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Review

Tackling sabotaging cognitive processes to reduce overeating; expectancy violation during food cue exposure

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ABSTRACT

Calorie-reduced diets to combat obesity do work, but they only work when one sticks to the diet and the - relatively small - weight loss usually is short-lived. It is argued that calorie-reduced diets should converge with enduring lifestyle changes: the diet is just the start of a lifelong new eating pattern. Getting people to change their lifestyles forever could increase the amount of lost weight and prevent relapse. However, a real behavior change is difficult, especially when longstanding habits are involved and the change is intended for the rest of life. It is argued here that adherence to a new lifestyle is much easier if sabotaging cognitive processes are tackled. An overview is given of four studies into the effects of exposure to reduce appetitive responding to tempting food cues. A robust effect of exposure on the *ad lib* intake of exposed foods was found in all studies: participants ate significantly less of exposed foods after exposure compared to control interventions but no generalization to non-exposed foods was found. The reduced food intake after exposure was associated with a violation of overeating expectancies. It is discussed that lifestyle interventions might benefit from techniques that are really able to change longstanding habits. Specifically, the violation of overeating expectancies during exposure seems to be critical for controlled eating and should therefore be part of lifestyle interventions for obesity.

1. Introduction

Non-surgical approaches to tackle obesity usually work as long as they include calorie-reduced diets [22,30]. All types of diets, whether they reduce the relative amount of carbohydrates or fats, work well; it is the calorie reduction that is important, and the best predictor of weight loss is adherence to the calorie-reduced diet [30,37]. A closer look at the literature shows that people on calorie-reduced diets often lose less than 5–10% of their starting weights [14,22], though there is much variability across people. This degree of weight loss produces significant health benefits, but the relatively small weight loss almost never matches with the weight loss dreams and expectations of overweight people.

After losing weight, weight loss maintenance is a next huge challenge. Most people who lose weight experience that their weights slowly rise again [14,22,44]. So, calorie-reduced diets work, but they only work when one sticks to the diet and the relatively small weight loss usually is short-lived. That is why calorie-reduced diets should converge with enduring lifestyle changes: the diet is the start of a lifelong new eating pattern. Getting people to change their lifestyles forever could increase the amount of lost weight and prevent relapse. Behavior change is however extremely difficult, especially when longstanding habits are involved and the change is for the rest of life.

There are a number of cognitive processes that can sabotage behavior change and healthier lifestyles (see e.g., [18]). The brain is continuously processing information that is received from the environment, to enable individuals to operate effectively. The processing of information determines largely how one behaves. Many mental processes require attention and effort (control) but habits are mainly ruled by automatic cognitive processes. Automatic cognitive processes occur without any effort; they require little or no cognitive capacity and easily interfere with controlled efforts to eat healthier. One of the most frequently studied sabotaging automatic processes in overeating is inhibitory control, also known as response inhibition. This executive function is related to impulse control, or the ability to withhold a response, which is a necessary skill to change one's lifestyle. It refers, for example, to the ability to overrule automatic intentions to directly respond without thinking, such as mindless eating when tempting tasty

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foods are presented. Obesity and overeating are associated with weaker inhibition skills [11,12,15,24,27,29]. Weak inhibition skills facilitate overeating, not only when tempting foods are available but also when other cues or contexts, like a restaurant or specific time of the day, signal the availability of desired foods. This responding to cues or contexts that signal the availability of tasty foods is called food cue reactivity [16]. Food cravings, eating desires, hormonal and salivation responses reflect food cue reactivity; they prepare for intake and strong food cue reactivity easily leads to overeating [2,16,20,21]. Food cue reactivity is significantly stronger in obese people [2,6,13,21,36,40], and variance in food cue reactivity was found to account for 26% of the variance in eating and weight gain [2]. Food cue reactivity also increases the risk of relapse during or after weight loss diets. Preliminary data suggest that weak inhibition skills influence the persistence of food cue reactivity: weaker skills are associated with more persistent cue reactivity [28,39].

1.1. Inhibitory learning

Adherence to a new lifestyle is much easier without sabotaging cognitive processes [18]. Reduced reactivity to tempting food cues, i.e. less appetitive responding to palatable food cues, might make healthy and controlled eating easier. The food cue reactivity model (e.g., [20]) predicts that exposure with response prevention is the way to decrease disinhibitive appetitive responding and overeating. During the exposure, one is exposed to cues and contexts that signal unhealthy eating and elicit food cravings, while the cues and contexts remain systematically unreinforced, that is: the associated tasty foods are not eaten. For example, one is exposed to the sight, smell and taste of tempting sweets or snacks, while being prevented from actual eating. Or one is exposed to specific eating times and eating environments while being prevented from actual food intake. Preliminary data from clinical case studies, uncontrolled studies, and/or underpowered studies, suggest that food cue exposure is effective in the reduction of food cravings and overeating [3–5,17,19,23,25,26,31,38].

