

## Learned desires

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# **Learned desires**

**The acquisition and extinction  
of appetitive responses to  
food cues in humans**

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# **Learned desires**

## **The acquisition and extinction of appetitive responses to food cues in humans**

PROEFSCHRIFT

Ter verkrijging van de graad van doctor aan de Universiteit Maastricht,  
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## Table of contents

Chapter 1	General introduction	7
Chapter 2	Impulsivity makes more susceptible to overeating after contextual appetitive conditioning	21
Chapter 3	Appetitive conditioning to specific times of day	41
Chapter 4	Violation of eating expectancies does not reduce conditioned desires for chocolate	57
Chapter 5	Effects of occasional reinforced trials during extinction on the reacquisition of conditioned responses to food cues	75
Chapter 6	How partial reinforcement of food cues affects the extinction and reacquisition of appetitive responses. A new model for dieting success?	95
Chapter 7	Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity	123
Chapter 8	General discussion	141
	References	161
	Summary	179
	Samenvatting	185
	Valorisation addendum	193
	Dankwoord	201
	Curriculum Vitae	207



# **Chapter 1**

## **General introduction**



## Background

Overweight and obesity prevalence has reached dramatic proportions. It is estimated that currently, around 2.1 billion individuals worldwide are overweight (BMI > 25), of which 600 million are obese (BMI > 30) (Ezzati, 2016; Ng et al., 2014). Given that obesity is associated with an increased risk for diabetes, cardiovascular disease, certain cancers, and various psychological illnesses (Guh et al., 2009; Luppino et al., 2010; Pulgarón, 2013; Scott et al., 2007), and societies face exploding health care costs due to obesity-associated morbidity (Cawley & Meyerhoefer, 2012; Leung, Pollack, Colditz, & Chang, 2015), halting and reversing the obesity “pandemic” has become a priority in public health.

Because our genetic pool is unlikely to have changed significantly over the last decades, many researchers believe that the “obesogenic” environment is the main contributor to weight gain and obesity, for it promotes a sedentary lifestyle and provides an abundance of high-calorie foods (e.g., Goran & Weinsier, 2000; Swinburn, Egger, & Raza, 1999). Although it may seem obvious that this food-abundant environment is associated with increased food cravings and food intake, not so much is known about the precise causal mechanism involved. Especially the role of Pavlovian learning in human eating behaviour has received very little attention in both the scientific literature and obesity treatment plans, despite the fact that several experts have emphasized its importance in overeating and obesity and its contribution to the difficulty in achieving long-term weight loss (Boggiano, Dorsey, Thomas, & Murdaugh, 2009; Bouton, 2011; Jansen, 2010; Jansen, Nederkoorn, & Havermans, 2011). This dissertation aims to address some of the links between appetitive conditioning, eating behaviour, and (un)successful dieting.

In the remainder of the introduction, the role of Pavlovian (classical) conditioning in food cue reactivity and eating behaviour is outlined, describing the main theory this dissertation builds on. Next, an overview of prior appetitive conditioning studies in the food domain is provided, and important gaps in current knowledge are identified. Finally, an outline of the dissertation is provided.

## Food cue reactivity and Pavlovian conditioning

The obesogenic environment contains an abundance of food-associated cues, such as the sight and smell of tasty food. Exposure to these food cues activates a central appetitive state (Bouton, 2007). Responses that reflect this appetitive state consist of psychological (craving), physiological preparatory (e.g., increased salivation and insulin release), and neurocognitive components (e.g., brain activa-

tion patterns, allocation of attentional resources). The physiologic preparatory responses (cephalic phase responses) enable the organism to better digest, absorb, and metabolize nutrients (Power & Schulkin, 2008), and overall, appetitive responses motivate the organism to obtain and consume food. In line with this, increased levels of food cue reactivity (e.g., cue-elicited desires to eat) have been associated with overeating, unsuccessful dieting, higher BMI, and eating psychopathology (Boswell & Kober, 2016; Ferriday & Brunstrom, 2011; Ferriday & Brunstrom, 2008; Jansen, 1998; Jansen et al., 2003; Staiger, Dawe, & McCarthy, 2000; van den Akker, Stewart, Antoniou, Palmberg, & Jansen, 2014).

Although food cue reactivity has a strong genetic component (Carnell, Haworth, Plomin, & Wardle, 2008), Pavlovian conditioning plays an important role as well. Every time palatable food is consumed, it can easily become associated with cues in the environment, and these cues can promote reactivity. In Pavlovian terms, the intake of palatable food is an unconditioned stimulus (US), and its metabolic consequences the unconditioned response (UR). Once a cue (conditioned stimulus; CS) has become associated with the intake of palatable food, it can stimulate appetitive responses / cue reactivity (conditioned response: CR), promoting food intake (Bouton, 2011; Jansen, 1998, Pavlov, 1927). In principle, any cue can become associated with palatable food intake; be it the sight or smell of food, a certain time of day, a hormonal state, rituals, cognitions, or a certain emotion (Bongers & Jansen, 2015; Davidson et al., 2005; Jansen, 1998; Vohs, Wang, Gino, & Norton, 2013; Wardle, 1990) – although some (more ‘natural’) food cues likely become associated with food intake more easily than others (Bouton, 2007, p. 66). This learning account of food cue reactivity has originally been proposed to explain binge eating: when a binge eater repeatedly consumes large amounts of palatable food in a specific context, this context may become a CS associated with a large US. As a result, the CS elicits a strong CR (e.g., a strong craving) and promotes a binge (Jansen, 1998; Wardle, 1990). However, this model can also explain more “normal” eating and dieting behaviour (Jansen, Havermans, & Nederkoorn, 2011). For example, consider a person who repeatedly eats crisps in the evening when watching a certain TV show. The context (watching a certain TV show in the evening) may become associated with eating crisps (US), subsequently eliciting desires for crisps and promoting intake.

Learning theory also predicts that conditioned food cue reactivity will diminish after repeated CS–noUS pairings (extinction) (Jansen et al., 2011). When a person has acquired a conditioned craving for crisps in the evening and stops eating crisps, he or she presumably practices extinction. Over time, the conditioned crisp cravings are expected to extinguish. A more successful/durable extinction is thought to promote dieting success, since it should become easier to refrain from

eating in the absence of strong food cue reactivity (Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010). This suggests that interventions aimed at extinguishing food cue reactivity can increase the effectiveness of dieting efforts and treatments that tackle eating psychopathology (such as binge eating). This is the aim of cue exposure therapy (the clinical equivalent of extinction), in which individuals with overweight and/or eating psychopathology are repeatedly exposed to food cues (e.g., the sight and smell of high-calorie foods, food-associated contexts). In line with a learning-based interpretation of food cue reactivity and overeating, the few studies that have been conducted on cue exposure therapy indeed suggest it effectively reduces cue-elicited cravings and eating binges (Boutelle et al., 2014; Jansen, Broekmate, & Heymans, 1992; Jansen, Van Den Hout, De Loof, Zandbergen, & Griez, 1989; Martinez-Mallén et al., 2007; Schyns, Roefs, Mulkens, & Jansen, 2016; Toro, Cervera, Feliu, Garriga, Jou, Martinez, & Toro, 2003) – although evidence for its long-term efficacy is mixed (Boutelle et al., 2014; Jansen et al., 1992). A deeper understanding of the role of learning in food cue reactivity can shed light on the etiology of food cravings and binge eating, and can ultimately help optimize treatments.

## **Appetitive conditioning involving food rewards**

### Acquisition

Appetitive conditioning has mainly been studied in rodents. For example, Weingarten (1983) conditioned rats to expect food when presented with a CS (a buzzer accompanied by a light) through repeated CS–US pairings. After acquisition, food was made continuously available for these rats so they would be satiated at test. Still, after presentation of the CS the rats initiated eating, ingesting on average 20% of their daily total energy intake. Thus, the conditioned cue was able to stimulate food intake even in the absence of a need for additional calories. Other studies have replicated the finding that a distinct cue or context (usually a visual or an auditory cue, or certain environment) that predicted food intake in the past (CS+) can stimulate food consumption, compared with for example 1) a stimulus that was never followed by food intake (CS–), 2) a group of rats that received a training in which presentations of the CSs and USs were unpaired, or 3) a group of rats that received a training in which presentations of the CSs followed (rather than preceded) the USs (Boggiano et al., 2009; Holland, Petrovich, & Gallagher, 2002; Petrovich, Holland, & Gallagher, 2005; Reppucci & Petrovich, 2012; Petrovich, Ross, Gallagher, & Holland, 2007; Petrovich, Ross, Holland, & Gallagher, 2007; Weingarten, 1984; Zamble, 1973). Thus, conditioned cues have reliably been

shown to be able to stimulate food intake in rodents and they support Pavlovian conditioning as mechanism underlying context and cue-elicited eating.

Studies on *human* classical conditioning using food rewards are scarcer. In two small early studies conducted in preschool children, two different cues/contextes were used as CS+ and CS-. After conditioning, the CS+ caused children to eat more and to initiate eating quicker, relative to the CS-. Additionally, evidence was reported that a greater food intake in the CS+ only occurred in children who reported awareness of the CS-US contingency (i.e., who could correctly identify which cues had or had not been followed by food) (Birch, McPhee, Sullivan, & Johnson, 1989). More recently, in a series of studies, Van Gucht and colleagues investigated appetitive conditioning to food rewards in adults. They repeatedly presented their participants with two trays, one functioning as CS+ and the other as CS-. A piece of chocolate functioned as the US. After only a few CS-US pairings, participants reported increased chocolate cravings and increased eating expectancies when presented with the CS+ vs. CS- (Van Gucht, Baeyens, Hermans, & Beckers, 2013; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008) – a finding that has also been reported by other researchers (Bongers & Jansen, 2015; Bongers, van den Akker, Havermans, & Jansen, 2015; Papachristou, Nederkoorn, Beunen, & Jansen, 2013; Zhang, Manson, Schiller, & Levy, 2014). Notably, a recent study even found increased craving to the CS+ vs. CS- after only one conditioning trial (Blechert, Testa, Georgii, Klimesch, & Wilhelm, 2016). In addition to increased US expectancies and eating desires, studies also reported evidence for a conditioned approach tendency towards the CS+, as well as a greater conditioned liking for the CS+ (Blechert et al., 2016; Papachristou et al., 2013; Van Gucht et al., 2010; Van Gucht, Vansteenwegen, Van den Bergh, et al., 2008). Differential neural responses to a food-paired CS+ vs. CS- have also been reported (Blechert et al., 2016; Burger & Stice, 2014; Franken, Huijding, Nijs, & van Strien, 2011). Thus, the relatively limited evidence available suggests that humans quickly develop conditioned appetitive responses through repeated pairings between an arbitrary stimulus and palatable food intake – in line with a Pavlovian learning account of food cue reactivity. The finding that appetitive responses are rapidly acquired makes sense from an evolutionary viewpoint: it minimizes the chance to miss an eating opportunity.

### Extinction

One notable finding of the conditioning studies conducted by Van Gucht and colleagues relates to the reported extinction patterns. During acquisition, participants were generally quick to learn about CS-US contingencies and started to desire

chocolate when presented with the CS+. However, when no more USs were provided during extinction, US expectancies diminished to some extent whereas eating desires did not appear to (Van Gucht, Vansteenwegen, Beckers, et al., 2008). The researchers noted that the apparent insensitivity of desires to extinction resembles the difficulty to extinguish acquired evaluations that is often reported in evaluative conditioning studies. Since evaluations might be based on mere activation of the US representation in memory (i.e., the CS makes one “think of” the US) (Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002; Baeyens, Eelen, Crombez, & Van den Bergh, 1992; Van Gucht, Vansteenwegen, Beckers, et al., 2008), Van Gucht and colleagues proposed that cravings may also be based on this activation of the US representation, and not on current US expectancies. In contrast to this possible hedonic/evaluative system, US expectancies have been proposed to reflect another response system related to preparatory reactions to food cues that is more sensitive to extinction (Van Gucht et al., 2008). If acquired eating desires are indeed relatively resistant to extinction, this has important implications: it suggests that procedures other than extinction / cue exposure therapy may be necessary to achieve a successful reduction in eating desires. However, drawing these conclusions may be premature. US expectancies only reduced *partly* during extinction, and it may be that these residual differential US expectancies were responsible for the heightened eating desires during extinction. Another possibility is that more extinction trials and/or multiple days of extinction are necessary to successfully extinguish eating desires – a notion that a two-session study seems to confirm (Van Gucht, Vansteenwegen, Beckers, et al., 2008).

Extinction does not reflect mere “unlearning” of the CS–US relationship. Rather, it reflects *new* learning: a second - contextually controlled – inhibitory association is created (CS–noUS) that competes with the original CS–US association (Bouton, 2002). Consistent with this account, a large amount of (animal) data show that after extinction procedures, seemingly extinguished responses can return under certain conditions – as demonstrated by phenomena such as rapid reacquisition, reinstatement, renewal, and spontaneous recovery (Bouton, 2011; Van Gucht et al., 2008). Extinction is dependent on the context for expression, and therefore, a change in context may promote a return of conditioned responses (Bouton, 2002, 2004). Various types of cues can provide contexts (Bouton, 1993). For example, one might learn that recent CS–US pairings are part of the acquisition “context”, and recent CS–alone presentations are part of the extinction “context”. When providing renewed CS–US pairings (as is the case during a reacquisition phase), this returns an individual to the acquisition context, resulting in a rapid return of responding (Bouton, 2004).

The finding that responses can re-emerge after extinction seems consistent with the very limited long-term successfulness of dieting attempts. Whereas dieters are often able to achieve substantial weight loss during a diet, only few are able to also successfully *maintain* their weight loss – most dieters relapse, re-gaining the lost weight (or even more) (e.g., Mann, Tomiyama, Westling, Lew, Samuels, & Chatman, 2007; Wing & Phelan, 2005). The following example illustrates how conditioning phenomena can explain relapse in dieters. A dieter who previously repeatedly consumed crisps in the evening may have successfully extinguished his or her evening-crisp-cravings by refraining from eating crisps for a while (CS-alone presentations, extinction). However, after months of strictly sticking to his or her diet, this person may have some friends over and consumes crisps again in her crisp-associated context (reinforcing the original CS-US association). Because this person may be returned to the original acquisition ‘context’, he or she starts to experience a renewed craving for crisps in the evenings over the next days or even weeks, and is at increased risk of relapse. Preventing or diminishing the strength of returns of appetitive responses can potentially help improve the long-term successfulness of dieting efforts and treatments. However, while learning theorists have proposed a number of techniques that may counteract returns of appetitive responses (Boutelle & Bouton, 2015; Mark E. Bouton, 2011; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Havermans & Jansen, 2003; Jansen, Schyns, Bongers, & van den Akker, 2016; Laborda, McConnell, & Miller, 2011), their effectiveness in humans remains largely untested.

Two promising techniques that could strengthen extinction learning and reduce the magnitude of returns of appetitive responses are 1) occasional reinforced extinction and 2) eating expectancy violation.

*Occasional reinforced extinction*: can the occasional intake of high-calorie food during a diet promote long-term dieting success? Although somewhat inconsistent, there is evidence to suggest that successful long-term dieting is associated with *flexible* (as opposed to rigid) control (e.g., Teixeira et al., 2010; Westenhoefer et al., 2013) – i.e., an ability to plan and self-regulate intake, including occasionally eating limited amounts of “fattening” foods. Relatedly, giving smokers the opportunity to smoke only occasionally can reduce smoking (Cinciripini et al., 1995). Findings of conditioning studies in rodents seem to confirm the notion that occasionally eating tasty foods during a diet may reduce risk of relapse (Bouton, Woods, & Pineño, 2004; Woods & Bouton, 2007). After an acquisition phase in which repeated pairings between a CS (a tone) and a US (food) took place, rats received one of two different extinction treatments (normal extinction, occasional reinforced extinction). In normal extinction, the CS was repeatedly presented without the US. In occasional reinforced extinction, some of the CS presentations were

followed by the US. In a subsequent *reacquisition* phase, the CS–US pairings were again fully reinforced (Bouton et al., 2004). It was found that although extinction was slowed, reacquisition was less rapid after occasional reinforced extinction. It may be that the occasionally reinforced trials become associated with extinction, and during reacquisition, this reduced the impact that renewed CS–US pairings have on responding (Bouton et al., 2004). Similarly, humans who occasionally allow themselves one CS–US pairing during their diet (e.g., occasionally eating crisps in the evening) may be at reduced risk of a full-blown relapse. Occasional reinforced extinction has not yet been empirically tested in humans.

A related procedure also involves occasionally consuming a US during extinction, but explicitly uncoupled from the CS+ (i.e., USs are provided in the inter-trial intervals). This procedure has also been shown to markedly reduce rapid reacquisition (Bouton et al., 2004). However, its clinical applications seem more limited than for occasional reinforced extinction – there are several food-associated CSs that are not easily uncoupled from their US (e.g., the taste/smell of food and its consumption).

*Eating expectancy violation*: Surprise, or violation of US expectancies, is thought to play a central role in (extinction) learning (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Rescorla & Wagner, 1972): extinction learning should be better when there is a greater discrepancy between the expected and actual (non-)occurrence of the US. In support, this approach seems effective for exposure therapy in anxiety disorders (Craske et al., 2014; Salkovskis, Hackmann, Wells, Gelder, & Clark, 2007). However, whether extinction learning of *appetitive responses* to food cues can be similarly strengthened by increasing (eating) expectancy violation during extinction is not clear. This would have direct implications for the manner in which cue exposure sessions are designed. For example, when instructing patients prior to a session that no eating will occur during the session, the non-occurrence of the US (eating) is rather unsurprising, and little inhibitory learning may occur. One may wish to avoid such cognitive interventions prior to an exposure session, and instead aim at increasing US expectancies and their violation. In support, in a recent study that we conducted on the effects of a cue exposure vs. control intervention in overweight individuals, it was found that participants receiving the cue exposure intervention consumed fewer calories of a food item exposed during therapy, and analyses showed that this effect was mediated by expectancy violation. (Schyns, van den Akker, Roefs, Houben, & Jansen, in prep).

## Individual differences

Not everybody reacts to food cues to the same extent, possibly rendering some individuals more prone to weight gain and less successful at weight loss. Individual differences in food cue reactivity might be partly explained by differences in the manner in which appetitive responses are learned and extinguished.

