairburn, C. G., & Beglin, S. J. (1994). The assessment of eating disorders: Interview or self-report questionnaire? *International Journal of Eating Disorders, 16*, 363–370.
Ferriday, D., & Brunstrom, J. M. (2011). 'I just can't help myself': Effects of food-cue exposure in overweight and lean individuals. *International Journal of Obesity, 35*(1), 142–149. https://doi.org/10.1038/ijo.2010.117.
Glautier, S., Drummond, C., & Remington, B. (1994). Alcohol as an unconditioned stimulus in human classical conditioning. *Psychopharmacology, 116*(3), 360–368. https://doi.org/10.1007/BF02245341.
Grillon, C., & Davis, M. (1997). Fear-potentiated startle conditioning in humans: Explicit and contextual cue conditioning following paired versus unpaired training. *Psychophysiology, 34*, 451–458. https://doi.org/10.1111/j.1469-8986.1997.tb02389.x.
Hermans, D., Baeyens, F., & Vervliet, B. (2013). Generalization of acquired emotional responses. *Handbook of Cognition and Emotion*, 117–134.
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*. New York: Springer.
Jansen, A., Houben, K., & Roefs, A. (2015). A cognitive profile of obesity and its translation into new interventions. *Frontiers in Psychology, 6*(Suppl.), 282. https://doi.org/10.3389/fpsyg.2015.01807.
Jansen, A., Schyns, G., Bongers, P., & van den Akker, K. (2016). From lab to clinic: Extinction of cued cravings to reduce overeating. *Physiology & Behavior*. https://doi.org/10.1016/j.physbeh.2016.03.018.
Jansen, A., Stegerman, S., Roefs, A., Nederkoorn, C., & Havermans, R. C. (2010). Decreased salivation to food cues in formerly obese successful dieters. *Psychotherapy and Psychosomatics, 79*(4), 257–258. https://doi.org/10.1159/000315131.
King, B. M. (2013). The modern obesity epidemic, ancestral hunter-gatherers, and the sensory/reward control of food intake. *American Psychologist, 68*(2), 88. https://doi.org/10.1037/a0030684.
Klucken, T., Kruse, O., Wehrum-Osinsky, S., Hennig, J., Schweckendiek, J., & Stark, R. (2015). Impact of COMT Val158Met-polymorphism on appetitive conditioning and amygdala/prefrontal effective connectivity. *Human Brain Mapping, 36*(3), 1093–1101. https://doi.org/10.1002/hbm.22688.
Kroemer, N. B., & Small, D. M. (2016). Fuel not fun: Reinterpreting attenuated brain responses to reward in obesity. *Physiology & Behavior, 162*, 37–45.
Lissek, S., Pine, D. S., & Grillon, C. (2006). The strong situation: A potential impediment to studying the psychobiology and pharmacology of anxiety disorders. *Biological Psychology, 72*(3), 265–270. https://doi.org/10.1016/j.biopsycho.2005.11.004.
Lissek, S., Powers, A. S., McClure, E. B., Phelps, E. A., Woldehawariat, G., Grillon, C., et al. (2005). Classical fear conditioning in the anxiety disorders: A meta-analysis. *Behaviour Research and Therapy, 43*(11), 1391–1424. https://doi.org/10.1016/j.brat.2004.10.007.
Lissek, S., Rabin, S., Heller, R. E., Lukenbaugh, D., Geraci, M., Pine, D. S., et al. (2010). Overgeneralization of conditioned fear as a pathogenic marker of panic disorder. *American Journal of Psychiatry*. https://doi.org/10.1176/appi.ajp.2009.09030410.
Mallan, K. M., & Lipp, O. V. (2007). Does emotion modulate the blink reflex in human conditioning? Startle potentiation during pleasant and unpleasant cues in the picture-picture paradigm. *Psychophysiology, 44*, 737–748. https://doi.org/10.1111/j.1469-8986.2007.00541.x.
Meyer, M. D., Risbrough, V. B., Liang, J., & Boutelle, K. N. (2015). Pavlovian conditioning to hedonic food cues in overweight and lean individuals. *Appetite, 87*, 56–61. https://doi.org/10.1016/j.appet.2014.12.002.
Miller, G. A., & Chapman, J. P. (2001). Misunderstanding analysis of covariance. *Journal of Abnormal Psychology, 110*(1), 40. https://doi.org/10.1037/0021-843X.110.1.40.
Mutter, S. A., & Plumlee, L. F. (2014). The effects of age on associative and rule-based causal learning and generalization. *Psychology and Aging, 29*, 173–186. https://doi.org/10.1037/a0035930.
Nederkoorn, C., Smulders, F. T. Y., & Jansen, A. (2000). Cephalic phase responses, craving and food intake in normal subjects. *Appetite, 35*(1), 45–55. https://doi.org/10.1006/appe.2000.0328.
Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., et al. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the global burden of disease study 2013. *The Lancet, 384*(9945), 766–781. https://doi.org/10.1016/S0140-6736(14)60460-8.
