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BRIEF REPORT

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Individual differences in extinction learning predict weight loss after treatment: A pilot study

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Abstract

Learning theorists suggest extinction learning to be a central mechanism in weight loss success; however, empirical studies are scarce. In this pilot study, it was examined whether individual differences in extinction learning predict outcome after weight loss treatment. Overweight and obese individuals first completed a laboratory conditioning task in which individual differences in extinction learning were assessed. Next, they were randomised to one of two weight loss interventions: cue exposure therapy (CET), which is considered the clinical analogue of laboratory extinction, or a control lifestyle intervention. In line with expectations, better extinction learning in the laboratory task was associated with more weight loss at both post-treatment (CET only) and follow-up (both interventions) measurements. In contrast, two other indices of treatment success (reduction in overeating expectancies and ad libitum food intake during a laboratory taste test) showed no associations with pre-treatment extinction learning. It is suggested that extinction learning may be a core mechanism underlying weight loss success, and hence, an important target for new obesity interventions.

KEYWORDS

appetitive conditioning, cue exposure, extinction, obesity, weight loss

1 | INTRODUCTION

Overweight and obesity remain highly prevalent, as do attempts to lose excess weight (Ogden, Carroll, Kit, & Flegal, 2014; Santos, Sniehotta, Marques, Carraça, & Teixeira, 2017). However, dieting attempts are often unsuccessful: only one in five dieters is able to achieve a 10% weight loss and to maintain this loss for at least 1 year (Wing & Hill, 2001). The current environment's abundance of tasty 'food cues' (e.g. the smell of freshly baked goods, the sight of a café) is thought to be a major cause of unsuccessful dieting, as exposure to these cues easily stimulates appetitive reactivity such as food cravings, promoting (over)eating—even in the absence of an energy need (Boswell & Kober, 2016; Jansen, Houben, & Roefs, 2015; Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010; Murdaugh, Cox, Cook Iii, & Weller, 2012).

Learning models of overeating view this food cue reactivity as a conditioned response (CR) to a conditioned stimulus (CS; food cue) that has previously become associated with tasty food intake (unconditioned stimulus, US) through repeated CS–US pairings (Bouton, 2011; Jansen, Schyns, Bongers, & van den Akker, 2016). This way, any stimulus could become a CS evoking appetitive reactivity—including, for example, the sight or smell of food, a certain time of day, an emotion, or a specific context (van den Akker, Schyns, & Jansen, 2018). Learning models also predict that food cue reactivity may diminish during a restrictive diet. If one is repeatedly exposed to CSs during the diet and refrains from eating (no US)—but *not* when CSs are avoided—*extinction* is presumably practiced. During extinction, new inhibitory learning occurs in which CS–noUS associations are strengthened, with stronger extinction learning translating to lower cued responding, making adherence to a diet easier (Bouton, 2011; Jansen et al., 2010, 2015, 2016). This is also the rationale behind cue exposure therapy (CET), in which obese individuals or those with overeating psychopathology are repeatedly exposed to problematic food cues without eating to extinguish learned appetitive responding. Indeed, CET (vs. control interventions) has shown effective in reducing overeating expectancies (one's expectancy to overeat upon food cue exposure), cued cravings, actual overeating, binge eating, and weight (e.g. Boutelle et al., 2011, 2014; Jansen, Van den Hout, De Loof, Zandbergen, & Griez, 1989; Martinez-Mallén et al., 2007; Schyns, Roefs, Mulkens, & Jansen, 2016; Schyns, Roefs, Smulders, & Jansen, 2018; Schyns, van den Akker, Roefs, Houben, & Jansen, 2020; Toro et al., 2003).