### Impulsivity

The personality trait impulsivity is a multi-faceted construct, and consists of at least two dimensions: reward sensitivity (a heightened sensitivity to rewarding stimuli in the environment) and rash impulsiveness (the inability to inhibit predominant approach responses) (Dawe, Gullo, & Loxton, 2004). Impulsivity has been related to increased food cue reactivity, less successful dieting, overeating, weight gain, and obesity (Guerrieri, Nederkoorn, & Jansen, 2008; Guerrieri, Nederkoorn, Schrooten, Martijn, & Jansen, 2009; Jansen, Nederkoorn, van Baak, Keirse, Guerrieri, & Havermans, 2009; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Nederkoorn, Jansen, Mulkens, & Jansen, 2007; Sullivan, Cloninger, Przybeck, & Klein, 2006; Tetley, Brunstrom, & Griffiths, 2010; van den Akker, Stewart, Antoniou, Palmberg, & Jansen, 2014; Van Koningsbruggen, Stroebe, & Aarts, 2013), and with a greater risk of relapse in addiction treatments (Doran, Spring, McChargue, Pergadia, & Richmond, 2004; Goudriaan, Oosterlaan, De Beurs, & Van Den Brink, 2008; Yoon et al., 2007). Several researchers have proposed roles for impulsivity in appetitive learning (e.g., Corr, Pickering, & Gray, 1995). For example, it has been proposed that impulsive individuals have a greater number (and/or strength) of appetitive associational resources, causing them to acquire appetitive associations quicker (Zinbarg & Reville, 1989). Another possibility is that (rash) impulsivity is related to a worse extinction due to a worse functioning orbitofrontal cortex, which is involved in learning when reward contingencies change (Dawe et al., 2004; McDannald, Jones, Takahashi, & Schoenbaum, 2014). To date, however, the role of impulsivity in appetitive conditioning remains unclear (see Papachristou et al., 2013).

### Learning history

It can be assumed that every individual has a distinct learning history with regards to their eating behaviour. For example, individuals likely show large differences in the extent to which they reinforce food cues: one individual may consistently reinforce similar food cues on a day-to-day basis, while another may show a more inconsistent eating pattern, reinforcing a different set of cues every day (Kirk & Hill, 1997). These variations in the consistency with which food cues are reinforced es-

entially reflect different *schedules of reinforcement*. It has long been known that schedules of reinforcement can differentially impact conditioned responses. For example, rats that experienced partial reinforcement of the CS–US contingency (e.g., when only 50% of the trials were reinforced) during acquisition have been found to perform worse during an extinction training, relative to rats that received continuous reinforcement (i.e., when the CS was always followed by the US) (e.g., Bouton, Woods, & Todd, 2014; Haselgrove, Aydin, & Pearce, 2004). The worse extinction of partially reinforced cues is known as the partial reinforcement extinction effect (PREE). In humans, the PREE could explain some individual differences in dieting success. An individual who has an inconsistent eating pattern (i.e., who reinforces a different set of cues every day) may practice partial reinforcement of food cues. Due to PREEs, this dieter may experience heightened appetitive responses even after having successfully abstained from reinforcing food cues for a while – lowering the chances of successful dieting and weight loss. However, if the dieter manages to successfully extinguish his persistent food cue reactivity and hence overcome the PREEs, he or she may be at *reduced* risk of relapse: since in partial (vs. continuous) reinforcement, a reinforced CS does not predict as strongly that the subsequent trial will be reinforced, reacquisition may be less rapid. Thus, conditioning history (more specifically, reinforcement schedules) may be causally related to unsuccessful dieting by interfering with the extinction and returns of appetitive responses. Despite the large amount of animal data on differential effects of reinforcement schedules on extinction, no efforts have been made to translate to and test these findings in humans.

## **Measuring differential responding in appetitive conditioning**

In human appetitive conditioning studies using food intake as US, conditioned responses that have been examined include psychological (US expectancies, craving/desire to eat, CS liking) (e.g., Papachristou et al., 2013), neural (e.g., Burger & Stice, 2014), and sometimes behavioural (approach tendencies, intake, choice) responses (Bongers & Jansen, 2015; Van Gucht et al., 2010; Van Gucht, Vansteenkeweg, Van den Bergh, et al., 2008). Including psychophysiological measures in appetitive paradigms can overcome limitations of some of these measures (e.g., sensitivity to experimental demand in case of self-report measures), and can help cover different indices of (appetitive) learning (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Delamater & Oakeshott, 2007).

Two psychophysiological responses that might be sensitive to detecting differences between a food CS+ and CS– are salivation and skin conductance. Salivation

is considered a cephalic phase response (Power & Schulkin, 2008), it is increased upon exposure to the sight and smell of palatable food (Nederkoorn, Smulders, & Jansen, 2000), and might be unaffected by current eating expectancies (Hardman, Scott, Field, & Jones, 2014). Skin conductance is thought to provide a nonspecific measure for arousal. It is heightened during food cue exposure (Nederkoorn et al., 2000) and to newly conditioned stimuli predictive for rewarding (e.g., drugs, sexual images), aversive (e.g., an electric shock), and relatively neutral outcomes (e.g., vibrotactile stimulation) (Hamm & Vaitl, 1996; Klucken et al., 2015; Purkis & Lipp, 2001; Winkler et al., 2011). In addition, skin conductance seems very sensitive to US expectancies in fear conditioning (e.g., Sevenster, Beckers, & Kindt, 2012). To our knowledge, skin conductance has not yet been studied as a measure of responding to newly conditioned food cues, but might provide an additional measure of learning – specifically, skin conductance may index cognitive contingency learning (Hamm & Weike, 2005; Soeter & Kindt, 2010).

## **This dissertation**

Taken together, the few human food conditioning studies that have been conducted suggest that after several pairings, stimuli can come to elicit a range of appetitive responses, including heightened food cravings / eating desires, approach tendencies, a quicker meal initiation, and a larger food intake. It also seems that these appetitive responses can be acquired very quickly (i.e., after a few CS–US pairings), while extinction of some responses (eating desires) might be more difficult to achieve. However, human appetitive conditioning to food rewards remains a profoundly understudied field, and many questions remain. For example, conditioning studies are typically conducted in a very tightly controlled environment (the laboratory). This situation likely differs from conditioning in real-life in many respects (e.g., types of cues, US size, inter-trial intervals, etc.), and it is not clear whether laboratory conditioning findings would generalize to more naturalistic situations. In addition, it is unclear if and why eating desires are so difficult to extinguish, and how (long-term) extinction of appetitive responses *can* be successfully achieved. Research on inter-individual differences in food conditioning is also still lacking, and in this area impulsivity and learning history seem especially promising factors. Finally, previous studies have mainly used self-report, behavioural, and neural measures in food conditioning. Identifying sensitive psychophysiological measures can help deepen our understanding of appetitive conditioning.

The overarching aim of this dissertation is to deepen our understanding of appetitive conditioning involving food rewards. The dissertation has four more specific aims:

1. Establish conditioning to food under more real-life circumstances (**Chapters 2 and 3**)
2. Investigate mechanisms of extinction and methods to optimize long-term extinction (**Chapters 4 and 5**)
3. Examine individual differences in conditioning, i.e., impulsivity and conditioning history (**Chapters 2, 5, and 6**)
4. Test whether salivation and skin conductance can function as psychophysiological measures of differential responding in appetitive conditioning using food rewards (**Chapter 2, 4, 5, and 7**)

In **Chapter 8**, the main results of the studies reported in this dissertation are summarized and discussed. Some important directions for future research are outlined and clinical implications are addressed. Further, findings of an additional recent study that my supervisors and I conducted are described and their implications are discussed.



# Chapter 2

## **Impulsivity makes more susceptible to overeating after contextual appetitive conditioning**

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## Abstract

Animals can learn that specific contexts are associated with important biological events such as food intake through classical conditioning. Very few studies suggest this is also possible in humans and contextual appetitive conditioning might even be a main determinant of habitual overeating in vulnerable humans. A Virtual Reality laboratory was used to test whether humans show conditioned responding (increased food desires and expectations, increased salivation and increased food intake) to a specific context after repeated pairings of this context with intake. It was also examined whether the personality trait impulsivity strengthens this contextual appetitive conditioning. Conditioned context-induced reactivity was indeed demonstrated and impulsivity predicted increased intake in only the intake-associated context. It is concluded that humans easily learn desires to eat in intake-related environments. The data also suggest that in particular more impulsive people are vulnerable for conditioned context-induced overeating. This relatively easy learning of associations between specific contexts and intake might stimulate habitual overeating and contribute to increased obesity prevalence.

**Keywords:** appetitive conditioning, impulsivity, cue reactivity, salivation, overeating

## Introduction

The prevalence of overweight and obesity has been rapidly increasing, adversely affecting quality of life and leading to increased health care costs (Flegal, Carroll, Ogden, & Curtin, 2010; Sturm, 2002). The obesogenic environment plays an important role in the current rise in obesity prevalence (Swinburn, Egger, & Raza, 1999), although it is not clear yet why some people are more vulnerable to overeat in a tempting environment than others. The abundant environment is characterized by many cues that signal high-calorie food availability (Burton, Smit, & Lightowler, 2007; Rodin & Slochower, 1976), and classical conditioning has been put forward as a mechanism that might explain why it is so difficult for some people to resist environmental temptations: in case of strong reinforcers, like tasty high-calorie foods, one easily learns to associate a predictor of intake with the actual eating. The learning of such an association facilitates cue-elicited eating: the cue prepares the person for intake, for instance by increasing salivation, elicits a desire to eat, and stimulates actual eating, frequently in the absence of physical hunger (Jansen, 1998; Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010; Wardle, 1990). Virtually any cue has the ability to become associated with food intake and to elicit preparatory responses of the body. These preparatory responses, also termed cephalic phase responses, are thought to be experienced as a desire to eat (Jansen, 1998; Nederkoorn, Smulders, & Jansen, 2000; Powley, 1977). Both the physiological preparatory responses and eating desires are labeled cue reactivity (Jansen, 1998; Jansen, et al., 2010). Classical conditioning studies with animals show that contexts might act as conditioned stimuli as well: sated rats showed an increased food intake in a cage previously associated with eating (Boggiano, Dorsey, Thomas, & Murdaugh, 2009; Petrovich, Ross, Gallagher, & Holland, 2007). The current obesogenic environment provides many opportunities to associate everyday contexts with food intake and therefore is able to elicit frequently recurring cue reactivity and overeating in conditioned contexts. Indeed, it has been found that among eating behaviour characteristics the strongest correlate of future weight gain was habitual overeating, or the susceptibility to overeat in response to everyday cues within the environment (Hays & Roberts, 2007).

Very few experimental studies have been conducted investigating classical conditioning as causal mechanism for context-induced cravings and overeating in humans. In these studies, an initially neutral contextual stimulus is repeatedly paired with food intake (the unconditioned stimulus, US) so this context becomes a predictor (conditioned stimulus, CS) for consumption. A study in preschool children found evidence of contextual conditioning of meal initiation (Birch, McPhee, Sullivan, & Johnson, 1989), and a conditioning procedure using chocolate shows

differential acquisition of craving and automatic approach tendencies towards a specific contextual cue (a tray) (Van Gucht, Baeyens, Hermans, & Beckers, 2013; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008a; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008b).

Appetitive conditioning studies usually do not take personality characteristics into account. It is known however that obesity, overeating and impulsivity frequently go together; several studies have found that trait impulsivity is positively associated with obesity (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006a; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006b; Rydén et al., 2003). Furthermore, impulsivity has been associated with increased food cue reactivity (Tetley, Brunstrom, & Griffiths, 2010), increased attention for food cues (Hou et al., 2011), binge eating (De Zwaan et al., 1994; Nasser, Gluck, & Geliebter, 2004) and increased food intake (Guerrieri, Nederkoorn, & Jansen, 2008; Nederkoorn, et al., 2006a). It has even been reported that obese children receiving cognitive behaviour therapy lost significantly less weight with increasing impulsivity (Nederkoorn, Jansen, Mulken, & Jansen, 2007). A possible role of impulsivity in conditioning has been proposed as well. Gray's BIS-BAS theory postulated that trait impulsivity should be related to activation of a system sensitive to appetitive conditions (i.e., the behavioural activation system or BAS) (Corr, Pickering, & Gray, 1995). It can be argued that impulsives' stronger output of the BAS is related to changes in arousal and emotional states which in turn can strengthen CS-US associations currently undergoing processing (Corr, 2001). Other authors have proposed impulsivity to be related to an increased strength (and/or number) of appetitive associational resources, thereby rendering them predisposed to forming appetitive associations (Zinbarg & Reville, 1989). However, evidence for the validity of these models is scarce (e.g., Corr, et al., 1995; Gupta & Shukla, 1989; Paisey & Mangan, 1988; Zinbarg & Mohlman, 1998). Knowing that impulsivity is positively associated with overeating and obesity, it is of interest to study whether impulsivity predicts a facilitated acquisition of conditioned responding to a CS that signals a food reward and in this way stimulates overeating in especially the high impulsive people.

In the present study, a Virtual Reality (VR) laboratory is used to create different contexts that are either associated with milkshake intake or not. In VR, participants are immersed in a programmed three-dimensional world, while perceiving this virtual world as 'real' (Hoffman, Richards, Coda, Richards, & Sharar, 2003). These complex environments likely have a stronger connection to real-life situations than the usual distinct stimuli (e.g., pictures or objects). It is expected that after conditioning, the intake-associated environment (CS+) will elicit a stronger desire for milkshake, an increased expectancy to receive milkshake, more salivation and

an increased intake during a bogus taste test, compared with a control environment (CS-). The CS+ is also expected to be liked more. Further, it is predicted that impulsivity facilitates conditioning.

## Methods and materials

### Participants

Seventy participants took part in the study. Female students were invited for participation if they were proficient in Dutch, aged between 18 and 25 years, had a normal BMI (19–25) and were in the 1<sup>st</sup> or 2<sup>nd</sup> year of their bachelor program. Furthermore, to be included in the study their score on the Restraint Scale had to be below 15, meaning that they are unrestrained eaters (Polivy, Herman, & Howard, 1988), and a requisite was that they liked at least one milkshake flavour (vanilla, chocolate, or strawberry). The questions were incorporated into a set of filler items. Participants were asked to have a small meal (e.g., a sandwich) two hours prior to the experiment, and to refrain from calorie intake thereafter. To reduce demand characteristics, participants were told that this study was about investigating ‘the influence of environmental stimulation on taste perception’. They received either €10 or were given course credits for participation. The study’s procedure was approved by the local ethical committee.

### Measures

Questionnaires were administered in Dutch.

*Desire and expectancy:* 100mm-Visual Analogue Scales (VAS) were used to assess subjective desire for milkshake and expectancy to receive milkshake (Huskisson, 1974; Van Gucht, et al., 2008b). The desire-VAS was accompanied by the question ‘How strong is your desire for milkshake at this moment?’, and the expectancy-VAS was accompanied by the question ‘How strong do you expect to be allowed to taste milkshake at this moment?’. Ratings ranged from 0 (*no desire for milkshake at all / certainly expect not to taste milkshake*) to 100 (*very strong desire for milkshake / certainly expect to taste milkshake*). The order of presentation of these two VASs was randomized.

*Salivation:* Salivation was measured using dental rolls (Hartmann, nr 2, 10×35 mm) which the participant was instructed to place and remove herself. Two dental rolls were placed between the cheek and lower gum on the left and right sides. A third, halved dental roll was placed under the tongue. They were removed after precisely 1 min. The dental rolls were kept in a sealed plastic bag and their weight

was registered before and after the saliva was collected, using a weighing scale accurate to 0.01 g (Mettler Toledo, PB3002).

*Intake during taste test:* Ad libitum milkshake intake was measured during a 5-minute bogus taste test, during which participants answered questions about supposed differences between three identical milkshakes. The flavour of these milkshakes was identical to the flavour during conditioning (vanilla, chocolate, or strawberry). Liking of the milkshake was measured during the taste test. The milkshakes were weighed before and after the taste test to assess total food intake. Each cup contained approximately 250g of milkshake, equivalent to 300 ml and 450 kcal.

*CS preference:* CS liking was measured using two different questionnaires. Before and after conditioning, participants rated their liking for the CS+ and CS- environments on a VAS accompanied by the question 'How much do you like this environment?', ranging from 0 (*not at all*) to 100 (*very much*). Additionally, after conditioning, participants were asked to give a ranking on how much they liked the four different virtual environments they had been exposed to, from most liked to least liked. This was done to assess the preferred CS (CS+ or CS-).

*Contingency awareness:* Participants completed a contingency awareness check to find out whether they were aware of the association between the CS+ and milkshake intake.

*Presence:* Feelings of presence in the virtual environments were measured using a questionnaire, adapted from another study (Hoffman, Hollander, Schroder, Rousseau, & Furness, 1998; experiment 2, items A, D, E G). An average score was calculated. This was assessed since low levels of presence can have a substantial impact on responding (Witmer & Singer, 1998).

*Nausea:* To check for nausea due to exposure to virtual environments, participants were asked to indicate whether they felt nauseated before and after AR exposure on a VAS ranging from 0 (*not at all nauseated*) to 100 (*extremely nauseated*).

*Hunger:* To control for hunger at the start of the experiment, participants filled in a VAS accompanied by the question 'How hungry are you at this moment?' ranging from 0 (*not hungry at all*) to 100 (*extremely hungry*).

*Milkshake liking:* To control for possible differences in liking of milkshake, participants filled in a VAS accompanied by the question 'How much did you like the milkshakes?' ranging from 0 (*not at all*) to 100 (*extremely*).

*Barrett Impulsivity Scale-11 (BIS-11; Patton, Stanford et al. 1995):* The BIS-11 was used to measure impulsivity. It is a self-report questionnaire and consists of 30 items. Each statement can be rated on a 4-point scale, ranging from *rarely/never* to *always/almost always*. Total scores were calculated, a higher score indi-

cating higher impulsiveness. The BIS-11 has good internal consistency and good construct validity (Patton, Stanford, & Barratt, 1995).

*Revised Restraint Scale (RS; Polivy, et al., 1988)*: The 10-item RS was used to assess dietary restraint, i.e. the intention to restrict food intake. Scores range from 0–35, a higher score indicates increased intentions to restrain intake.