Orr, S. P., Metzger, L. J., Lasko, N. B., Macklin, M. L., Peri, T., & Pitman, R. K. (2000). De novo conditioning in trauma-exposed individuals with and without post-traumatic stress disorder. *Journal of Abnormal Psychology, 109*(2), 290. https://doi.org/10.1037/0021-843X.109.2.290.
Papachristou, H., Nederkoorn, C., Beunen, S., & Jansen, A. (2013). Dissection of appetitive conditioning. Does impulsivity play a role? *Appetite, 69*, 46–53. https://doi.org/10.1016/j.appet.2013.05.011.
Pearce, J. M. (1987). A model for stimulus generalization in Pavlovian conditioning. *Psychological Review, 94*, 61–73. https://doi.org/10.1037//0033-295X.94.1.61.
Prokasy, W. F., & Kumpfer, K. (1973). Classical conditioning. *Electrodermal Activity in Psychological Research*, 157–202.
Roefs, A., Quaedackers, L., Werrij, M. Q., Wolters, G., Havermans, R., Nederkoorn, C., et al. (2006). The environment influences whether high-fat foods are associated with palatable or with unhealthy. *Behaviour Research and Therapy, 44*, 715–736. https://doi.org/10.1016/j.brat.2005.05.007.
Sandt, A. R., Sloan, D. M., & Johnson, K. J. (2009). Measuring appetitive responding with the postauricular reflex. *Psychophysiology, 46*, 491–497. https://doi.org/10.1111/j.1469-8986.2009.00797.x.
Spoormaker, V. I., Andrade, K. C., Schröter, M. S., Sturm, A., Goya-Maldonado, R., Sämann, P. G., et al. (2011). The neural correlates of negative prediction error signaling in human fear conditioning. *NeuroImage, 54*(3), 2250–2256. https://doi.org/10.1016/j.neuroimage.2010.09.042.
Urland, G. R., & Ito, T. A. (2005). Have your cake and hate it, too: Ambivalent food attitudes are associated with dietary restraint. *Basic and Applied Social Psychology, 27*, 353–360. https://doi.org/10.1207/s15324834basp2704_8.
van den Akker, K., Havermans, R. C., Bouton, M. E., & Jansen, A. (2014). How partial reinforcement of food cues affects the extinction and reacquisition of appetitive responses. A new model for dieting success? *Appetite, 81*, 242–252. https://doi.org/10.1016/j.appet.2014.06.024.
van den Akker, K., Havermans, R. C., & Jansen, A. (2015). Effects of occasional reinforced trials during extinction on the reacquisition of conditioned responses to food cues. *Journal of Behavior Therapy and Experimental Psychiatry, 48*, 50–58. https://doi.org/10.1016/j.jbtep.2015.02.001.
van den Akker, K., Havermans, R. C., & Jansen, A. (2017). Appetitive conditioning to specific times of day. *Appetite, 116*, 232–238. https://doi.org/10.1016/j.appet.2017.05.014.
van den Akker, K., Jansen, A., Frentz, F., & Havermans, R. C. (2013). Impulsivity makes more susceptible to overeating after contextual appetitive conditioning. *Appetite, 70*, 73–80. https://doi.org/10.1016/j.appet.2013.06.092.
van den Akker, K., Nederkoorn, C., & Jansen, A. (2017). Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity. *International Journal of Psychophysiology, 118*, 40–47. https://doi.org/10.1016/j.ijpsycho.2017.06.004.
van den Akker, K., Schyns, G. L. T., & Jansen, A. (2016). Enhancing inhibitory learning for the treatment of overeating: Design and rationale of a cue exposure therapy trial in overweight and obese women. *Contemporary Clinical Trials, 49*, 85–91. https://doi.org/10.1016/j.cct.2016.06.008.
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., Vansteenwegen, D., Beckers, T., & Van den Bergh, O. (2008a). 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. (2008b). 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.
Watson, P., Wiers, R. W., Hommel, B., Gerdes, V. E. A., & de Wit, S. (2017). Stimulus control over action for food in obese versus healthy-weight individuals.

Frontiers in Psychology, 8, 580. https://doi.org/10.3389/fpsyg.2017.00580.
Weike, A. I., & Hamm, A. O. (2005). The neuropsychology of fear learning and fear regulation. *57*, 5–14. https://doi.org/10.1016/j.ijpsycho.2005.01.006.
Weiss, E. C., Galuska, D. A., Khan, L. K., & Serdula, M. K. (2006). Weight-control practices among US adults, 2001–2002. *American Journal of Preventive Medicine, 31*(1), 18–24. https://doi.org/10.1016/j.amepre.2006.03.016.
Wing, R. R., & Phelan, S. (2005). Long-term weight loss maintenance. *The American Journal of Clinical Nutrition, 82*(1), 222S–225S.
Zhang, Z., Manson, K. F., Schiller, D., & Levy, I. (2014). Impaired associative learning with food rewards in obese women. *Current Biology, 24*(15), 1731–1736. https://doi.org/10.1016/j.cub.2014.05.075.