Despite the fact that several experts proposed extinction learning as central mechanism in dieting success (Boutelle & Bouton, 2015; Bouton, 2011; Jansen et al., 2016; Schyns, van den Akker, Roefs, Hilberath, & Jansen, 2018), and the very promising effects of (extinction-focused) CET, empirical examinations into the role of extinction learning in dieting success are very scarce. Circumstantial evidence stems from two laboratory conditioning studies assessing extinction learning experimentally by first pairing a stimulus (CS) with food intake and then measuring the decline in CS-elicited responding that occurs with repeated CS-alone presentations (van den Akker, Havermans, Bouton, & Jansen, 2014). In these studies, participants exhibiting worse extinction learning (i.e. showing a slower and/or less complete decline in responding during extinction) appeared to be more impulsive, which is a personality characteristic that is associated with unsuccessful dieting (van den Akker et al., 2014). Importantly, a closer examination of the link between individual differences in extinction learning and dieting success might provide insight into the mechanisms that determine why some dieters are more successful than others, and eventually guide treatment: individuals who exhibit worse extinction learning may, for example, require prolonged (cue exposure) treatment.

The current pilot study examined if individual differences in extinction learning predict outcome after weight loss treatment. To this end, we analysed data from overweight individuals who first completed a standardised appetitive conditioning task including an extinction phase (van den Akker, Schyns, & Jansen, 2017), and were then assigned to an eight-session CET or control intervention aimed at diminishing food intake via lifestyle changes (van den Akker, Schyns, & Jansen, 2016). In the conditioning task, the extinction of eating (US) expectancies was used as an index of extinction learning.[1] As a cognitive index of extinction during *treatment*, the decrease in overeating expectancies was examined. As treatment outcomes, (a) ad libitum intake of personalised food incorporated during exposure therapy and (b) weight loss were examined.[2] It was hypothesised that a more successful extinction of US expectancies in the laboratory would be associated with a greater reduction in overeating expectancies, less food intake, and more weight loss following treatment—and especially so for individuals who explicitly practiced extinction during treatment (i.e. those who received CET).

2 | METHODS AND MATERIALS

2.1 | Participants

Thirty-eight female overweight participants were included who completed an appetitive conditioning paradigm as well as a subsequent CET or control intervention. Of these, 14 participants were excluded who did not learn the CS–US contingency during acquisition (see *appetitive conditioning task*), and one further participant was excluded as her responses in the conditioning task were missing due to technical issues, leaving a final sample of 23 individuals (CET: n = 10, control: n = 13). No differences between the interventions were found for BMI (CET: M = 33.02, SD = 3.51; control: M = 34.13, SD = 4.81, p = .55), global EDE-Q score (CET: M = 2.44, SD = 0.70; control: M = 2.65, SD = 1.27, p = .63), binge eating (CET: n = 4; control: n = 3 who had at least one eating binge within the last week, p = .45), and age (CET: M = 40.30, SD = 13.54; control: M = 42.15, SD = 12.89, p = .74). Inclusion criteria for the study were: a female gender, a BMI ≥27, an age between 18 and 60 years, a strong motivation to lose weight, a clear difficulty to refrain from eating high-calorie snack foods, and a liking for the US (chocolate); exclusion criteria were: self-reported smelling problems (since smelling is an important part of CET), current psychotherapeutic or psychopharmacological treatment, pregnancy, bariatric surgery (pre and post-operative), and insufficient time for the interventions and measurements.

The data used in the study stem from a randomised controlled trial conducted previously, in which randomisation to either CET or control occurred after completion of the conditioning paradigm. Six participants dropped out during treatment (CET: $n = 4$; control: $n = 2$). The detailed methodology of the RCT is described in van den Akker et al. (2016). The overall treatment results are provided in Schyns et al. (2020), and the methodology of the conditioning paradigm is described in van den Akker et al. (2017; in which learning performance in the overweight sample was compared with a separately recruited healthy weight control group).[3] The study was approved by the local ethical committee.

2.2 | Appetitive conditioning task

Participants completed a differential appetitive conditioning task including two phases: acquisition and extinction. Geometric shapes (a blue square and a yellow circle) functioned as CSs and small pieces of handmade chocolate (approximately 0.9 g) functioned as USs.