## Stimuli

*US*: The intake of milkshake served as the US. During conditioning, small milkshake cups with lid and a translucent straw were used. Each cup was weighed before and after a conditioning trial. One cup contained approximately 10g (18 kcal) of freshly-prepared milkshake, of which on average 5.41g ( $\pm 1.22$ ) was ingested during a CS+ trial. The milkshakes were kept in a cooler that remained out of sight of the participants at all times. Milkshakes could not be smelled.

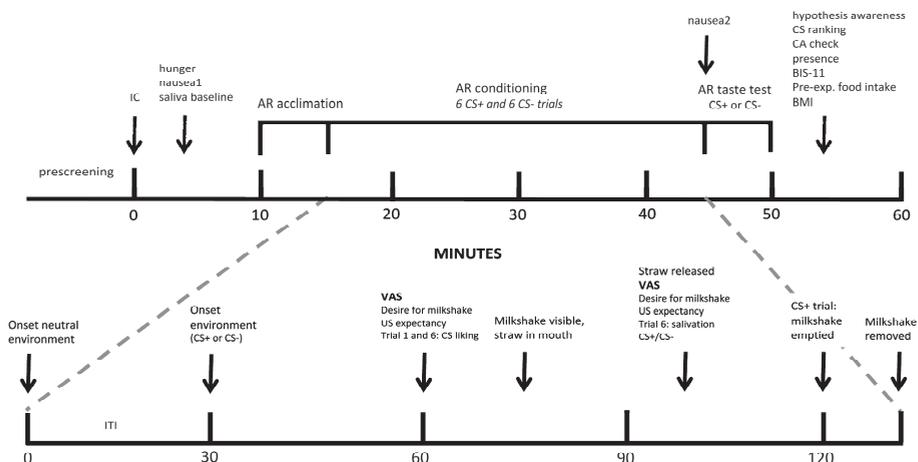
*CS*: Four different virtual environments were used. One environment served as practice and acclimation environment, which was a largely empty room. The other three environments were presented during conditioning: An Italian square served as the (neutral) environment that appeared during the inter-trial interval (ITI), and two rooms served as CS+ or CS–; one of these depicted (non-food related) paintings, a window and seats, another room depicted a dojo (Japanese room to practice martial arts). These environments were accompanied by two distinct musical pieces (Beethoven's Violin romance no. 2 F major and Mussorgsky's Pictures at an Exhibition), which have been found to be emotionally neutral (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007). Which room and musical piece combination (four combinations) served as CS+ or CS– was counterbalanced across participants.

*Augmented Reality (AR)*: In AR, virtual environments are visible, but objects that are close to the participant in the real world can still be perceived (Botella et al., 2005). In this experiment, AR was used so the participant could see her own hands and the milkshakes, and she was able to fill out VAS questionnaires. To display the virtual environments, a Head-Mounted Display (HMD) was used (NVIS nVisor ST50), which was placed on the head of the participant. An HMD enables the display of virtual environments on screens inside the HMD. A tracking system was used to precisely locate movements of participants' heads (PhaseSpace), and the images projected on the screens inside the HMD change according to the participants' movements. Thus, when a participant turns her head to the left, the virtual images change according to her head movement. The software used for programming is Vizard Virtual Reality Toolkit, WorldViz. A sound system was used to play pre-recorded instructions and musical pieces (Ambisonic Auralizer System, WorldViz).

## Design and procedure

See Figure 1 for an overview of the study's design. Participants were run individually between 11 AM and 6 PM. Upon arrival in the laboratory, the participant gave written consent. She was seated at a table during the whole experiment. The participant was instructed on how to fill in a VAS, and was then asked to rate her hunger and nausea. Also, a baseline measure of saliva production was conducted. When looking around in the virtual environment, she had to take care not to move her head too fast, which was done to minimize cybersickness. She was explicitly informed that one of the environments would be followed by being asked to drink something. After thirty participants had participated in the study, twelve still appeared unaware of an association between the rooms and being allowed to drink milkshake. Therefore, we changed the instructions regarding the CS-US contingency slightly by additionally showing participants coloured, printed pictures of the environments during this introduction session (no milkshake was given yet).

A participant first received an acclimation and practice session in AR, after which the conditioning procedure started (duration approximately 30 minutes, see Figure 1). She then performed a taste test in either the CS+ or CS- environment, depending on which condition she had been assigned to. Assignment to a condition was random and counterbalanced. All instructions given during conditioning and the taste test were pre-recorded and played through the sound system.



**Figure 1.** Overview of the study's design. The upper time line depicts the chronological order (from left to right) of the entire experimental procedure. The lower time line specifies a single conditioning trial. The onset of an environment automatically causes the offset of the previous environment.

### *Conditioning*

In total, 6 CS+ and 6 CS- trials were presented to each participant. The order of the presentation of these trials was random, but with the restriction of no more than two consecutive trials of the same trial type. Further, the first two and last two trials always consisted of one CS+ and one CS-, counterbalanced across participants.

A trial started when the CS+ or CS- environment became visible. The participant was told to look around slowly. After 30 seconds, she filled out the first desire and expectancy-VAS. Then, a milkshake cup was placed on the table in front of her, and she picked it up and placed the milkshake's straw into her mouth but was not allowed to drink. She still was exposed to the environment. After another 30 seconds, she placed the cup on the table and filled in the second desire and expectancy-VAS. In case of a CS- trial, the milkshake cup was now removed. In case of a CS+ trial, the participant picked up the milkshake cup again and emptied it. After this, the inter-trial interval (ITI) started, during which the neutral environment appeared for 30 seconds. During the 1<sup>st</sup> and 6<sup>th</sup> CS+ and CS- trials, CS liking was assessed. On both the 6<sup>th</sup> CS+ and the 6<sup>th</sup> CS- trial, salivation was measured. After all conditioning trials had been completed, the participant filled in a 2<sup>nd</sup> nausea VAS during the ITI, after which the taste test started.

### *Taste test*

Depending on the participant's assigned environment, the CS+ or CS- environment was presented during the taste test. Three large milkshake cups with lids were placed in front of the participant. The participant received questions about the taste of the milkshakes, and was told that if she would finish early she was invited to drink as much as she liked to. After the taste test the HMD was removed.

### *Questionnaires*

After the taste test, the participant filled out the following questionnaires: her ideas about the study's hypotheses, CS ranking, contingency awareness, presence, BIS-11, and time of pre-experimental food intake. Finally, the participant's weight and height were measured. She was thanked for participation and received her reward.

**Table 1.** Participant characteristics across conditions, with standard deviations in parentheses.

	<b>CS+ taste test</b>	<b>CS- taste test</b>	<b>F(1, 65)</b>	<b>p</b>
<i>n</i>	34	33		
<i>Contingency aware</i>	25	26		
<i>Age</i>	19.71 (1.53)	19.67 (1.83)	0.01	.92
<i>BMI</i>	22.06 (2.08)	21.49 (1.72)	1.51	.22
<i>Baseline hunger</i>	48.74 (21.33)	49.45 (24.10)	0.02	.90
<i>BIS-11</i>	60.59 (8.08)	58.18 (9.46)	1.26	.27
<i>Restraint Scale</i>	9.48 (2.98)	9.42 (3.26)	0.09	.77
<i>Presence*</i>	57.06 (12.78)	55.88 (16.83)	0.10	.75
<i>Baseline milkshake liking</i>	65.88 (24.55)	73.85 (14.80)	2.57	.11
<i>Nausea</i>	26.35 (27.78)	13.67 (17.60)	4.95	.03

\* Due to missing data, the degrees of freedom for this analysis were 1, 64.

## Results

### Exclusion of participants and statistical analyses

Three participants were excluded from analysis: one participant because she felt too nauseated to perform the taste test, another because she did not understand the instructions and a third was excluded because she scored > 3 SDs above the mean on the BIS-11.

Despite the explicit instructions regarding the US-environment association, a substantial part of the sample (23.9%; see Table 1) could not retrospectively indicate which room had been followed by being allowed to drink milkshake and/or did not develop a differential expectancy. These participants were classified as not being aware of the contingency between an environment and the opportunity to drink (non-CA). Previous studies have shown that contingency awareness is likely necessary for the formation of associations (Hogarth, Dickinson, Hutton, Bamborough, & Duka, 2006; Lovibond & Shanks, 2002). Therefore, contingency awareness was included as a between-subjects variable in the ANOVAs.

Differential acquisition of expectancy and desire for milkshake were analyzed using 2 x 6 (CS-type x Trial) repeated-measures ANOVAs. Analyses were conducted on the 2<sup>nd</sup> expectancy and desire-VAS scores of each trial<sup>1</sup>. Saliva production was also analyzed using repeated-measures ANOVA, with measurement (baseline, CS+, CS-) as within-subjects variable, as was CS liking, with CS-type (CS+, CS-) and Trial (1<sup>st</sup>, 6<sup>th</sup>) as within-subjects variables. Preference for the CS+

1 Each trial included two VAS measurements for each CS-type. Analyses including the first VAS scores of each trial revealed similar patterns.

over the CS- was tested using a binomial test. The total score of the BIS-11 was included as covariate in the ANOVAs to study effects of impulsivity on US-expectancy, desire for milkshake, salivation and CS liking. A student's t-test was used to test for differences in milkshake consumption across conditions (taste test environment: CS+ or CS-). A hierarchical linear regression model was used to analyze the effects of impulsivity and condition on milkshake consumption. Greenhouse-Geisser epsilon corrections are reported for repeated-measures analyses whenever sphericity was violated.

### Participant characteristics

No significant differences across conditions emerged for age, BMI, hunger, BIS-11 total, RS, presence and milkshake liking, however nausea differed significantly between conditions (see Table 1).

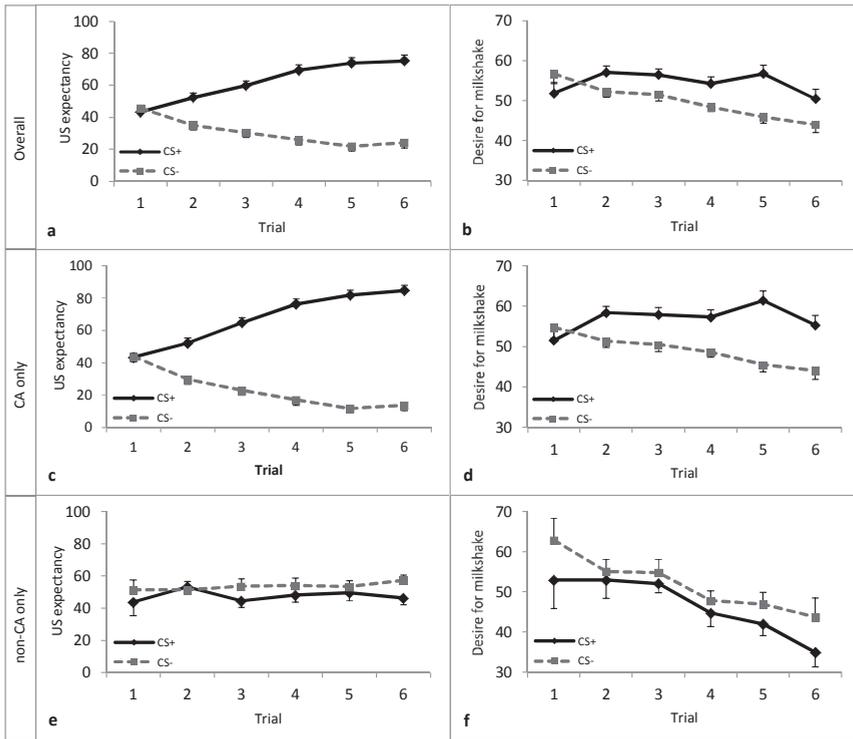
### US expectancy and desire for milkshake

Overall, differential acquisition of expectancy was present, as indicated by a significant CS-type x Trial interaction,  $F(3.12, 202.50) = 33.84, p < .001$  (see Figure 2a). Including contingency awareness (CA) as between-subjects variable yielded a significant CS-type x Trial x CA interaction,  $F(3.62, 231.62) = 14.93, p < .001$ . Contingency non-aware participants failed to develop differential expectancy,  $F(5, 75) = 0.46, p = .81$  (see Figures 2c and 2e). Impulsivity had no significant effect on the differentiation,  $F(3.18, 203.34) = 1.68, p = .17$ .

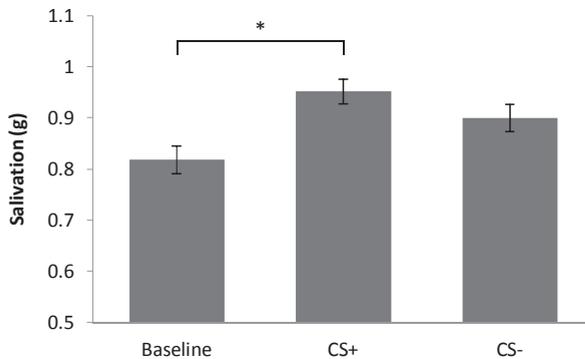
Participants also developed a differential acquisition of the desire for milkshake, as shown by a significant CS-type x Trial interaction,  $F(3.03, 200.51) = 5.81, p = .001$  (see Figure 2b). This differentiation was characterized by a decrease in desire for milkshake in response to the CS-,  $F(2.98, 196.43) = 7.38, p < .001$ , while no change in desire for milkshake was found for the CS+,  $F(3.10, 204.50) = 1.90, p = .13$ .

No significant interaction between acquisition of differential desire for milkshake and CA was found,  $F(3.04, 197.27) = 1.39, p = .25$ . However, the CA x trial interaction was significant,  $F(3.04, 197.27) = 2.67, p < .05$ , indicating an overall decrease in desire for milkshake in the non-CA group,  $F(2.69, 39.35) = 4.65, p = .001$  but no overall change in the CA group,  $F(3.00, 150.20) = 1.09, p = .36$  (see Figures 2d and 2f). Impulsivity did not influence differential desire over time,  $F(3.03, 197.07) = 0.68, p = .57$ .<sup>2</sup>

<sup>2</sup> The differential acquisition of US expectancy and desire for milkshake did not differ between the conditions, as the CS-type x Trial x Condition interactions were not significant,  $F(3.10, 198.56) = 0.85, p = .47$ ;  $F(3.03, 196.77) = 1.13, p = .34$ . Thus, as expected, the conditions did not differ in acquisition of differential US expectancy and desire for milkshake.



**Figure 2.** Mean US expectancy and desire for milkshake (+SEM) by CS-type and trial. The figures present overall responses of the entire sample (2a and 2b), for contingency-aware participants only (2c and 2d), and for non-contingency-aware participants only (2e and 2f).



**Figure 3.** Mean salivation (+SEM) at baseline, CS+ and CS-.

## Salivation

Salivation differed significantly between the three measurements,  $F(2, 128) = 4.97$ ,  $p = .01$ , with Bonferroni-corrected pairwise comparisons indicating that salivation in the CS+ was significantly higher than baseline ( $p = .01$ ) but not compared with salivation in the CS- ( $p = .49$ ). Salivation in the CS- did not significantly differ from baseline ( $p = .32$ ) (see Figure 3). No interaction with CA was found,  $F(2, 126) = 0.06$ ,  $p = .94$ , nor with impulsivity,  $F(2, 126) = 0.42$ ,  $p = .66$ . As expected, the conditions did not differ in salivation pattern,  $F(2, 126) = 1.71$ ,  $p = .19$ .

## Milkshake consumption

*Overall.* Taste test environment did not influence total milkshake consumption,  $t(65) = 0.28$ ,  $p = .78$  [mean consumed milkshake in the CS+: 137.23g ( $\pm 97.39$ ); CS-: 130.73 ( $\pm 89.00$ )].

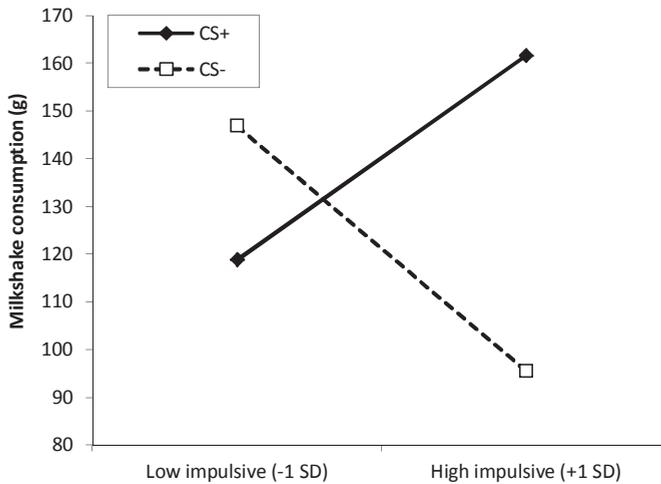
*Impulsivity.* To examine influences of impulsivity on milkshake consumption, a hierarchical regression analysis was conducted (see Table 2 and Figure 4). Both nausea and milkshake liking correlated significantly with total milkshake consumption,  $r(65) = -0.25$ ,  $p = .04$ ,  $r(65) = 0.25$ ,  $p < .05$  and with each other,  $r(65) = 0.42$ ,  $p < .001$ . Since the conditions significantly differed in nausea but not in liking (see Table 1: nausea in the CS+ condition was higher), nausea was included in the

**Table 2.** Summary of the hierarchical regression analysis.

Variable	B	B (s.e.)	$\beta$
<i>Step 1</i>			
<i>Nausea</i>	-0.98	0.47	-0.25*
<i>Step 2</i>			
<i>Nausea</i>	-1.11	0.49	-0.29*
<i>Condition</i>	-22.09	23.47	-0.12
<i>Impulsivity</i>	-0.65	1.30	-0.06
<i>Step 3</i>			
<i>Nausea</i>	-0.93	0.48	-0.24#
<i>Condition</i>	-18.97	22.92	-0.10
<i>Impulsivity</i>	2.43	1.95	0.23
<i>Condition x Impulsivity</i>	-5.35	2.59	-0.38*

$R^2 = 0.06$  for Step 1 ( $p = .04$ ),  $\Delta R^2 = 0.02$  for Step 2 (ns),  $\Delta R^2 = 0.06$  for Step 3 ( $p = .05$ )

\* $p < .05$ ; # $p < .06$



**Figure 4.** Milkshake consumption in low and high impulsive participants, for the CS+ or CS- taste test.

regression model<sup>3</sup>. All variables were centered before entering in the regression model. The analysis showed that condition and impulsivity interacted ( $\Delta R^2 = 0.06$ ,  $p = .04$ ). Follow-up analyses revealed that participants who were highly impulsive (1 SD above the mean of the BIS-11) consumed significantly more milkshake in the CS+ than in the CS- ( $p = .04$ ). In contrast, within low-impulsive participants (1 SD below the mean of the BIS-11) no difference in milkshake consumption between the conditions was found ( $p = .44$ ). Analyzing the slope of the CS- regression line revealed a trend ( $p = .08$ ), suggesting a decreased food intake in the CS- in more impulsive relative to less impulsive participants. The slope of the CS+ regression line was not significant ( $p = .24$ ).