In some of these early studies, desires to eat were measured and it was found that the desires to eat decrease during the exposures. This so-called habituation of eating desires was considered to be important for treatment success (e.g., [16]), but studies in the field of anxiety disorders indicate that habituation of anxiety during exposures is not at all related to treatment outcome (see [10]). Rather, it appears to be important that expectancies about the exposure effects are disconfirmed [8,9]. Thus, beliefs like ‘When I am alone at home with a box of chocolate, I will eat them all’, ‘If I eat one bite of a cookie, I can't stop eating’ or ‘I will panic if I do not eat’ should be violated during exposure. A belief is violated, for example, when one succeeds in being at home alone without eating the whole box of chocolate, when taking one bite of a cookie without eating them all, or when there is no panic attack even though one did not eat.

It is well-known nowadays that exposure works through inhibitory learning [7,10]: it is not the forgetting, unlearning, replacement or erasing of an association between cues/contexts on the one hand and overeating on the other. Instead, a new memory is added about the association between the cue/context and *not* eating. During exposure or inhibitory learning, it is learned that the cue/context (also) predicts no overeating. The cues and contexts that originally were associated with overeating become increasingly ambiguous during repeated exposures: they signal both the overeating and the absence of overeating. Both meanings remain in memory and compete for retrieval. The learning of new inhibitory pathways is of course fragile at the start of the exposure intervention and should therefore be practiced frequently. The original association (cue/context signals overeating) is more and more inhibited but still exists, which makes vulnerable to relapse. Exposures should explicitly aim for the violation of beliefs that cues/contexts signal the occurrence of overeating because frequent violations of those beliefs do strengthen the learning of new inhibitory associations [9,10].

We performed a series of four randomized controlled trials into the effectiveness of exposure interventions to reduce overeating, and to test the relative importance of both eating desire habituation and the violation of overeating expectancies [32–35]. It was hypothesized that the exposure interventions would be more effective to reduce actual food intake than control interventions, and that expectancy violation would be associated with the reduced food intake whereas the habituation of eating desires would not.

2. Methods

2.1. Interventions

Studies included one [33] or two [34,35] or eight [32] exposure sessions. During the exposure sessions, participants were repeatedly exposed to unreinforced cues, thereby learning that the cue/context signals no eating. The control interventions were matched on length and included lifestyle interventions [32,34], psychoeducation and assignments to increase body satisfaction [33]. One study used a waiting-list condition [35].

2.2. Participants

Participants were adult females [32,33,35] or male and female adolescents [34] with overweight or obesity. They were exposed individually [32,35] or in small groups [33,34] to cues and/or contexts associated with the intake of their personal favourite overeating foods.

2.3. Desires to eat

In all studies, eating desires were rated repeatedly on 100 mm Visual Analogue Scales (VAS), ranging from ‘no desire to eat at all’ (0) to an ‘extreme desire to eat’ (100). Within session habituation was calculated by subtracting the end eating desire from the session's peak eating desire, and, in case of more than one exposure session, the average over sessions was calculated. Between sessions habituation was calculated by subtracting peak desires of the final session from peak desires in the first session.

2.4. Overeating expectancies

Overeating expectancies were measured before and after exposure, using ‘If, then’ expressions. General expressions like *‘If I have tasty foods in front of me, then I cannot resist to eat it’* and *‘If I eat a small amount of tasty foods, then I cannot stop eating’* were used in three studies [33–35], while Schyns et al. [32] used personalized ‘If, then’ expressions as well. Participants rated how strongly they believed the expressions on 100 mm VASs [32,33,35] or 5-point Likert scales [34], with higher scores reflecting stronger beliefs in the overeating expectancies. Change scores (pre- minus post-measurement) were considered to reflect the strength of expectancy violation.

2.5. Food intake

In all studies, *ad lib* food intake was measured after the exposure or control intervention, during 10-min bogus taste tests using personalized favorite snack foods. Three out of four studies [33–35] used the Eating in the Absence of Hunger (EAH) paradigm [1], meaning that the bogus taste test was preceded by eating until satiation. The studies also tested exposure effects on the intake of non-exposed foods, to measure generalization effects.