During *acquisition*, one shape (CS+) was always followed by US intake. The other shape (CS−) was never followed by the US. A partially variable number of acquisition trials was used depending on one's CS–US contingency learning: acquisition continued until a participant's CS+ versus CS− differentiation in US expectancies was >50 on a 100-point scale for three consecutive trials (minimum of 4, maximum of 15 trials per CS). During *extinction*, both the CS+ and CS− were presented without the US. Extinction proceeded until the CS+ versus CS− differentiation in US expectancies <20 for three consecutive trials (minimum of 8, maximum of 15 trials). In each trial, a CS was presented on a computer screen for 10 s, after which the expectancy (and then desire) VAS appeared under the CS. After completion, in case of a CS+ acquisition trial, a US was provided and consumed by the participant. The inter-trial interval was 17–23 s.

2.3 | Interventions

2.3.1 | Cue exposure therapy

Participants were individually seen during eight cue exposure sessions that took place within approximately 1 month. Two sessions took place at the university, and six in each participants' personal overeating contexts (e.g. at their homes). Exposure sessions were designed to maximise inhibitory learning, for example, by focusing on maximising the discrepancy between expected (overeating) outcome and actual (not overeating) outcome (i.e. expectancy violation). A variety of food cues, which were personalised for each participant, were incorporated during exposure sessions. These food cues included food items (e.g. 'personalised exposed item', see ad libitum food intake) as well as other food-associated cues (e.g. certain times of day) and contexts (e.g. snack bars). Participants also performed additional daily homework exposure sessions.

2.3.2 | Control

Participants received eight individual lifestyle and psycho-education sessions within approximately 1 month, including two at the university, two or at home, and four via phone (alternated with university/home sessions). The sessions included advice about healthy lifestyle including dietary advice, mindfulness, power-posing, and psycho-education about body image. Participants completed additional daily homework such as mindfulness exercises.

2.4 | Measurements

2.4.1 | Extinction learning

Computerised visual analogue scales (VAS) were used to measure US expectancies in the conditioning task (*To what extent do you expect to receive chocolate right now?*), ranging from 0 (*certainly not expect to receive* chocolate) to 100 (*certainly expect to receive chocolate*).

The reduction in differential responding during extinction is typically strongest during the first four or five extinction trials; responding on later trials (on which extinction has occurred to a large extent even in slow extinguishers) may therefore be a weaker index of individual differences in extinction (see Lommen, Engelhard, Sijbrandij, van den Hout, & Hermans, 2013). In line with this, a prior study showed that early, but not late extinction learning predicted post-deployment posttraumatic stress symptoms (Lommen et al., 2013). Consistent with this prior study, we used trial 4 as cut-off. Specifically, we calculated the average differentiation (i.e. CS+ vs. CS− difference, to exclude non-associative effects) of extinction trials 2–4, and divided this by initial acquisition levels (average differentiation on the last acquisition and first extinction trial). Lower scores thus represent a better/earlier extinction.

2.4.2 | Reduction in overeating expectancies

Eight 100 mm-VAS were used to measure CS–US expectancies [e.g. if palatable food is in front of me (CS), then I cannot refrain from eating it (US)]. Reduction in overeating expectancies at post-treatment and follow-up was calculated by dividing expectancies at these time points by pre-treatment expectancies, with smaller scores indicating a greater reduction.

2.4.3 | Ad libitum food intake

Ad libitum food intake (kcal) was measured during a bogus taste test including three different foods (personalised exposed, personalised non-exposed, non-personalised exposed). Only the personalised item used during the exposures was used because it was the only one effectively reduced by CET (and hence, supposedly, extinguished; Schyns et al., submitted).

2.4.4 | Weight loss

Weight loss at post-treatment and follow-up was calculated by the percentage weight change relative to pre-treatment, more negative values indicating greater weight loss.