CA. CA was added to the model (not shown in the model) and was not found to predict milkshake consumption overall,  $b = -.09$ ,  $t(62) = -0.72$ ,  $p = .47$ . Furthermore, no significant Condition x Impulsivity x CA interaction was found,  $b = -.002$ ,  $t(60) = -0.02$ ,  $p = .99$ , suggesting no differences in milkshake consumption patterns between CA and non-CA participants.

<sup>3</sup> When excluding participants who scored highest on nausea (scoring  $\geq 50$  on the 2nd nausea-VAS,  $n = 10$ ) instead of entering nausea as covariate in regression analysis, the condition\*impulsivity interaction remained significant ( $\Delta R^2 = 0.09$ ,  $p = .03$ ). Thus, both methods to control for nausea resulted in similar effects.

## CS liking

Conditioned CS liking was evident with repeated-measures analyses when including CA in the CS-Type\**Trial* interaction,  $F(1, 63) = 5.92, p = .02$ ; CA participants developed a significant differentiation in CS liking,  $F(1, 49) = 6.67, p = .01$  [mean change in CS+ liking:  $0.80 (\pm 14.84)$ ; CS-:  $-8.10 (\pm 18.48)$ ], whereas non-CA participants did not,  $F(1, 14) = 1.79, p = .20$  [mean change in CS+ liking:  $-8.43 (\pm 18.79)$ ; CS-:  $0.13 (\pm 13.37)$ ]. Impulsivity did not have an effect on this interaction,  $F(1, 61) = 2.21, p = .14$ . In the ranking, the CS+ was not more preferred than the CS-; the CS+ was preferred by 56% of the participants,  $p = .46$ .

## Discussion

This study provides evidence of contextual appetitive conditioning in females. After six conditioning trials, conditioned cue reactivity in response to the contextual CS+ was found: participants salivated significantly more in response to this context compared to baseline and this increase was non-significant for the CS-. Likewise, the contextual CS+ elicited a greater desire for milkshake and higher US expectations than the CS- after conditioning. Differential CS+ liking increased on the within-subjects assessment in contingency-aware participants, also indicating conditioned responding. In line with previous research, this conditioning appeared to depend largely on awareness of the contingency between the CSs and the US. Impulsivity did not moderate the acquired context cue reactivity (salivation and subjective responses). However, increased consumption after appetitive conditioning was found in impulsive participants: high impulsive participants consumed more milkshake when being present in the CS+ compared with the CS-, while low impulsive participants consumed similar amounts in the CS+ and CS-.

This study contributes to the existing literature by showing that not only isolated proximal food cues but also complex non-food related environmental stimuli are able to become triggers of conditioned appetitive responding in humans. Another new finding was that preparatory responses of the body (salivation) may be involved in human contextual appetitive conditioning: we found some evidence that initially neutral contexts are able to elicit an adaptive physiological change that is similar to physiological reactions to the sight or smell of food. The current obesogenic environment (context) offers many potential opportunities to associate different contexts (e.g., home, office, friends) with calorie intake, and in this way stimulates contextual appetitive conditioning. Contextual eating might be considered a form of habitual eating that occurs relatively automatic without people being aware of these conditioning processes and context-induced cue

reactivity. Intriguingly, those participants in our sample who were unaware of the CS-US contingency also showed some evidence of conditioned responding on the behavioral measures, suggesting that they, too, prepared for food intake. Not intervening on these conditioning processes might make it more difficult to change overeating patterns. It was for instance found that conditioned food cue reactivity was absent in successful post-obese dieters - presumably extinguished - whereas it was present in unsuccessful obese dieters (Jansen, Havermans, & Nederkoorn, 2011; Jansen, et al., 2010).

Another new and intriguing finding is that impulsivity was a significant predictor of milkshake consumption in the CS+. Although the milkshake US was available in both the CS+ and CS- during the taste test (in large amounts), only the more impulsive participants ingested significantly more milkshake in the food-associated environment (and not in the CS-). Since impulsivity did not appear to moderate the acquisition of other conditioned responses over trials, these data seem to suggest that impulsivity as measured by the BIS-11 is not related to a facilitated acquisition whereas it is to the behavioural expression of the (conditioned) motivational state (i.e., increased intake) (Corr, 2001). This is consistent with previous research reporting that increased food intake in impulsive participants only occurs when participants are hungry (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009). Our findings are also in line with the idea that 'rash impulsiveness' is related to an inability to inhibit predominant approach responses, since our present measure of impulsivity (the BIS-11) is supposed to provide a measure of this form of impulsiveness (Dawe, Gullo, & Loxton, 2004). Thus, once an approach response was activated by the CS+, the high impulsives in our study might have been unable to inhibit approach behaviour and subsequently increased their food intake. On the other hand, the present findings also suggest a trend towards higher impulsivity being related to a suppression of intake in the CS-, possibly pointing towards *more* effective response inhibition in a non-food associated context (see also Jansen, Klaver, Merckelbach, & van den Hout, 1989). In the CS-, participants were exposed to milkshake cups but were not allowed to consume the milkshake. It is possible that the more impulsive participants had to put greater effort into inhibiting their approach response in the CS-, which could have led to effective inhibitory learning in impulsives in specifically this context. This suggests that high impulsives (e.g., binge eaters and people with obesity) could benefit from food cue exposure therapy, in which a food cue is repeatedly presented while the actual eating is prevented (i.e., inhibited) in order to decrease cue reactivity. However, the present experiment was not designed to test these ideas, and future studies should include truly neutral stimuli to see whether the increased intake in the CS+

compared with the CS– in higher impulsives is due to facilitatory or inhibitory mechanisms, or a combination of both.

It is possible that impulsivity is related to an increased speed of acquisition of conditioned responding to food cues under certain conditions. For instance, previous findings have suggested that both the size and type of the US may be important for an increased acquisition speed in impulsives: extraverts vs. introverts have been found to show stronger appetitive conditioning of electrodermal responses when stronger, but not when weaker, sexual stimuli were involved (Paisey & Mangan, 1988), and a positive relation between reward responsiveness and speed of acquisition of US expectancies has been reported when a monetary reward was involved but not when an ego-related reward was involved (Zinbarg & Mohlman, 1998). In contrast, in our study, participants received a food reward during conditioning which was relatively weak (i.e., a very small amount of milkshake). Additionally, the same reward may be perceived differently by different participants; for instance, impulsive individuals could have been disappointed by the small US in the present study (Corr, 2001). Moreover, different measures or forms of impulsivity might also be differentially related to appetitive conditioning (Corr, 2001; Papachristou, Nederkoorn, Beunen, & Jansen, 2013).

Cue and context-elicited cravings are well-known in addiction research (Drummond, 2001). Cue exposure therapy has been used in the treatment of both addiction and eating disorders. A major problem with cue exposure treatment is renewal, in which a supposedly extinguished response re-emerges after treatment when a patient returns to the acquisition environment (Bouton, 2002; Havermans & Jansen, 2003). This is thought to occur because of differences between the contexts in which the behaviour was learned, extinguished and tested, and stresses the need for exposures in the context that is associated with intake or use (Bouton, 2002; Havermans & Jansen, 2003; Jansen, 1998; Thewissen, Van Den Hout, Havermans, & Jansen, 2005). VR and AR could therefore become useful tools for improving cue exposure therapy: it is possible to create contexts very similar to those in which one usually overeats or uses a drug. Researchers conducting experiments and/or therapies involving food in AR or VR should however be aware of the possibility of inducing additional nausea in participants by the incorporation of sensory exposure to foods ('cybersickness'). Nausea might in particular affect appetitive responding.

In sum, the present study adds to the existing literature that contextual appetitive conditioning induces conditioned responding (i.e., an increased desire for food and an increased liking of the CS) in healthy women, and it provides some evidence for the involvement of preparatory responses of the body (i.e., a conditioned salivary response). This study also uniquely associates impulsivity

with increased food consumption in specifically a conditioned food-associated context. Future research should elucidate the complex role of impulsivity in the acquisition and expression of appetitive conditioning and ask the question why impulsivity is related to increased vulnerability to conditioned context-induced overeating. Also, research is needed on the implications for cue/context exposure therapy, and how AR and VR can be used to develop optimal exposure therapy for appetitive disorders and substance use disorders.

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# Chapter 3

## **Appetitive conditioning to specific times of day**

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## Abstract

Human laboratory studies have consistently shown that eating desires are easily learned through classical conditioning: after a few pairings of an initially neutral stimulus (e.g., a box) with the intake of palatable food (e.g., chocolate), the stimulus elicits increased eating expectancies and desires (acquisition). After repeated non-reinforced presentations of the chocolate-associated stimulus, eating expectancies and desires decrease again (extinction). It is commonly assumed that eating desires in daily life are acquired and extinguished in a similar manner, but to date, this has not been empirically tested. In the present study, a differential conditioning paradigm was implemented in daily life over a period of seventeen days, including an acquisition and subsequent extinction phase. A specific time of day was paired with eating chocolate during acquisition. Ecological momentary assessment was used to measure conditioned eating expectancies and desires. It was found that eating expectancies increased over the course of acquisition whereas eating desires did not. However, exploratory analyses suggested a successful acquisition of differential eating desires in a subsample. We cautiously conclude that while eating desires are not learned in real-life as easily as in the laboratory, the study provides preliminary evidence that eating desires can be conditioned to ecologically valid cues and under real-life circumstances.

**Keywords:** classical conditioning, appetitive conditioning, eating desires, ecological momentary assessment

## Introduction

Overweight and obesity prevalence have increased dramatically over the past decades (Ogden, Carroll, Kit, & Flegal, 2014). Experts agree that the ‘obesogenic’ environment plays an important role in this: it is characterized by an abundance of stimuli that signal the availability of palatable high-calorie foods. Exposure to these food cues results in psychological and physiological changes that promote overeating (Jansen, 1998), even in the absence of a physiological need for additional energy (e.g., Rozin, Dow, Moscovitch, & Rajaram, 1998). One important psychological component of this reactivity to food cues is a heightened craving or desire to eat. As cue-elicited food cravings primarily concern an intense desire for high-calorie foods and can occur even when sated, eating desires contribute to excessive weight gain (Ferriday & Brunstrom, 2011; Havermans, 2013; Jansen, Havermans, & Nederkoorn, 2011). This highlights the importance for investigating the etiology of eating desires.

Cue-elicited eating desires likely have a learned component. In theory, food cues have once become associated with intake through repeated pairings of a stimulus (conditioned stimulus or CS) with eating (unconditioned stimulus or US) (Jansen, 1998). Upon exposure, conditioned food cues elicit conditioned appetitive responses (CRs) including a heightened desire to eat. Any cue may come to function as CS, including the sight or smell of food, a certain emotion (Bongers & Jansen, 2015), or a specific situation or context (van den Akker, Jansen, Frentz, & Havermans, 2013). For example, when a person repeatedly consumes chocolate (US) in the evening, “evening time” may become a predictor (CS) for intake, subsequently eliciting an increased desire to eat (CR). Similarly, when a CS is no longer followed by the US, conditioned eating desires are expected to extinguish, and (over)eating should become less likely (Jansen, Havermans, & Nederkoorn, 2011). Findings of conditioning studies are in line with this learning-based interpretation of cued eating desires (e.g., Bongers, van den Akker, Havermans, & Jansen, 2015; van den Akker, Havermans, Bouton, & Jansen, 2014; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008; Birch, McPhee, Sullivan, & Johnson, 1989). These studies also suggest that eating desires are readily acquired. After only a few pairings of a stimulus (e.g., a box, vase, or tray) with the intake of food (the US; e.g., chocolate), this stimulus (CS+) heightens eating desires relative to a stimulus not paired with food (CS–), at least when participants are aware of the CS–US association (i.e., when they report heightened expectancies to receive the US when presented with the CS+) (van den Akker et al., 2013; Hogarth & Duka, 2005). During extinction, in which the CSs are repeatedly presented but no USs are provided, US expectancies and desires both diminish - although it seems that

a complete extinction of eating desires is difficult to achieve (van den Akker, van den Broek, Havermans, & Jansen, 2016; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008).

Laboratory conditioning studies are very useful to investigate the basic learning processes underlying appetitive responses to food cues. Their ultimate aim, however, is to model real-life situations. Based on the finding that arbitrary stimuli (e.g., boxes) can quickly come to function as CSs that promote eating desires, one would expect similar effects in case of more “natural” stimuli in daily life (e.g., specific times of day) that have been paired with palatable food intake. However, laboratory findings do not necessarily translate to real-life circumstances, as conditioning studies differ from everyday life in many potentially important respects. For instance, in contrast to the complex real-life world, laboratory studies are usually relatively simple and highly controlled: the participants’ attention is directed to the CSs in an environment that contains very few distractors. Laboratory studies also typically use very brief intervals between subsequent CS presentations (i.e., several seconds or minutes), unusually small US sizes (e.g., one small bite of chocolate), and relatively novel cues that have received little prior exposure (e.g., a novel box). All of these factors are known to potentially affect the acquisition and extinction of conditioned responses and might decrease the ecological validity of the paradigm.

Despite these potentially important manners in which laboratory studies differ from more natural situations, to our knowledge, no published studies have investigated appetitive conditioning in daily lives and using ecologically valid cues. Therefore, the aim of the present study was to test whether acquisition and extinction of conditioned appetitive responses can be established under real-life circumstances. Over a period of seventeen days (five acquisition and twelve extinction days), a within-subject conditioning paradigm was implemented, using two specific times of day as CS+ and CS-. A smartphone application was used for ecological momentary assessment of US expectancies and eating desires at these time points. It was expected that differential US expectancies and eating desires would increase during an acquisition phase, and decrease again during a subsequent extinction phase.

## **Methods and Materials**

### **Participants**

27 participants completed the study. Before conducting the study, a sample size calculation on the post-acquisition differentiation in desires to eat between a

CS+ and a CS- of a previous study (van den Akker et al., 2015). This calculation indicated that using an alpha of .05 and to achieve a power of .80, N = 19 participants would be needed. Before participation, a screening questionnaire was filled in. Participants were eligible to participate in the study if they were female undergraduate students, aged between 17 – 25, owned a well-functioning Android smartphone, were not currently dieting, had no allergies/intolerances for, and indicated to like, chocolate and caramel. As a cover story, participants were told the study would be about “cacao and cognitive performance”. Participants received course credit or a monetary voucher worth € 50,- for participation. The study was approved by the local ethical committee.

### Measurements

*US expectancy and desire to eat:* 100mm-Visual Analogue Scales (VAS) were used to assess the expectancy to be allowed to consume the US (“*How strong do you expect to be allowed to eat Chokito’s, at this moment?*”) and the desire to eat the US (“*Pay attention to the current time of day. How strong is your desire for Chokito’s, at this moment?*”), ranging from 0 (*certainly do not expect it / no desire at all*) to 100 (*certainly expect it / very strong desire*).

*US liking:* 100mm-VAS was used to assess liking of the taste of the US (“*How much did you like the Chokito’s?*”) as well as its size (“*What did you think about the size of the Chokito’s?*”), ranging from 0 (*not at all / far too little*) to 100 (*very much / far too big*).

*Compliance:* a semi-structured interview was conducted to assess the participant’s compliance in following the instructions. Participants were asked whether they had eaten the USs whenever asked to, and whether they had always carried at least one US during each time of day. Participants were also required to return any USs that they had not consumed. These were counted and then returned to the participant.

### Stimuli

*US:* Two handmade Belgian chocolates with a caramel filling (Rousseau chocolade; approximately 30 grams / 120 kcal) were used as US. To highlight their novelty to participants, they were introduced as “Chokito’s” (this name was made-up by the researchers). Each pair of chocolates was wrapped in a non-transparent bag.

*CS:* Two specific times of day were used as conditioned stimuli. Prior to attending the first session, participants were asked to identify two specific times of day between 10:30 and 18:00 during which they were usually not eating or otherwise busy, and which were at least 2.5 hours apart. Whether a participant’s

earlier or later time point served as CS+ (chocolate-associated) or CS- (control) was counterbalanced across participants.

#### Smartphone app and trial sequence

On all participants' mobile phones the application movisensXS, Version 0.4 2469 (movisens GmbH, Karlsruhe, Germany) was installed. This application was personalized for each participant, triggering an auditory alarm (lasting up to 5 minutes) on the two times of day selected by the participant. When the alarm was answered, a trial started.

#### Design and procedure

Participants were individually seen on two sessions. The conditioning procedure took place in between these sessions. The personalized app was programmed prior to session 1.

#### *Session 1*

On the first session, the participant gave written consent, after which she was provided with detailed oral and written instructions she was required to adhere to during the study period. On the two selected times of day, she had to make sure the sound on her phone was turned on, and she needed to have sufficient time to complete the questionnaires and to precisely follow all instructions given in the application. The participant was also required not to be eating anything or being otherwise occupied during the two times of day. Besides this, she was instructed to follow her usual eating pattern. She also had to have access to at least one Chokito package during each time of day (she thus had to carry two packages in case one had to be consumed at the earlier time of day). This was done to ensure that at least one US would be present during *both* the CS+ and CS- times of day to prevent eating desires to be increased during the CS+ times simply because chocolate is available. Apart from this, the participant was not allowed to handle or open any of the packages. In addition, she received a plastic container to avoid damaging the chocolates when carrying them. While it was stressed that it was very important for the participant to precisely follow the instructions, she was also encouraged to indicate in the application whenever she had not been able to adhere to all instructions. To further increase compliance, the participant was informed she would receive a call from the experimenter whenever she failed to answer an alarm. Next, the personalized program was installed on the participant's phone, and she was shown an example trial sequence on a tablet computer. After this, she was explicitly instructed she would be repeatedly asked to consume one package of chocolates on one specific time of day, while she would never be asked

to consume the chocolates on the other time of day. This instruction was modeled after laboratory conditioning studies and given to facilitate conditioning (e.g., van den Akker et al., 2015). Next, the participant was given twenty packages of the US (in order for participants not to be able to estimate the number of chocolates they would be asked to consume). It was stressed she had to return any remaining chocolates on the next session. Finally, she was asked not to discuss the study with anyone.