Table 1.
Summary of main results: effects of exposure.

Study	WSH	BSH	EV	INTAKE	GEN
[33]	Yes	n.a.	Yes	Less	No
[34]	No	Yes	No	Less	Yes
[35]	Yes	Yes	Yes	Less	No
[32]	Yes	Yes	Yes	Less	No

WSH = within-session habituation, BSH = between-session habituation, EV = expectancy violation, Intake = food intake after exposure compared to control intervention, Gen = generalization of reduced food intake to non-exposed foods during taste test.

3. Findings

3.1. Habituation of desires to eat

Three studies report within session habituation [32,33,35] and three studies report between session habituation [32,34,35]. One study shows habituated desires to eat between two sessions but not within sessions [34] and two studies show decreased desires (habituation) both within and between sessions [32,35]. See also Table 1.

3.2. Violation of overeating expectancies

Three out of four studies [32,33,35] show that exposure reduced the beliefs in overeating expectancies contrary to control interventions. The study with adolescent participants [34] did however not show significant expectancy violation.

3.3. Food intake

A robust effect of cue exposure on the *ad lib* intake of exposed foods was found: in all studies, participants ate significantly less of the exposed foods after food cue exposure compared to control conditions [32–35]. Only the study with adolescent participants showed generalization, meaning that participants ate less of both the exposed and non-exposed foods after exposure compared to the control condition [34]. The other three studies did not show generalization effects: participants did not eat less of the non-exposed foods after exposure compared to control interventions [32,33,35].

3.4. Working mechanism

Exposure is theorized to be most effective when inhibitory learning is strong [9] and inhibitory learning is supposed to be strong when beliefs about cued overeating are disconfirmed during the exposure. In all four studies, expectancy violation, habituation of eating desires and *ad lib* food intakes after exposure were measured [32–35]. The studies had however modest sample sizes and therefore limited statistical power. Since three out of four studies were comparable in design and used identical measurements, whereas the fourth study [34] differed somewhat from the others, the data of the three comparable studies [32,33,35] were aggregated into one dataset to overcome the power issues. This aggregated dataset enables to examine the associations between habituation of eating desires, expectancy violation and ad lib calorie intake.

Table 2 shows the correlations between kcal intake (using *z*-scores), habituation of eating desires (within and between sessions), post-intervention overeating expectancies and the violation of overeating expectancies, over all conditions.

The data show that neither the within session habituation nor the between session habituation of eating desires correlates significantly with food intake after exposure. In contrast, post-intervention overeating expectancies correlate positively with the intake of exposed foods, indicating that stronger overeating expectancies are related to increased intake. Importantly, the violation of expectancies during exposure is negatively associated with the intake of exposed foods and non-exposed foods. The negative correlations show that a stronger violation of expectancies is associated with decreased food intake. These data might indicate that a stronger violation of expectancies during treatment is critical to reduce overeating.

The correlation between expectancy violation and within session habituation was also calculated. The violation of expectancies correlated positively with the within session habituation of eating desires, $r(132) = 0.20$, $p = 0.019$, meaning that a stronger violation of expectancies is associated with a stronger habituation of eating desires during exposure sessions.

4. Discussion

All four studies presented here show a robust effect of exposure on the ad lib intake of exposed foods: after exposure, participants eat significantly less calories of the foods to which they were exposed. The effect did not generalize to other tasty foods in the bogus taste tests, which is in line with earlier findings of extinction being context- and stimulus specific [42,43]. However, in one of the studies [32], body weight was also measured before and after eight sessions of exposure and it was found that the exposure intervention induced significant weight loss whereas the control lifestyle intervention did not. This body weight effect might point to the specific intake reduction of exposed foods being sufficient for significant weight loss to occur, or it could be considered circumstantial evidence for generalization of the exposure effects to non-exposed foods in daily life. The finding of generalization in youth was considered a coincidence but it could also follow from children being less burdened with an ingrained learning history: they might be better able to change existing behavioural patterns than adults.

The aggregated data show that reduced food intake after exposure is associated with a violation of expectancies and not with the habituation of eating desires, either within or between exposure sessions. These findings are in line with what is known from anxiety exposures: habituation of anxiety during exposures is not predictive of treatment outcome [10]. The present data would suggest that exposures should explicitly aim for the violation of beliefs that the cue/context signals the occurrence of overeating. It is the expectancy violation and not the habituation that is associated with reduced overeating.