2.5 | Procedure

Participants completed a pre-measurement, a post-measurement immediately following the intervention, and a 3-month follow-up measurement. At pre-measurement, participants completed the appetitive conditioning task and they were, on a separate day, interviewed about their favourite personal snack foods and their overeating expectancies. After this, participants' height and weight were recorded and they were randomised to either the CET or control intervention. On post-measurement and follow-up sessions, participants completed the bogus taste test and, on a separate day, the overeating expectancy VAS.

2.6 | Statistical analysis

The previously reported group comparisons in BMI, EDE-Q score, and age were carried out using independent samples t tests; group differences in binge eating were examined using a Pearson's chi-square test. To examine extinction learning as predictor for treatment outcome, regression analyses were conducted with reduction in overeating expectancies, ad libitum food intake (kcal), and percentage weight loss as dependent variables, and (centred score of) extinction learning and intervention (CET or control) as independent variables. The data were approximately normally distributed.

3 | RESULTS

Extinction learning predicted weight loss both at post-treatment and at follow-up. Specifically, at post-treatment, a significant Extinction learning × Intervention interaction was found (see Table 1). Follow-up analyses showed that after CET only, better extinction learning was significantly and strongly related to greater weight loss (r = .87, p = .001; control: r = −.06, p = .85). At follow-up, better extinction learning also predicted more weight loss, irrespective of intervention type (see Table 2).

In contrast, extinction learning did not predict changes in overeating expectancies and ad libitum food intake (expectancies post-treatment: β = .17, t[19] = 0.75, p = .46, β = −.36, t[17] = −1.26, p = .23 for main effect and interaction; expectancies follow-up: β = .01, t[19] = 0.04, p = .97, β = −.21, t[17] = −0.69, p = .50 for main effect and interaction; intake post-treatment: β = .12, t[20] = 0.55, p = .59, β = −.20, t[18] = −0.66, p = .52 for main effect and interaction; intake follow-up: β = .11, t[21] = 0.50, p = .63, β = −.24, t[19] = −0.79, p = .44 for main effect and interaction).

4 | DISCUSSION

The aim of this study was to examine the link between extinction performance in a laboratory conditioning task (i.e. extinction learning) and treatment outcome after an extinction-focused intervention (CET) and a control intervention. In line with the hypotheses, findings showed that immediately after completion of an eight-session CET (but not control) intervention, better extinction learning was strongly associated with more weight loss. Three months after the interventions, extinction learning still predicted weight loss, but similarly so across the interventions. In contrast, ad libitum food intake and changes in overeating expectancies were not associated with extinction learning.

The finding that better extinction performance predicted short and longer-term weight loss indicates that extinction learning could reflect a critical mechanism underlying weight loss success, and hence, an important

TABLE 1 Summary of the hierarchical regression analysis (outcome: post-treatment weight loss)

Variable	R^2	β	t	p
Step 1	0.23			
Extinction learning		.48	2.45	.02
Step 2	0.46			
Extinction learning		.44	2.59	.02
Intervention		−.48	−2.84	.01
Step 3	0.66			
Extinction learning		−.04	−0.21	.84
Intervention		−.47	−3.40	.003
Extinction learning × Intervention		.66	3.30	.004

TABLE 2 Summary of the hierarchical regression analysis (outcome: follow-up weight loss)

Variable	R^2	β	t	p
Step 1	0.37			
Extinction learning		.61	3.51	.002
Step 2	0.52			
Extinction learning		.58	3.74	.001
Intervention		−.39	−2.50	.02
Step 3	0.57			
Extinction learning		.35	1.60	.13
Intervention		−.38	−2.50	.02
Extinction learning × Intervention		.32	1.46	.16