### *Conditioning procedure*

All participants completed a similar seventeen-day conditioning paradigm. Auditory alarms (prompts) were triggered twice each day (i.e., on one CS+ and one CS- time of day). The first five days of testing functioned as acquisition phase. Five CS+ and five CS- trials were presented during this phase (for trial sequence see below), the CS+ trials being followed by consumption of one US. The subsequent twelve days functioned as extinction phase during which participants received twelve CS+ and twelve CS- extinction trials (no US consumption took place).

*Trial sequence:* A trial started when an auditory alarm was answered, and proceeded as follows. First, the participant filled in the current time of day. This was done to direct the participant's attention towards the CS (i.e., the specific time of the day). Next, the participant rated her US expectancy. A bogus VAS regarding the participant's level of concentration was then completed. After this, she rated her desire for the US, followed by another bogus VAS (level of fatigue). Only in case of a CS+ acquisition trial, the participant was now asked to open and consume one package of Chokito's. Next, two more bogus VASs (level of concentration and fatigue) were presented. This was followed by a bogus arithmetic puzzle that the participant had to finish as quickly as possible, allegedly to measure her cognitive performance. Next, the participant entered the time at which she had last eaten, was given the opportunity to write down any non-adherence to the instructions, and was asked not to eat anything within the next 30 minutes.

### *Session 2*

The second session took place right after the last extinction day. The participant completed the hypothesis awareness check and the US liking VAS. Next, the compliance interview was administered, after which the RS was filled in and the participant's length and weight were measured. The number of packages of chocolates returned by the participant was counted. The participant was thanked for participation, received her compensation, and was asked not to discuss the study with anyone.

### Statistical analysis

To test whether differential US expectancies and eating desires were acquired and extinguished, 2 (CS-type: CS+ vs. CS-)  $\times$  2 (Day: acq1 vs. acq5 / ext1 vs. ext12) repeated-measures ANOVAs were conducted, using CS-type and Day as within-subject factors. In addition, paired samples t-tests were conducted at baseline (acq1), on the last day of acquisition, at the start (ext1), and at the end of extinction (ext12).

Excluding participants who did not show clear evidence for awareness of the CS-US relationship ( $n = 2$ ) did not change the results of the primary analyses. Therefore, in the reported analyses, all participants were included.

## Results

### Participant characteristics, missing data, and compliance

Participants had a healthy mean BMI ( $M = 22.7$ ;  $SD = 4.22$ ) and indicated a strong liking for the US ( $M = 82.8$ ;  $SD = 10.53$ ). Their mean age was 20.0 ( $SD = 1.37$ ), and their mean score on the Restraint Scale was 10.9 ( $SD = 3.78$ ). On average, participants received 4.6 CS-US pairings ( $SD = 0.63$ ). Some data were missing due to participants missing some of the prompts and due to technical issues. In total, data were available for 813 trials (88.6% of all trials; CS+: 413 trials; CS-: 400 trials).

All participants indicated having consumed the US when prompted to. Nine participants failed to return all leftover USs (1 – 4 USs were missing out of 15 leftover USs). When questioned about this, all but one participant stated they did not consume these USs but threw them away or must have lost them. Most participants indicated having (almost) always had access to at least one US at each time of day ( $n = 21$ ); the remaining participants reported repeatedly carrying no US during the CS- ( $n = 3$ ), or not carrying any USs as soon as they realized they were no longer asked to consume any during extinction ( $n = 3$ ).

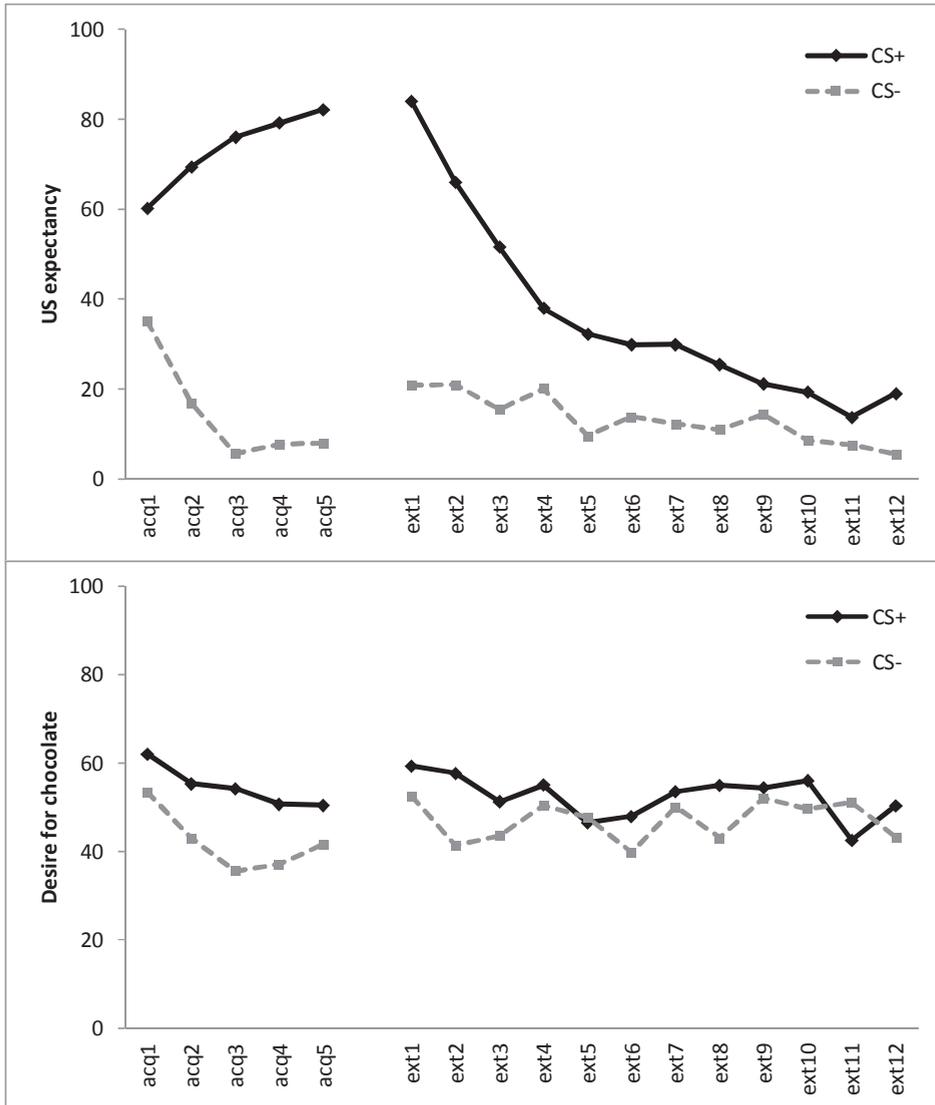
### Primary analyses

Mean US expectancies and eating desires for each (time of) day are presented in Figure 1.

Participants successfully acquired US expectancies at the time of day associated with eating chocolate, as indicated by a significant CS-type  $\times$  Day interaction,  $F(1, 17) = 12.62$ ,  $p = .002^1$ . This resulted in a significant differentiation on the

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<sup>1</sup> Degrees of freedom vary across analyses due to missing data.



**Figure 1.** Mean US expectancies and desires for all available data, by CS-type and day. “acq” refers to the acquisition phase (5 days), in which the CS+ time of day was repeatedly paired with eating chocolate. “ext” refers to the extinction phase (12 days), during which no more chocolate was consumed.

last acquisition day: US expectancies were significantly larger in response to the CS+ vs. CS–,  $t(23) = 9.77, p < .001$ . Extinction of differential US expectancies was also found (CS–type  $\times$  Day),  $F(1, 18) = 29.65, p < .001$ . This extinction was not complete: on the last trial a significant difference between CS+ and CS– expectancies was still present,  $t(22) = 2.47, p = .02$ .

In contrast, we failed to find evidence for an acquisition of the desire to eat (CS-type  $\times$  Day),  $F < 1$ . Unsurprisingly then, no differential desire to eat was present on the last day of acquisition,  $t(23) = 1.00$ ,  $p = .33$ . Since a conditioned response cannot be extinguished when not first acquired, extinction of eating desires was not tested.

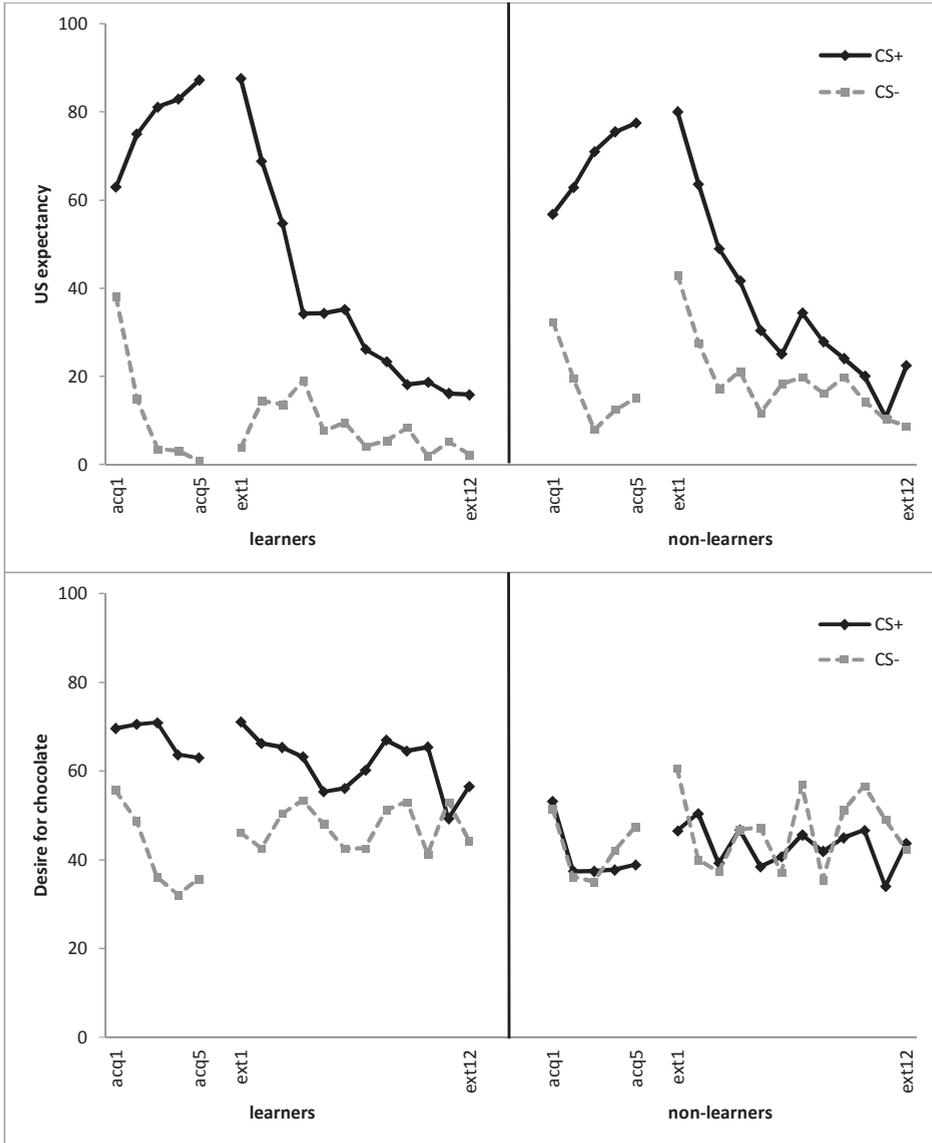
In sum, while expectancies were successfully acquired and extinguished, eating desires did not show this pattern. This is in contrast to findings of laboratory conditioning studies, which generally report a successful acquisition of desires after a similar amount of pairings between a stimulus and a US, provided that differential US expectancies were successfully acquired.

#### Exploratory analyses: learners vs. non-learners

Because no evidence for acquisition of conditioned desires for chocolate was found, analyses were conducted on two subgroups of participants: those who have successfully developed differential eating desires based on visual inspection of acquisition patterns (“learners”,  $n = 13$ ), and those who have not (“non-learners”,  $n = 14$ ) (see Figure 2). Although exploratory, these analyses may give important insights into the potential causes for an (un)successful acquisition of conditioned eating desires.

The analyses suggest that the “learners” indeed acquired a marginally significant desire to eat over time (CS-type  $\times$  Day),  $F(1, 9) = 4.12$ ,  $p = .07$ , while “non-learners” ( $n = 14$ ) did not,  $F < 1$ . In line with this, on the last acquisition day (day 5), learners reported a significantly greater desire to eat in response to the CS+ vs. CS-,  $t(11) = 2.84$ ,  $p = .016$ , while non-learners did not,  $t(11) = -.80$ ,  $p = .44$  (overall CS-type  $\times$  Group:  $F(1, 22) = 5.59$ ,  $p = .03$ ). Some evidence was also found for learners to show increased differential US expectancies on the last acquisition day, relative to non-learners,  $F(1, 22) = 3.42$ ,  $p = .08$ .

Although visual inspection of the data suggests partial extinction of eating desires within learners, the CS-type  $\times$  Day interaction was not significant,  $F < 1$ . Conditioned eating desires were also still present in this group on the last extinction day,  $t(11) = 2.40$ ,  $p = .035$ . However, interpretation of this finding is somewhat complicated by the apparent (though non-significant,  $t(10) = 1.62$ ,  $p = .14$ ) differentiation of US desires on the first acquisition day in learners (acq1 vs ext12:  $F < 1$ ). It may be that the differentiation between the CS+ vs. CS- on acquisition day 1 was present due to already-heightened US expectancies (i.e., simply reflecting a rapid learning),  $t(10) = 3.61$ ,  $p = .005$ . In support, differential US expectancies and eating desires on acquisition day 1 strongly correlated within learners,  $r(11) = .83$ ,  $p = .002$ , suggesting that the somewhat heightened “baseline” eating desires were a result of our manipulation.



**Figure 2.** Mean US expectancies and eating desires by CS-type, day, and assigned group. “learners” ( $n = 13$ ) refer to participants who developed a conditioned desire for chocolate during acquisition, while “non-learners” ( $n = 14$ ) are participants who did not show an acquisition of chocolate desires.

In addition to stronger US expectancies, learners vs. non-learners showed differences in the number of experienced acquisition trials,  $U = 40.5$ ,  $p = .01$ : learners had experienced significantly more acquisition trials than non-learners (learners:  $M = 9.54$ ,  $SD = 0.52$ ; non-learners:  $M = 8.50$ ,  $SD = 1.16$ ), indicating that learners had

more opportunities to learn about the CS–US relationship. Follow-up analyses suggested that learners missed fewer prompts in general than non-learners ( $M = 2.54$ ,  $SD = 2.07$  vs.  $M = 5.14$ ;  $SD = 2.71$ ),  $U = 35.0$ ,  $p = .01$ . The two subgroups did not differ in age, BMI, or US liking ( $F_s \leq 1.64$ , *ns*).

In sum, exploratory analyses suggest that a better acquisition of cued US (chocolate) desires co-occurred with stronger US expectancies during the chocolate-associated time of day and with fewer missed prompts (and more opportunities to learn about the CS–US relationship). This suggests that while acquiring conditioned eating desires under real-life circumstances may be more difficult than in the laboratory, their acquisition may be facilitated when US expectancies are stronger and/or when participants have more opportunities to learn about the CS–US relationship. Thus, a successful acquisition of eating desires in real-life may require more CS–US pairings.

## Discussion

The current study examined whether eating expectancies and desires can be learned and extinguished using a classical conditioning paradigm implemented in real-life and using ecologically valid cues (two different times of day). It was found that while US expectancies were successfully acquired, eating desires were not. However, exploratory analyses suggested the acquisition of differential eating desires in a subsample of the participants.

The finding that overall, eating desires were not successfully acquired despite a successful acquisition of US expectancies seems in contrast to findings of laboratory studies (e.g., van den Akker et al., 2013; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008; for an overview, see Jansen, Schyns, Bongers, & van den Akker, 2016). In these studies, a few CS–US pairings are usually sufficient to establish conditioned eating expectancies and desires, a recent report even showing conditioned responding after a single CS–US pairing (Blechert, Testa, Georgii, Klimesch, & Wilhelm, 2016). Thus, the present findings suggest that the relative ease of acquisition of conditioned eating desires usually seen in laboratory studies does not translate to the acquisition of eating desires in real-life. As mentioned in the introduction, attenuated conditioning in real-life may be due to a more distracting environment relative to laboratory studies, decreasing attention to the CSs. In addition, the times of day may have functioned as conditioned inhibitors: since participants did not usually consume food at these time points, acquisition may be slowed down. Another possibility is that the nature of the stimuli used in the present study slowed acquisition: time of day is a relatively diffuse stimulus,

compared with the more distinct and salient stimuli used in laboratory conditioning studies.

Interestingly however, a part of our sample (approximately half) successfully acquired greater chocolate desires to the CS+ vs. CS-, suggesting that it is possible to acquire eating desires in real-life through classical conditioning. Closer inspection of the data indicated that the learners developed greater differential US expectancies relative to non-learners, and on average experienced more CS-US pairings due to a lower amount of missed prompts – suggesting that a successful acquisition of eating desires might be achieved with a strict adherence to the study protocol. Interestingly, it was found that acquired chocolate desires did not (fully) extinguish, mirroring findings of laboratory conditioning studies (Jansen et al., 2016; van den Akker, van den Broek, Havermans, & Jansen, 2016; Van Gucht et al., 2008). Although we cannot rule out the possibility that the differentiation in chocolate desires that was present after extinction was due to random (though non-significant) baseline differences in desires at the two times of day, the strong correlation found between differential US expectancies and eating desires on the first acquisition day suggests that our conditioning procedure was responsible for the (non-significant) heightened differential “baseline” eating desires.