Note, however, that an exposure intervention focusing on the habituation of eating desires versus an exposure intervention focusing on the violation of overeating expectancies shows that both are as successful in the reduction of food intake [35]. This could possibly be

Table 2
Correlations between z scores of kcal intake and habituation of eating desires, post-intervention overeating expectancies and expectancy violation (pre minus post expectancies) among adult participants (aggregated data from [33, 35], and [32]). WSH = within-session habituation, BSH = between-session habituation.

	WSH of eating desires (n = 100)	BSH of eating desires (n = 54)	Post-intervention expectancies (n = 136)	Expectancy violation (n = 118)
z intake of exposed food	−0.09	−0.02	0.41**	−0.23*
z intake of non-exposed food	−0.05	0.03	0.12	−0.19*

* $p < 0.05$.
** $p < 0.01$.

explained by the significant correlations between the habituation of eating desires and the violation of overeating expectancies; $r(35) = 0.61, p < 0.001$ (in [35]) and $r(132) = 0.20, p = 0.019$ for the aggregated data. Clearly, both cannot easily be disentangled; reduced eating desires could violate expectancies whereas violated expectancies, in turn, could decrease eating desires. It was concluded [35] that the targeting of expectancies during food cue exposure works as good as the targeting of eating desires; both reduce expectancies, desires and food intake. An explicit focus on the violation of expectancies during exposure treatment clearly is not necessary for expectancies to change. The need of expectancy violation for the extinction of conditioned chocolate desires has also been studied in an experimental appetitive conditioning study in the laboratory [41]. After healthy-weight participants acquired chocolate eating expectancies in an acquisition phase, eating expectancies were explicitly disconfirmed during the extinction procedure (i.e., instructed extinction). It was found that the explicit disconfirmation of beliefs did not reduce eating desires more than an extinction procedure without instructions [41]. Thus, though both the experimental and clinical data suggest that the explicit targeting of expectancies does not lead to better extinction than the targeting of eating desires, expectancy violation seems to be necessary for reduced intake to occur whereas a habituation of eating desires is not.

A notable strength of the current studies is the robust replication of reduced food intake of exposed foods in all four studies. In addition, control conditions were included in every study, in contrast to most food cue exposure studies published so far ([5,19,25,31,38]). Limitations of the current studies are the inclusion of only females in three out of four studies, the focus on short term effects and the relatively limited sample sizes in all studies. We tried to overcome this power problem by aggregating all data.

Clinical implications of the current studies should be clear: lifestyle interventions usually focus on nutrition and physical activity by providing education, advice, support and coaching but it could be beneficial to include techniques that are really able to change longstanding habits, like exposure. During the exposure, careful attention should be paid to the selection of cues, contexts and foods. Foods should be associated with the overeating and disinhibited control of the individual patient. As long as it is not clear how generalization can be increased, it is good to use a large range of potentially disinhibiting cues, contexts and foods in the exposures. Apart from proximal food cues, such as seeing, holding, smelling and tasting foods, individually tailored external cues (e.g., company), internal cues (e.g., specific feelings or mood state) and other contexts (e.g., time, Netflix) should be used in the exposures. Note that exposures can also be done using virtual reality applications and during homework sessions.

Though the habituation of eating desires is the usual target for exposure interventions, stronger habituation of eating desires was found to be unrelated to better outcomes in our studies. Instead, our studies did show the necessity of a reduction of overeating expectancies during food cue exposure. But it was also found that what you focus on during the exposures did not matter: the habituation of desires and less believed expectancies were significantly associated. So, exposures should ultimately get a reduction of overeating expectancies done, though this reduction can as well be reached by focusing on eating desires, the overeating beliefs, or alternating both, during the exposure sessions.

Exposure violates sabotaging overeating expectancies and reduces reactivity to tempting food cues, thereby making healthy and controlled eating a bit easier. Especially the violation of overeating expectancies seems to be critical for reduced food intake and should therefore be part of lifestyle interventions for obesity. Lifestyle interventions usually focus on healthier eating and increasing physical activity by providing education, advice, support and coaching. It could however be beneficial to include techniques that are really able to change longstanding habits. The four studies that we presented and discussed here, suggest that frequent exposure sessions might help to combat bad habits and enable to better adhere to a new and healthier lifestyle.

Declaration of Competing Interest

The authors declare no conflict of interest.

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