target for weight loss interventions. This is consistent with the theoretical basis of CET and, more generally, with predictions of learning models of overeating (Jansen, 1998; Jansen et al., 2016; van den Akker et al., 2018). Also consistent with hypotheses, only individuals who received CET showed a (strong) association between extinction learning and weight loss immediately following the intervention, presumably because these individuals practiced extinction extensively, with many achieving a certain degree of extinction within the 4 weeks of intervention. In contrast, individuals who received the control intervention may have had too few opportunities to experience sufficient CS–noUS pairings for extinction to occur. Conversely, at 3-month follow-up, a similarly strong association between extinction learning and weight loss success across the interventions was found. This might be explained by participants in the control intervention now having had sufficient opportunities to practice extinction (i.e. the natural repeated non-reinforcement of food cues that occurs during a diet), leading to more variation in real-life extinction levels and hence, stronger correlations between extinction learning and treatment outcome. However, given the limited sample size of the study (in particular within each treatment condition), it is important to note that these findings await replication in larger samples. Nevertheless, the present findings provide initial evidence that extinction learning may be central to weight loss success, and support the use of cue exposure techniques to optimise weight loss interventions.

The lack of significant correlations between extinction learning on the one hand and overeating expectancies and ad libitum food intake on the other was unexpected. This might suggest that even though CET (vs. control) resulted in selective reductions in these measures (Schyns et al., 2020), mechanisms other than extinction learning might underlie these reductions. Alternatively, one could speculate that the measures represent less precise (more distal) indices of real-life dieting (extinction) success. For example, eating less of a certain food in a specific laboratory context (or indicating a reduced expectancy to overeat in the laboratory) may not guarantee a similarly reduced intake of that food (or expectancy) outside the laboratory. In addition, to achieve successful weight loss, a lowered intake across various foods is often necessary; extinction of responding to only one (or a few) food cues may therefore be a poorer indicator of overall dieting success than weight loss. This might have resulted in weakened relationships between extinction learning and ad libitum intake/overeating expectancies. Further research is needed to determine if and why extinction learning might be differentially related to reductions in overeating expectancies, ad libitum food intake, and weight.

Next to helping to gain more insight into the mechanisms underlying weight loss success, the current findings also provide important evidence for the external validity of the extinction model. While at face value, laboratory extinction seems a good model for real-life restriction (i.e. both involve repeated non-reinforced presentations of a food cue that seem to result in a reduction in responding), it is still a highly simplified one that requires rigorous tests of its real-life applicability (Scheveneels, Boddez, Vervliet, & Hermans, 2016). The current study supports the external validity of the extinction model by showing that performance in the model was meaningfully related to weight loss success. Such validity tests are important as they can eventually inform treatment; for example, a technique found to enhance extinction learning in an externally valid laboratory model is likely to be also effective in optimising weight loss treatments (Scheveneels et al., 2016).

Finally, one may note that the current study examined only one index of extinction learning (US expectancies). Different extinction indices have been shown to diverge during extinction (e.g. extinction of eating desires is typically much slower than the extinction of US expectancies; Van Gucht, Baeyens, Hermans, & Beckers, 2013), and it remains unknown if or to what extent various indices are predictive for treatment success. Further, since only females were studied, it is unknown whether the findings would generalise to males. This seems especially relevant given that multiple studies have reported gender differences in extinction (e.g. Graham & Milad, 2013).

In sum, the current pilot data point towards a critical role of extinction learning in weight loss success. This suggests that the optimization of extinction learning could be an important target for weight loss interventions.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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ENDNOTES

[1] Other responses (US desires, CS liking, and skin conductance responses) were assessed as well, but since overweight participants—contrary to the successful acquisition of expectancies—did not show strong evidence for a successful acquisition on these measures (see van den Akker, Schyns, & Jansen, 2017), they were not included in the current analyses; extinction cannot be examined if not first acquired.

[2] Cue reactivity to a snack food was assessed as a separate outcome measure, but it was not included in the present investigation because reactivity was not reliably elicited. Likewise, binge eating frequency was assessed but not included in this study due to very little variation in eating binges after the interventions (e.g. only three participants reported having experienced eating binges in the past week at post-measurement).

[3] Of note, part of the sample of this RCT additionally completed fMRI tasks before and after the intervention, in order to examine the neural correlates of food cue exposure therapy. These data are published in Franssen, Jansen, Schyns, van den Akker, and Roefs (2020).

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