Of note, the differential desires that were acquired (i.e., CS+ vs CS-) were due to a decrease in chocolate desires to the CS- [ $t(10) = 2.83, p = .018$ ], rather than an increase of desires to the CS+. It is standard in conditioning studies to compare responding to the CS+ with a CS- to control for non-associative processes (e.g., overall changes in eating desires), and based on this, one would conclude that eating desires were acquired in this group. On the other hand, one could argue that the current pattern suggests a mere inhibition of desires to the CS-, rather than a true acquisition of conditioned desires to the CS+ (Lissek et al., 2005). To what extent the results can be explained by inhibitory influences of the CS- remains an empirical question. Still, irrespective of what has caused the differentiation, the current data suggest that eating desires in real-life can be influenced by prior learning experiences.

In sum, the findings suggest that eating desires are not acquired as easily in real-life as in the laboratory. However, initial evidence was found that eating desires in real-life can be learned through (or influenced by) classical conditioning, but frequent CS-US pairings and strong differential US expectancies may be necessary. Once acquired, differential desires seemed difficult to extinguish – similar to findings of laboratory studies. To our knowledge, this is the first study that attempts to condition eating expectancies and desires in real-life, and hence, to empirically test the assumption that many stimuli in daily life can become desire-evoking CSs after repeated CS-US pairings (e.g., Bouton, 2011; Jansen, Havermans,

Nederkoorn, 2011). Future research may aim to study the specific circumstances under which participants acquire conditioned desires to eat, including e.g. the number of CS–US pairings and the nature of the CSs (diffuse versus distinct cues), and the contribution of the CS– to differential responding. In addition, extinction patterns of naturalistically conditioned eating desires should be investigated to examine their similarity with findings of laboratory studies. This would provide further evidence for the ecological validity of laboratory conditioning studies.

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# Chapter 4

## **Violation of eating expectancies does not reduce conditioned desires for chocolate**

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## Abstract

Although eating desires can be easily learned, their extinction appears more difficult. The present two-session study aimed to investigate the role of eating expectancies in the short and longer-term extinction of eating desires. In addition, the relationship between eating desires and conditioned evaluations was examined to test whether they might share a similar mechanism. It was hypothesized that the short-term extinction of eating desires would be more successful after the disconfirmation of eating expectancies (instructed extinction or IE), while resulting in worse longer-term extinction because omission of the food reward during extinction is not surprising. In contrast to the hypotheses, it was found that IE had no effect on the short-term and longer-term extinction of eating desires. Eating desires correlated with conditioned evaluations only to some extent. It is concluded that eating expectancies do not mediate the short-term extinction of conditioned eating desires. In addition, their longer-term extinction does not appear to be facilitated by a greater violation of eating expectancies. This suggests that it might not be necessary to focus on expectancy violation in cue exposure therapy to reduce eating desires.

**Keywords:** appetitive conditioning, instructed extinction, extinction, spontaneous recovery, expectancy violation, cue exposure therapy

## Introduction

Obesity prevalence has increased substantially over the last decades, most western countries now reporting approximately 10–35% of their adult population to be obese (Berghofer et al., 2008; Ogden, Carroll, Kit, & Flegal, 2014). One important contributor to obesity is the “obesogenic” environment, in which omnipresent food cues signal the availability of palatable, high-calorie foods. Exposure to these cues can elicit physiological and psychological reactions, including an increased desire to consume the food (Jansen, 1998). These cue-elicited eating desires are thought to stimulate overeating and weight gain (Fedoroff, Polivy, & Peter Herman, 2003; Jansen, Havermans, & Nederkoorn, 2011), and appear heightened in overweight individuals and in those with eating psychopathology (Ferriday & Brunstrom, 2011; Karhunen, Lappalainen, Tammela, Turpeinen, & Uusitupa, 1997; Jansen et al., 2003). This highlights the need for investigating the etiology of cued eating desires, as well as finding ways to effectively tackle them.

It is thought that learning processes play an important role in cue-elicited eating desires. For instance, the sight and smell of food are thought to have become conditioned stimuli (CSs) predictive for food intake (unconditioned stimulus or US) through repeated CS–US pairings (Jansen, 1998). As a result, a CS (food cue) can elicit conditioned appetitive responses (CRs) such as a heightened desire to eat, increased salivation, and an explicit eating expectancy. Moreover, learning theory predicts that these CRs extinguish after repeated exposures to the CS alone. Thus, theoretically, after repeated exposure to the sight and smell of palatable food without consumption, conditioned responses such as desires to eat should decline. Such successful extinction of responses to food cues is thought to increase one’s ability to abstain from eating, and ultimately, result in improved weight loss success (Jansen, 1998; Jansen et al., 2011; Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010; Wardle, 1990). In support, the few studies conducted on cue exposure therapy (CET), in which overweight individuals or those with eating psychopathology are repeatedly exposed to food cues without eating, indeed suggest CET to be effective in reducing cue-elicited cravings and eating binges (e.g., Boutelle et al., 2014; Jansen, Broekmate, & Heymans, 1992; Jansen, Van Den Hout, De Loof, Zandbergen, & Griez, 1989; Martinez-Mallén et al., 2007; Schyns, Roefs, Mulkens, & Jansen, 2015; Toro, Cervera, Feliu, Garriga, Jou, Martinez, & Toro, 2003). Despite these very promising findings, the evidence for a superiority of CET over control treatments at follow-up is mixed (Boutelle et al., 2014; Jansen et al., 1992). Since CET is rooted in learning theory, it might be optimized by studying the mechanisms that underlie the (long-term) extinction of appetitive responses to food cues.

Extinction can be studied using conditioning paradigms, in which cue-elicited eating desires and eating expectancies are first established by repeatedly pairing a cue (CS) with a US (food) (e.g., Bongers, van den Akker, Havermans, & Jansen, 2015; van den Akker, Havermans, Bouton, & Jansen, 2014; Van Gucht, Vansteenkeweg, Van den Bergh, & Beckers, 2008a). This acquisition phase is followed by an extinction phase, during which repeated CS - no US pairings occur. Findings suggest that eating desires can be quickly acquired, but only when a participant is consciously aware of the CS-US contingency (i.e., when reporting heightened US expectancies upon CS presentation) (van den Akker, Jansen, Frentz, & Havermans, 2013). Thus, during acquisition, US expectancies are likely essential for developing cued eating desires. During extinction however, the two responses can diverge: even when eating expectancies reduce, eating desires can remain heightened (Van Gucht, Vansteenkeweg, Beckers, & Van den Bergh, 2008b). These divergent extinction patterns suggest an involvement of separate response systems that are differentially affected by extinction. Specifically, it may be that eating expectancies relate more to an anticipatory response system, preparing the organism for an incoming stimulus (Van Gucht et al., 2008b). In contrast, regarding the desire to eat, it has been noted that its resistance to extinction resembles extinction in evaluative conditioning: conditioned evaluations do not extinguish easily as well (Baeyens, Crombez, Van den Bergh, & Eelen, 1988; Van Gucht et al., 2008b). It might be that CS evaluations are based on the mere activation of the US representation in memory, i.e., reflecting a mere referential learning in which the CS “makes one think of” the US in the absence of actual eating expectancies (Hermans, Vansteenkeweg, Crombez, Baeyens, & Eelen, 2002; Baeyens, Eelen, Crombez, & Van den Bergh, 1992). This activation of the US representation could also be sufficient for experiencing heightened eating desires (Van Gucht, Baeyens, Vansteenkeweg, Hermans, & Beckers, 2010). Extinction may have more impact on response systems that prepare an individual for an incoming stimulus than on systems that are based on the mere activation of the US representation in memory (Van Gucht et al., 2008b; see also Luck & Lipp, 2015; Sevenster, Beckers, & Kindt, 2012), causing eating desires and CS evaluations to extinguish more slowly than US expectancies.

However, there is also evidence suggesting a closer relationship between expectancies and eating desires during extinction. For instance, although it indeed seems difficult to completely extinguish cue-elicited eating desires, their extinction *can* be achieved to a certain extent (van den Akker et al., 2014; van den Akker et al., 2015). This pattern is, in fact, very similar to the extinction of US expectancies: although expectancies diminish, they usually do not show complete extinction either (van den Akker et al., 2014; van den Akker et al., 2015; Van Gucht et al.,

2008b). In addition, in a conditioning study conducted in smokers, explicit disconfirmation of acquired US expectancies (i.e., “instructed extinction” or IE) immediately eliminated cue-elicited craving for cigarettes, suggesting that expectancies acted as a mediator for cue-elicited cigarette craving (Field & Duka, 2001). Thus, it seems possible that the lack of complete extinction of eating desires during extinction in previous studies was caused by a lack of complete extinction of eating expectancies, rather than by the involvement of separate response systems. A complete and immediate elimination of acquired eating expectancies by IE can help determine how closely food cravings and US expectancies are related: if conditioned cravings were to disappear immediately after CS–US disconfirmation, this would provide evidence for a mediating role of expectancies in the extinction of eating desires, and against the involvement of different response systems. Conversely, if conditioned cravings remain heightened despite an elimination of expectancies, this would provide evidence against a mediating role of expectancies in the extinction of eating desires, and would provide additional support for the idea of different response systems underlying the extinction of US expectancies and conditioned desires.

Extinction performance during one experimental session does not need to be predictive for longer-term extinction learning. New memories require time to consolidate (McGaugh, 2000), which is why actual learning is best tested at a later point in time. In case of IE, one could expect *worse* longer-term extinction learning, despite a possibly better short-term extinction performance. One reason for this might be the altered degree of “surprise” of non-occurrence of the US during extinction. Surprise, or violation of US expectancies, is thought to play a major role in (extinction) learning: a smaller discrepancy between expected and actual occurrence of the US should result in poorer (inhibitory) learning (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Rescorla & Wagner, 1972). After IE, the US omission that occurs during extinction is not very surprising, therefore possibly resulting in worse longer-term extinction learning. This would have implications for cue exposure therapy. If a reduction in US expectancies prior exposure (extinction) sessions results in worse extinction learning, cue exposure therapy might benefit from maximizing these expectancies prior to an exposure session – i.e., heightening expectancies for the US (eating) to occur.

The primary aim of the present study was to evaluate the role of US expectancies in the short and longer-term extinction of conditioned eating desires. To examine this, extinction performance in an IE condition (i.e., receiving explicit disconfirmation of the acquired CS–US contingencies before extinction) was compared with a “normal” extinction condition (no extinction instructions) on two subsequent days. It was expected that IE would speed up the short-term extinction of eating desires

relative to a normal extinction procedure, while resulting in worse extinction learning, as reflected by a greater spontaneous recovery (the recovery of responding that occurs after the mere passage of time) (Pavlov, 1927; Rescorla, 2004) and slower re-extinction during test after a 24 hour delay. Alternatively, it may be that eating desires are more closely related to evaluations of the CS rather than to US expectancies because they may share a similar mechanism. To examine this possibility conditioned CS evaluations were measured before and after each extinction session, and correlations between US expectancies, eating desires, and CS evaluations were assessed.

## Methods and materials

### Participants

48 participants took part in the study, of which two participants were replaced by additional participants because they did not show awareness of the CS–US contingency (i.e., they did not report clear differential US expectancies towards the end of acquisition), and one other participant because she did not show up for the second session. Participants were eligible to participate in the study if they were 1<sup>st</sup> or 2<sup>nd</sup> year undergraduate female students, between 17 and 25 years old, proficient in Dutch, and had indicated to like chocolate. Further, care was taken that no participant had previously participated in an appetitive conditioning study. To standardize hunger, participants were instructed to have a small meal two hours prior to each session and to refrain from consumption thereafter (only the drinking of water was allowed). As a cover story, participants were told the study was about the memory of taste. Participants received either a voucher worth €12.50 or course credit for participation. The study was approved by the local ethical committee.

### Measurements

*US expectancy and desire to eat:* 100mm-Visual Analogue Scales (VAS) were used to assess expectancy to receive chocolate (*'To what extent do you expect this box to contain chocolate at this moment?'*) and subjective desire for chocolate (*'When looking at this box, how strong is your desire for chocolate at this moment?'*) (in this order). Ratings ranged from 0 (*certainly expect this box not to contain chocolate / no desire at all*) to 100 (*certainly expect this box to contain chocolate / very strong desire*).

*CS evaluations:* Evaluations for the CS+ and CS- were assessed using two VAS ('How pleasant do you find the box depicting the elephant/fish?') (in this order). Ratings ranged from 0 (*not pleasant at all*) to 100 (*extremely pleasant*).

*Hunger:* To be able to control for possible group differences in hunger, participants filled in a VAS ('How hungry are you at this moment?') ranging from 0 (*not hungry at all*) to 100 (*extremely hungry*).

*US liking:* To be able to control for possible group differences in the liking of the chocolate (the US) used, participants filled in a VAS ('How much did you like the chocolate?'), ranging from 0 (*not at all*) to 100 (*extremely*).

*Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien, Frijters, Bergers, & Defares, 1986):* the DEBQ was administered to be able to control for possible group differences in eating styles. This 33-item questionnaire provides a measure of external eating (10 items), emotional eating (13 items), and restraint (10 items). Each item is scored on a 5-point scale, ranging from "never" to "very often", higher scores indicating a higher degree of emotional or external eating, or restraint.

All questionnaires were administered in Dutch.

## Stimuli

*US:* A small piece of Belgian milk chocolate (approximately 1.3 – 1.5 g, Rousseau) served in a small cup served as US. The USs were kept out of sight of the participants.

*CS:* Two children's jewelry boxes served as CSs, and contained the US in case of a CS+ trial. One box depicted elephants ('Elmer the Patchwork Elephant') and had coloured squares and yellow linings, and the other depicted fish ('The Rainbow Fish') and was blue. Which box served as CS+ and CS- was counterbalanced across conditions.

## Design and procedure

Participants were randomly assigned to one of two conditions: instructed extinction (IE) or normal extinction (NE), which differed only in instructions that were given after the acquisition phase. Participants were individually seen on two sessions, the second session always taking place exactly 24 hours after the first session. Testing took place between 11 AM and 6 PM.

### Session 1

After arrival, participants gave written consent for participation and rated their hunger. Next, they were shown the boxes and were instructed that one of the boxes would sometimes contain something they would eat, whereas the other box

would never contain anything. Participants repeated this information once. After this, the conditioning procedure started.

*Acquisition:* During acquisition training, all participants received five CS+ and five CS- trials. A trial proceeded as follows: a box (CS+ or CS-) was placed in front of the participant for 10 seconds and she was instructed to look at the box. Next, she rated her US expectancy and desire to eat, after which she opened the box. In case of a CS+ trial, the box contained the US which the participant consumed. In case of a CS- trial, the box did not contain anything. The participant closed the box and an inter-trial interval of 20 seconds started, after which the next trial began. All instructions given during the trials were pre-recorded. Trials were presented in a random order, with the restriction that no more than two consecutive trials were of the same trial type (CS+ or CS-).

Pilot testing suggested that the interruption in the conditioning procedure after acquisition (which was necessary for instructed extinction and to measure conditioned evaluations) unwantedly diminished responses on the first extinction trial in the NE condition, likely because some participants suspected the “rules” had changed. Therefore, two VAS (US liking and US creaminess) were given to the participant after the first two CS+ trials had been completed, in order for participants to learn that an interruption would not be predictive for a discontinuation of CS-US pairings. These VAS were introduced in a manner similar to the interruption in the conditioning procedure after acquisition (see below).

*CS evaluations and manipulation:* After acquisition, CS evaluations were assessed in both conditions. The VASs were introduced as follows: “We now briefly interrupt the study so you can fill in this question.” Only in case of IE, this was followed by the instruction: “Please pay close attention; you will now receive a very important instruction. From now on, none of the boxes will contain chocolate. It is important for you to understand and remember this. Could you repeat this instruction?” Next, in both conditions, the participant was told: “Thank you. The study will now continue”. After this, the extinction phase started.

*Extinction:* All participants received a similar extinction procedure, during which 12 CS+ and 12 CS- trials were presented. Trials proceeded as during acquisition, with the exception that no USs were provided. Whether the first extinction trial was a CS+ or CS- was counterbalanced across conditions.

After extinction, CS evaluations, a bogus memory questionnaire, and the participant’s time of pre-experimental food intake were assessed.

## Session 2

After arrival in the laboratory, participants rated their current hunger, and CS evaluations were assessed. Next, participants received a second extinction phase.

*Re-extinction:* Participants received 12 CS+ and 12 CS- trials (no USs were given). Trials proceeded as during the previous phases. Whether the first extinction trial was a CS+ or CS- was counterbalanced across conditions.

After re-extinction, CS evaluations, the participant's suspicion about the study's hypothesis, their time of pre-experimental food intake, the DEBQ, and the participant's height and weight were assessed.

### Data reduction and statistical analyses

Differential acquisition, extinction, and re-extinction of the desire to eat and US expectancy over time and across conditions were analyzed using repeated-measures ANOVAs for each phase of the experiment (acquisition, extinction, and re-extinction) This resulted in 2 (Condition: IE vs. NE) x 2 (CS-type: CS+ vs. CS-) x 5 / 12 / 12 (Acquisition Trial / Extinction Trial / Re-extinction Trial) repeated-measures ANOVAs, including CS-type (CS) and Trial (T) as within-subjects factors and Condition (C) as between-subjects factor. Spontaneous recovery was analyzed using 2 (Condition: IE vs. NE) x 2 (CS-type: CS+ vs. CS-) x 2 (Trial: EXT12 vs. RE-EXT1) RM ANOVAs. To test the immediate effects of our manipulation, 2 (Condition: IE vs. NE) x 2 (CS-type: CS+ vs. CS-) x 2 (Trial: ACQ5 vs. EXT1) ANOVAs were conducted, as well as a paired t-test for the IE condition on the differentiation on the first extinction trial. Acquisition and extinction of differential CS evaluations were assessed using repeated-measures ANOVAs as well, using CS and T (acquisition, extinction, pre re-extinction, post re-extinction) as within-subjects variables, and C as between-subjects variable. Finally, to assess how strongly the different responses were associated, differential responses (i.e. CS+ minus CS-) were calculated for CS evaluations, US expectancies, and eating desires, before and after each extinction phase (expectancies and desires: ACQ5; EXT12; RE-EXT1; RE-EXT12; evaluations: ACQ; EXT; RE-EXT PRE; RE-EXT POST), and correlational analyses on these responses were performed. Greenhouse-Geisser epsilon corrections are reported for all repeated-measures analyses whenever sphericity was violated.

## Results

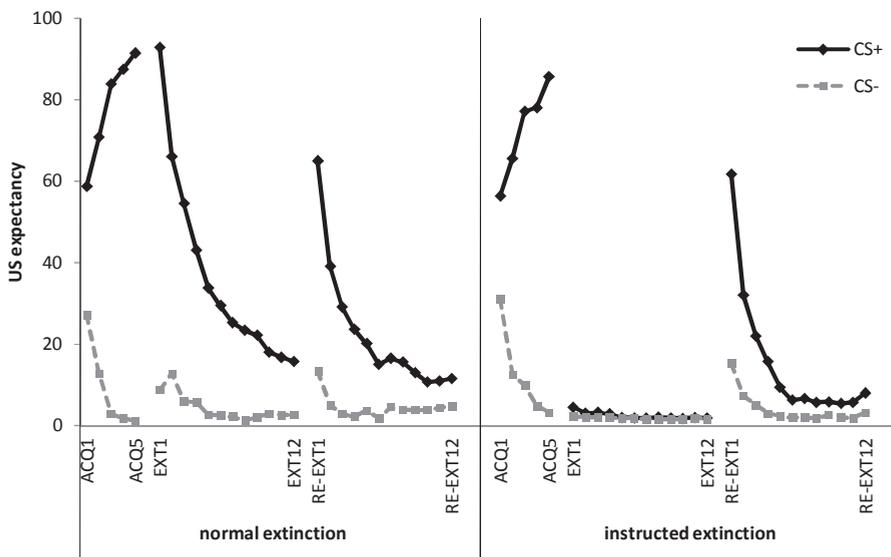
Participants characteristics are displayed in Table 1. Because baseline hunger on session 1 differed across the conditions, it was included as a centered covariate in the analyses. Since hunger did not influence patterns of conditioned responding in any of the phases, all  $ps > .05$ , in the final analyses, hunger was not included.

**Table 1.** Participants characteristics per condition; means with standard deviations in parentheses.

	normal extinction ( <i>N</i> = 24)	instructed extinction ( <i>N</i> = 24)	<i>t</i> (46)	<i>p</i>
Age	19.38 (1.47)	19.21 (1.28)	0.42	.68
BMI	23.45 (4.81)	22.96 (3.03)	0.43	.67
<i>Baseline hunger</i>				
Session 1	36.21 (19.38)	48.00 (22.32)	1.95	.06
Session 2	41.46 (26.73)	48.29 (27.18)	0.88	.38
US liking	76.58 (10.50)	75.71 (16.31)	0.05	.83
<i>DEBQ</i>				
Restrained	2.70 (0.73)	2.77 (0.69)	0.35	.73
Emotional	2.53 (0.65)	2.68 (0.53)	0.88	.38
External	3.26 (0.59)	3.21 (0.59)	0.27	.79

### US expectancy

*Acquisition:* Participants learned to expect to receive chocolate when presented with the CS+, as indicated by a significant CS × T interaction,  $F(2.89, 132.84) = 82.81$ ,  $p < .001$ ,  $\eta_p^2 = .64$ , with no differences across conditions (CS × T × C),  $F < 1$  (see Figure 1). This resulted in a significant CS+ vs. CS- differentiation on trial 5,  $F(1, 46) = 1550.71$ ,  $p < .001$ ,  $\eta_p^2 = .97$ , with a trend towards a greater differentiation in the IE condition,  $F(1, 46) = 3.33$ ,  $p = .08$ ,  $\eta_p^2 = .07$ .

**Figure 1.** Mean US expectancy by CS-type, trial, condition, and phase of the experiment.

*Effectiveness of the manipulation:* In the NE condition, differential US expectancies did not change from the last acquisition trial to the first extinction trial, as shown by a non-significant CS  $\times$  T (ACQ5 vs. EXT1) interaction,  $F(1, 23) = 2.59$ ,  $p = .12$ ,  $\eta_p^2 = .10$ . In contrast, in the IE condition, US expectancies reduced from acquisition to extinction,  $F(1, 23) = 446.96$ ,  $p < .001$ ,  $\eta_p^2 = .95$ . In this condition, analyses indicated a trend towards a CS+ vs. CS- differentiation on the first extinction trial,  $F(1, 23) = 3.15$ ,  $p = .09$ ,  $\eta_p^2 = .12$ , this differentiation being non-significant on the second extinction trial,  $F(1, 23) = 1.86$ ,  $p = .19$ ,  $\eta_p^2 = .08$ . Thus, the extinction instruction was effective: it resulted in an almost-immediate and complete reduction in differential US expectancies.

*Extinction:* In the NE condition, differential expectancies diminished during extinction (CS  $\times$  T),  $F(3.79, 87.22) = 42.56$ ,  $p < .001$ ,  $\eta_p^2 = .65$ , while unsurprisingly, this was not the case for the IE condition,  $F(2.05, 47.23) = 1.64$ ,  $p = .20$ ,  $\eta_p^2 = .07$ . On extinction trial 12, a significant differentiation remained in the NE condition,  $F(1, 23) = 11.01$ ,  $p = .003$ ,  $\eta_p^2 = .32$ , but not in the IE condition,  $F < 1$ .

*Spontaneous recovery and re-extinction:* Spontaneous recovery of US expectancies was present (EXT12 vs. RE-EXT1),  $F(1, 46) = 86.83$ ,  $p < .001$ ,  $\eta_p^2 = .65$ , and similar across conditions,  $F < 1$ . In line with this, on re-extinction trial 1 a significant differentiation in US expectancies was found,  $F(1, 46) = 150.15$ ,  $p < .001$ ,  $\eta_p^2 = .77$ , that did not differ between conditions,  $F < 1$ . Expectancies re-extinguished (CS  $\times$  T),  $F(2.89, 132.92) = 55.76$ ,  $p < .001$ ,  $\eta_p^2 = .55$ , although a significant differentiation remained on the last re-extinction trial,  $F(1, 46) = 10.12$ ,  $p = .003$ ,  $\eta_p^2 = .18$ . Conditions did not differ in the course of re-extinction (CS  $\times$  T  $\times$  C) and in final re-extinction levels,  $F_s < 1$ . Thus, overall, US expectancies recovered after a 24 hour interval and re-extinguished to a certain extent, but no differences across conditions were found.

### Desire to eat chocolate

*Acquisition:* Participants acquired a differential desire to eat chocolate during acquisition (CS  $\times$  T),  $F(2.33, 107.16) = 4.89$ ,  $p = .006$ ,  $\eta_p^2 = .10$ , and equally so for both conditions (CS  $\times$  T  $\times$  C),  $F < 1$  (see Figure 2). This resulted in a significantly higher desire to eat in response to the CS+ vs. the CS- on the last acquisition trial,  $F(1, 46) = 29.92$ ,  $p < .001$ ,  $\eta_p^2 = .39$ , independent of condition,  $F < 1$ .

*Immediate response to the manipulation:* The explicit CS-US disconfirmation did not appear to reduce differential desires to eat on the subsequent trial. Although differential desires diminished marginally significant from the last acquisition to the first extinction trial,  $F(1, 46) = 3.74$ ,  $p = .06$ ,  $\eta_p^2 = .08$ , importantly, this change did not interact with condition,  $F = 1.21$ , *ns*. A significant CS+ vs. CS- differentiation

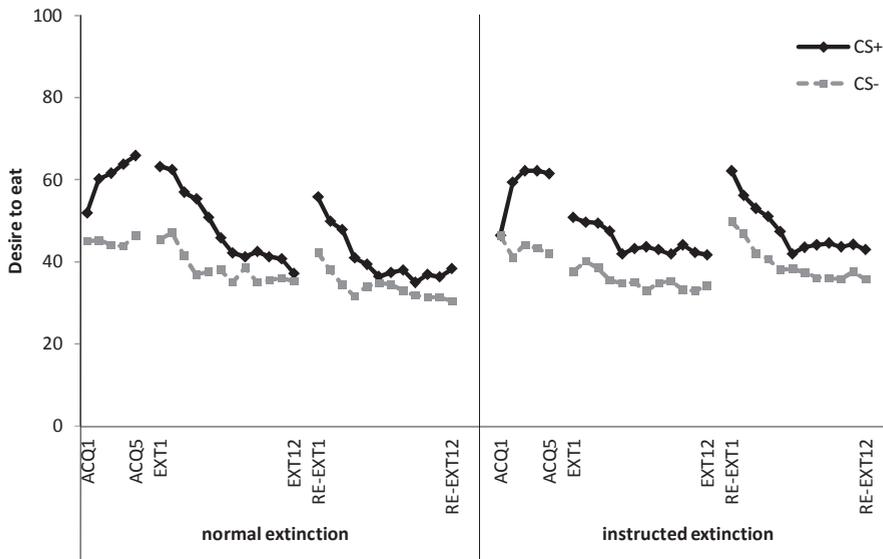


Figure 2. Mean desire to eat by CS-type, trial, condition, and phase of the experiment.

was still present on the first extinction trial,  $F(1, 46) = 17.40, p < .001, \eta_p^2 = .27$ , independent of condition,  $F < 1$ .

Because visual inspection of the figures suggested an overall decrease in eating desires in specifically the IE condition, additional analyses were performed on the overall change in eating desires (ACQ5 vs EXT1). These confirmed an overall reduction in desires in the IE condition,  $F(1, 23) = 10.51, p = .004, \eta_p^2 = .31$ , but not in the NE condition,  $F < 1$  (overall  $T \times C$  interaction:  $F(1, 46) = 4.37, p = .04, \eta_p^2 = .09$ ). Thus, while disconfirmation of US expectancies did not affect conditioned desires to eat, it appeared to diminish eating desires overall.

*Extinction:* Conditioned desires to eat extinguished ( $CS \times T$ ),  $F(3.42, 157.17) = 2.85, p = .033, \eta_p^2 = .06$ , and similarly so across conditions ( $CS \times T \times C$ ),  $F(3.42, 157.17) = 1.35, p = .26, \eta_p^2 = .03$ . Extinction of differential desires to eat was not complete: a marginally significant differentiation between the CS+ and CS- remained at the end of extinction (ext12),  $F(1, 46) = 3.91, p = .054, \eta_p^2 = .08$ , with no differences across conditions,  $F(1, 46) = 1.41, p = .24, \eta_p^2 = .03$ .

*Spontaneous recovery and re-extinction:* Conditioned desires recovered after a 24 hour delay (EXT12 vs RE-EXT1),  $F(1, 46) = 6.58, p = .014, \eta_p^2 = .13$ , and this was similar across conditions,  $F = 1.08, ns$ . This resulted in a significant CS+ vs CS- differentiation on the first re-extinction trial,  $F(1, 46) = 24.13, p < .001, \eta_p^2 = .34$ , that was similar across conditions,  $F < 1$ . Conditioned desires re-extinguished to some extent ( $CS \times T$ ),  $F(5.46, 251.08) = 3.80, p = .002, \eta_p^2 = .08$ , with no differ-

ences across conditions ( $CS \times T \times C$ ),  $F < 1$ . Again, extinction was not complete: the differential desire to eat was still significant on the last re-extinction trial,  $F(1, 46) = 13.81$ ,  $p = .001$ ,  $\eta_p^2 = .23$ , and similarly for both conditions,  $F < 1$ .

### CS evaluations

After acquisition, the CS+ was evaluated significantly more positively than the CS-,  $F(1, 46) = 23.13$ ,  $p < .001$ ,  $\eta_p^2 = .34$  (see Figure 3). This differential conditioned evaluation extinguished,  $F(1, 46) = 14.80$ ,  $p < .001$ ,  $\eta_p^2 = .24$ , though after extinction there was still a trend towards more positive evaluations for the CS+ vs CS-,  $F(1, 46) = 2.86$ ,  $p = .1$ ,  $\eta_p^2 = .06$ . The conditions did not differ in the acquisition or extinction of conditioned evaluations,  $F_s < 1$ .

Differential conditioned evaluations recovered during tests at the beginning of the second session (EXT vs RE-EXT PRE),  $F(1, 46) = 16.10$ ,  $p < .001$ ,  $\eta_p^2 = .26$ , and again resulting in significantly higher evaluations for the CS+ vs CS- before re-extinction,  $F(1, 46) = 17.22$ ,  $p < .001$ ,  $\eta_p^2 = .27$ . Again, evaluations extinguished,  $F(1, 46) = 27.57$ ,  $p < .001$ ,  $\eta_p^2 = .38$ , and this time, extinction was complete,  $F < 1$ . Spontaneous recovery, the course of extinction, and final extinction levels did not differ significantly across conditions,  $F < 1$ ,  $F(1, 46) = 2.11$ ,  $p = .15$ ,  $\eta_p^2 = .04$ ;  $F(1, 46) = 1.81$ ,  $p = .19$ ,  $\eta_p^2 = .04$ .

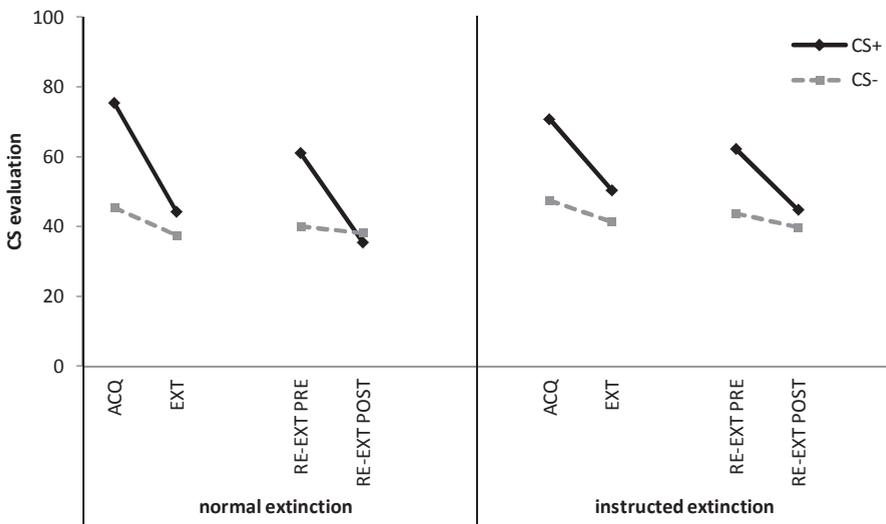


Figure 3. Mean CS evaluation by CS-type, condition, and phase of the experiment.

### Correlational analyses

At the end of acquisition, differential evaluations correlated only with eating desires,  $r(48) = .32, p = .03$ . Correlations between US expectancies and evaluations,  $r(48) = .03, ns$ , and US expectancies and eating desires were non-significant,  $r(48) = .24, p = .11$ . Similarly, after extinction, conditioned evaluations correlated significantly with differential eating desires,  $r(48) = .43, p = .002$ , while US expectancies did not correlate with evaluations,  $r(48) = -.01, ns$ , nor with eating desires,  $r(48) = .06, ns$ . Thus, on session 1, it seems that conditioned evaluations are linked with eating desires while US expectancies are not. At the start of re-extinction, differential desires correlated with both US expectancies,  $r(48) = .33, p = .02$  and conditioned evaluations,  $r(48) = .38, p = .008$ , which also correlated with each other,  $r(48) = .28, p = .051$ . After re-extinction, evaluations did not correlate with eating desires,  $r(48) = .20, p = .18$ , nor with US expectancies:  $r(48) = -.17, p = .25$ , while this time, US expectancies were *inversely* correlated with eating desires,  $r(48) = -.37, p = .01$ .

In sum, on session 1, greater positive evaluations of the CS+ (but not heightened US expectancies) appeared to consistently co-occur with increased eating desires. A different pattern was found on session 2: at the start of re-extinction, eating desires correlated with both conditioned evaluations and US expectancies. After re-extinction, differential eating desires did not correlate with conditioned evaluations and even showed an inverse correlation with US expectancies. Thus, overall, findings of correlational analyses were somewhat mixed but suggest eating desires to be more related to conditioned evaluations than to US expectancies.

## Discussion

The aim of the present study was to examine whether instructed extinction would affect the short-term and longer-term extinction of conditioned appetitive responses. In addition, the relationship between eating desires, eating expectancies, and CS evaluations was examined. It was found that disconfirming eating expectancies prior to extinction did not affect the short-term extinction of conditioned eating desires: in both conditions, differential desires reduced but did not extinguish completely. On session 2, spontaneous recovery and re-extinction of appetitive responses was found, while again, this was similar across the conditions. CS evaluations correlated with eating desires on session 1, but not on session 2.

The finding that on session 1, an explicit disconfirmation of eating expectancies did not affect the short-term extinction of eating desires suggests that

eating expectancy does not act as mediator for the extinction of eating desires. Hence, it seems unlikely that previously observed difficulties to extinguish eating desires were caused by a lack of complete extinction of eating expectancies. This is in line with the idea that eating expectancies and eating desires stem from loosely coupled response systems that are differentially susceptible to extinction (Delamater & Westbrook, 2014). As described in the Introduction, one possibility is that eating desires and conditioned evaluations share a common mechanism, which would cause them to behave similarly throughout the different conditioning phases. Only partial evidence was found for this in the present study. On session 1, conditioned evaluations and eating desires appeared to co-occur: both evaluations and eating desires seemed equally unaffected by instructed extinction, and differential acquisition and extinction of eating desires correlated with the differential acquisition and extinction of evaluations, but not with differential expectancies. In contrast however, on session 2, no evidence was found for eating desires to be more closely linked to evaluations than to eating expectancies. Thus, overall, our findings provide some evidence for eating desires to be associated more closely with conditioned evaluations than with US expectancies, although they also do not seem to behave in synchrony. The partial concordance between eating desires and evaluations may be explained by eating desires and CS evaluations being based on activation of the US representation in memory, reflecting a mere referential learning that is not dependent on current eating expectancies (Hermans et al., 2002). Their partial *discordance* however suggests that eating desires and evaluations are not homologous either. Alternatively, it may be that our self-report measure of CS evaluations did not provide accurate measures of underlying evaluative representations, but were influenced by judgment-related processes, contributing to divergences between eating desires and evaluations. Specifically, prior judgments of CS evaluations (i.e., after acquisition) may cause participants to use the most recent information rather than integrating all available information about the CS: there is evidence for (partial) extinction of CS evaluations to occur only when the CSs are also rated after acquisition (Gawronski, Gast, & De Houwer, 2014; Lipp & Luck, 2006). This could also account for the relative ease of extinguishing conditioned evaluations in the current study. Including reliable behavioural and physiological measures of appetitive responding in future studies may help clarify correlates of different response systems involved in appetitive conditioning (Van Gucht et al., 2008a; van den Akker et al., 2014).

Of note, the finding that instructed extinction did not affect the short-term extinction of eating desires on session 1 seems at odds with a study in smokers in which instructed extinction immediately eliminated conditioned cigarette cravings (Field & Duka, 2001). It may be that US expectancies differentially affect appetitive

responses to food vs drug cues. In cue reactivity studies, in which participants are exposed to the sight and/or smell of drugs or food, heightening use or consumption expectancies often results in an increase in drug craving (see Jędras, Jones, & Field, 2014), while food craving appears unaffected (Hardman, Scott, Field, & Jones, 2014; Werthmann, Roefs, Nederkoorn, & Jansen, 2013). The causes for these differential patterns are presently unclear.

A well-known finding in animal studies is that extinguished appetitive responses to food cues can easily return in certain situations. It is thought that in humans, such returns of responses can promote a full-blown relapse and undermine the long-term effectiveness of exposure therapy and other weight loss efforts or treatments (Bouton, 2011). Translational studies on this topic are however very sparse. The present study adds to this field by showing that conditioned responses such as eating desires can spontaneously recover after the mere passage of time. This finding highlights the importance of relapse prevention in cue exposure (and other weight loss) therapy, which can be achieved by incorporating techniques that reduce returns of responses caused by, for instance, spontaneous recovery. One of these potential techniques was investigated in the present study: less spontaneous recovery and re-extinction were expected after normal vs instructed extinction because of heightened expectancy violation in case of normal extinction (Craske et al., 2014). The finding that the groups did not differ in their longer-term extinction of eating desires suggests that expectancy violation is not as important for reducing conditioned eating desires as it is in the fear domain for reducing conditioned fear (Craske et al., 2014; Salkovskis, Hackmann, Wells, Gelder, & Clark, 2006). Although further studies are needed, the clinical implication would be that it might not be necessary to focus on expectancy violation in CET to reduce eating desires. Since CET does seem effective in reducing food cravings, it may be that mechanisms other than expectancy violation underlie its effectiveness. Alternatively, it is also possible that the returns of responses caused by spontaneous recovery were too strong to detect any effects of our manipulation. Perhaps a larger number of extinction sessions is needed for group differences to emerge, or effects on extinction learning would be reflected in other measures of appetitive responding. In any case, further research on the long-term extinction of appetitive responses to food cues in humans is clearly needed.

Our findings raise the question how one might effectively extinguish conditioned eating desires. If conditioned evaluations and eating desires share a common mechanism, one approach would be to use methods that have been shown to be effective in changing conditioned evaluations. For instance, counterconditioning (pairing the CS+ with a US of opposite valence) has been shown to eliminate acquired evaluations (Baeyens, Eelen, van den Bergh, & Crombez,

1989), as well as conditioned cravings for chocolate (Van Gucht et al., 2010). Other effective methods may include a more extensive extinction training (Luck & Lipp, 2015), US devaluation (decreasing the valence of the US) (e.g., Baeyens, Eelen, Van den Bergh, & Crombez, 1992; Leer, Engelhard, Altink, & van den Hout, 2013), or cognitive reappraisal of the CS (Blechert et al., 2015). Interestingly, and underlining the potential benefit of changing conditioned evaluations, (manipulating) CS evaluations has been found to be predictive for food choice (Veling, Aarts, & Stroebe, 2013), alcohol intake (Houben, Nederkoorn, Wiers, & Jansen, 2011), and for reinstatement of conditioned fear (Zbozinek, Hermans, Prenoveau, Liao, & Craske, 2014).

In sum, it was found that eating expectancies did not mediate the extinction of eating desires, nor did greater expectancy violation during extinction enhance extinction learning. Eating desires appeared only partially linked with conditioned evaluations. One implication could be that in CET, it is not necessary to attempt maximizing the violation of eating expectancies. Future research may aim to confirm that increased violation of eating expectancies is, indeed, not effective in reducing eating desires during CET. In addition, future studies may examine how successful long-term extinction of conditioned appetitive responses such as eating desires can be optimized, and in which manners these techniques can be implemented in weight loss therapies.

## **Acknowledgements**

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# Chapter 5

## **Effects of occasional reinforced trials during extinction on the reacquisition of conditioned responses to food cues**

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## Abstract

**Background and objectives.** Successful long-term dieting appears to be difficult, and part of its difficulty might be explained by processes related to classical appetitive conditioning. Increasing the speed of extinction of appetitive responses to food cues and decreasing the magnitude of returns of these responses could help increase the long-term effectiveness of weight loss attempts. Two extinction techniques hypothesized to slow down rapid reacquisition of conditioned appetitive responses were investigated: the provision of 1) occasional reinforced extinction trials (OR) and 2) unpaired unconditioned stimuli (USs) during extinction (UNP). **Methods.** After acquisition, participants (N = 90) received one of three extinction trainings: OR, UNP, or normal extinction, followed by a reacquisition phase. Their desire to eat, US expectancy, and salivation were measured. Effects of impulsivity on different phases of appetitive conditioning were also assessed. **Results.** It was found that both extinction trainings were successful in reducing the rate of reacquisition of US expectancies when CS–US pairings were renewed after extinction, and occasional reinforced extinction trials were related to a slower extinction of expectancies and desires to eat. However, the reacquisition of conditioned desires was not affected by either extinction technique. Impulsivity did not moderate responses during acquisition or extinction, but appeared to slow down the reacquisition of conditioned desires. **Limitations.** US expectancies and eating desires were not completely extinguished, and a few differences in baseline responses caused difficulty in interpreting some of the findings. **Conclusions.** It is concluded that the provision of occasional reinforced extinction trials and unpaired USs seem promising techniques to slow down reacquisition, but that additional studies are needed. **Keywords:** appetitive conditioning, occasional reinforcement, extinction, reacquisition, impulsivity, dieting success

## Introduction

Over the past decades, the prevalence of overweight and obesity has been continually increasing. Around 70% of the US population is currently overweight, of which half qualifies for obesity (Ogden, Carroll, Kit, & Flegal, 2012). Attempts to lose the excess weight are common: approximately 40% of all US adults have engaged in weight loss practices in the previous year (Weiss, Galuska, Khan, & Serdula, 2006). However, successful long-term weight loss appears difficult. Only one in five dieters is able to lose at least 10% of their initial weight and maintain the loss for at least one year (Wing & Phelan, 2005).

Conditioning models propose roles for learning processes in explaining the difficulty to chronically adhere to restrictive diets. In response to an (initially neutral) stimulus (conditioned stimulus, CS) that has become associated with eating palatable food (unconditioned stimulus or US), cue reactivity is elicited (Jansen, 1998). Any stimulus could become associated with food intake, such as the sight or smell of food, emotions, or environments (Jansen, 1998; van den Akker, Jansen, Frentz, & Havermans, 2013). Cue reactivity includes preparatory responses of the body and a subjective experience of craving, urge or desire to eat (Jansen, 1998; Power & Schulkin, 2008), and higher levels of cue reactivity are thought to be associated with an increased difficulty to abstain from eating (Jansen, 1998; Jansen, Havermans, & Nederkoorn, 2011). Therefore, chances to successfully lose weight might be increased by diminishing reactivity – for instance, through extinction. During extinction, one is repeatedly exposed to a food cue (CS) without eating (US) to learn that the CS no longer predicts the US. Consequently, cue reactivity should diminish (Jansen et al., 2011). Extinction of cue reactivity is essentially practiced when being on a restrictive diet: a person attempts not to reinforce certain food cues to which he is exposed. However, extinction may take a while, and as long as a CS promotes a relatively high degree of cue reactivity (e.g., desires to eat), dieting efforts are easily undermined. Indirect support for the idea that cue reactivity and dieting success are related stems from a study showing formerly obese successful dieters to be less cue reactive than their unsuccessful counterparts (Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010), suggesting that their food cue reactivity was successfully reduced (presumably extinguished). Additionally, food cue exposure therapy (during which an individual is repeatedly presented with “forbidden” foods without eating) seems to be effective in decreasing eating in the absence of hunger in obese children (Boutelle et al., 2011), and in reducing the desire to eat and the number of binges in binge eaters (Jansen, Broekmate, & Heymans, 1992). Thus, to maintain weight loss in

the long run it might be necessary to extinguish cue reactivity to certain food cues (CSs).

It is known that extinction results in inhibitory learning that is highly dependent on context, rather than erasure of the CS–US relationship (Bouton, 2002). This is why conditioned appetitive responses can suddenly re-emerge after extinction, promoting “relapse” and limiting the effectiveness of extinction treatments (e.g., Havermans & Jansen, 2003). There are several conditioning phenomena that can explain such returns of conditioned responses, one of which being rapid reacquisition (for an overview see Bouton, 2011). Rapid reacquisition is characterized by a quick return of responding when a CS is again paired with the US after extinction, and it presumably occurs because of contextual similarities to the original acquisition context (Bouton, 2011). Translated to dieting, rapid reacquisition could cause a “lapse” in the diet (i.e., a re-reinforced CS after extinction) to trigger a quick return of appetitive responding to a food cue (Bouton, 2011). This quick return of food cue reactivity after a period of successfully abstaining from eating tasty high-calorie foods could easily end up in a full-blown return of appetitive responses, resulting in a failure to maintain dietary restriction and weight loss.

This classical conditioning interpretation of unsuccessful dieting predicts that dieters can benefit from interventions that reduce or prevent the return of appetitive responses caused by, for instance, rapid reacquisition. While rodent studies, human fear conditioning studies, and a few human appetitive conditioning studies have identified an array of potentially effective techniques (Bouton, 2002; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Laborda, McConnell, & Miller, 2011; MacKillop & Lisman, 2008; Van Gucht, Baeyens, Hermans, & Beckers, 2013; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010), no studies have examined ways of tackling rapid reacquisition of appetitive responses in humans. In rats, one procedure that has been shown to be very effective in slowing down the reacquisition of appetitive responses after extinction is the presentation of some CS–US pairings during extinction (Bouton, Woods, & Pineño, 2004). During this procedure, after acquisition, a food cue (CS) is occasionally followed by the intake of food (US) during extinction. In a subsequent reacquisition phase, renewed CS–US pairings elicit *less* responding compared with rats that received a regular extinction training (never a US after the CSs), i.e. the reacquisition of appetitive responses was less rapid. It has been suggested that occasional reinforced trials during extinction enable reinforced trials to be associated with extinction trials, leading to a greater generalization between the extinction and reacquisition context and a slowing down of reacquisition (see Bouton, Woods, & Pineño, 2004; Woods and Bouton, 2007). If humans can similarly associate one reinforced CS–US pairing (e.g., eating chocolate once in response to a CS)

with no subsequent reinforcements (not eating chocolate during subsequent CS presentations), the effectiveness of extinction training on the long-term could be increased by preventing a full-blown relapse. An eating binge could be prevented using occasional reinforcements as well, by learning to associate consuming one small snack (the CS) with no further (over)eating (US) (Bouton, Woods, & Pineño, 2004).

Another technique that remarkably slows down reacquisition in rats also involves occasional US presentations during extinction, but in this technique the US is not presented in contingency with its CS; rather, it is not paired with a cue. Unpaired USs during extinction may slow down reacquisition through a mechanism similar to the one described for occasional reinforced extinction: a US may come to signal upcoming extinction trials, slowing down reacquisition (Bouton et al., 2004; Woods and Bouton, 2007; see also Rauhut, Thomas, & Ayres, 2001; Vervliet, Vansteenwegen, & Hermans, 2010). Thus, while animal studies show that extinction procedures that include occasional reinforcements and unpaired US presentations reduce reacquisition of appetitive responses, these techniques have yet to be studied in humans.

Some individuals may be predisposed to reacting stronger to food cues and/or reacting differently to the learning and extinction of appetitive responses. Having an impulsive personality has been related to increased food cue reactivity, over-eating, obesity, and reduced dieting success (Guerrieri, Nederkoorn, & Jansen, 2008; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Nederkoorn, Jansen, Mulken, & Jansen, 2007; Tetley, Brunstrom, & Griffiths, 2010). Additionally, some evidence was found for impulsivity to be related to slower extinction of food reward expectations, and to potential differences in acquisition and reacquisition rates (van den Akker, Jansen, Havermans, & Bouton, 2014; but see Papachristou, Nederkoorn, Beunen, & Jansen, 2013). Several authors have proposed mechanisms that may underlie a possible influence of impulsivity during different stages of appetitive conditioning (Corr, 2001, 2002; Corr, Pickering, & Gray, 1995; Dawe, Gullo, & Loxton, 2004; Franken, Van Strien, Nijs, & Muris, 2008; Gorenstein & Newman, 1980; Patterson & Newman, 1993; Zinbarg & Mohlman, 1998). For instance, impulsivity may be associated with greater changes in emotional states and increased arousal in appetitive situations, which could strengthen conditioning (Corr, 2001). Increased rash impulsiveness (as measured by the BIS-11) may be related to extinction deficits through worse functioning of the orbitofrontal cortex, which is involved in learning under conditions of changing reward contingencies (see Dawe et al., 2004; McDannald, Jones, Takahashi, & Schoenbaum, 2014). Based on these models and on previous findings, it may be expected that impulsivity facilitates the acquisition and slows down the extinction of appetitive responses.

In the present study, a differential conditioning paradigm was used in which two different (initially non-food related) boxes served as CSs. During an acquisition phase, one box (the CS+) was repeatedly paired with consumption of chocolate mousse (US), while another box (the CS-) served as within-subject control and was never paired with consumption. Consequently, the CS+ should elicit heightened expectancies to receive the US and an increased desire to eat, compared with the CS-. After acquisition, participants received one of three extinction trainings. Effects of occasional reinforced extinction and unpaired US presentations during extinction on the speed of extinction and reacquisition of appetitive responses to a food CS were examined. It was hypothesized that both techniques would slow down reacquisition relative to a normal extinction procedure, and that occasional reinforcements would slow down extinction. The second aim was to examine whether impulsivity is associated with a facilitated acquisition and slowed extinction of conditioned appetitive responses.

## Methods and materials

### Participants

Ninety participants took part in the study, of which five participants were replaced by additional participants (two were not aware of the CS-US contingency, and the data of three others was not usable due to technical issues). All participants were undergraduate female students who had indicated to like chocolate prior to participation. To reduce baseline differences in hunger participants were instructed to have a small meal two hours prior to participation and to refrain from calorie intake thereafter. Participants were told the study's aim was to investigate the memory of taste. Participants received either € 7,50 or course credit for participation. The study was approved by the local ethical committee.

### Measurements

*Desire and US expectancy:* 100mm-Visual Analogue Scales (VAS) were used to assess expectancy to receive chocolate mousse ('*How strong do you expect this box to contain chocolate mousse at this moment?*') and subjective desire for chocolate mousse ('*When looking at this box, how strong is your desire for chocolate mousse at this moment?*') (in this order). Ratings ranged from 0 (*certainly expect this box not to contain chocolate mousse / no desire at all*) to 100 (*certainly expect this box to contain chocolate mousse / very strong desire*).

*Salivation:* Salivation was measured using dental rolls (Hartmann, nr 2, 10×35 mm) which the participant was instructed to place and remove herself. Two dental

rolls were placed between the cheek and lower gum on the left and right side. They were removed after precisely one minute. The dental rolls were kept in a sealed plastic bag and their weight was registered before and after the saliva was collected, using a weighing scale accurate to 0.01 g (Mettler Toledo, PB3002).

*CS preference:* After having completed the conditioning phases, participants indicated their CS preference (CS+ or CS-) ('If you were allowed to take one of the boxes home, which one would you pick?').

*Hunger:* To control for hunger, participants filled in a VAS ('How hungry are you at this moment?') ranging from 0 (*not hungry at all*) to 100 (*extremely hungry*) before and after the conditioning procedure.

*Chocolate mousse liking:* To control for differences in the liking of chocolate mousse, participants filled in a VAS ('How much did you like the chocolate mousse?') ranging from 0 (*not at all*) to 100 (*extremely*).

*Barrett Impulsivity Scale-11 (BIS-11; Patton, Stanford et al. 1995):* The BIS-11 was used to measure impulsivity. The BIS-11 is a self-report questionnaire and consists of 30 items. Each statement can be rated on a 4-point scale, ranging from *rarely/never* to *always/almost always*. Total scores were calculated, a higher score indicating higher impulsiveness. The BIS-11 has good internal consistency and is well-validated (Patton, Stanford, & Barratt, 1995; Stanford et al., 2009).

*Revised Restraint Scale (RS; Polivy, Herman, & Howard, 1988):* To control for differences in dietary restraint (i.e. the intention to restrict food intake) the 10-item RS was used. Scores range from 0–35, a higher score indicating increased intentions to restrain intake. In student samples, the RS has high internal consistency and good test-retest reliability (Gorman & Allison, 1995).

All questionnaires were administered in Dutch.

## Stimuli

*US:* A heaped teaspoon of chocolate mousse (approximately 3.5 g, Almhof) served on a teaspoon in a small cup served as US.

*CS:* Two children's jewelry boxes served as CSs, and contained the US in case of a CS+ trial. One box depicted elephants ('Elmer the Patchwork Elephant') and had coloured squares and yellow linings, and the other depicted fish ('The Rainbow Fish') and was blue<sup>1</sup>. Each box functioned as CS+ or CS- for half of the participants within each condition.

<sup>1</sup> The characters depicted on the boxes are based on children's books.

## Design and procedure

Participants were seen individually between 11 AM and 6 PM. They gave written consent after arrival in the laboratory, filled in a hunger VAS, and baseline salivation was assessed. After that, the participants were shown the jewelry boxes and participants were explicitly instructed that one of these boxes sometimes contained something they would eat, whereas the other box would never contain anything.

All participants then went through three consecutive learning phases: acquisition, extinction, and reacquisition. Participants were randomly assigned to one of three conditions, which differed only in extinction training: normal extinction (control), occasional reinforced extinction trials (OR), or unpaired USs during extinction (UNP).

*Acquisition:* During acquisition training, all participants received five CS+ and five CS- trials (trials are described later).

*Extinction:* Participants then received one of three extinction trainings. All participants were presented with twenty CS0 (i.e., the CS+ without the US) trials and twenty CS- trials. Participants in the OR condition received two CS+ trials in addition to the twenty CS0 trials (not included in the main analyses and figures). These two reinforced CS+ trials were given relatively early during extinction (on trials 2 and 6) to provide sufficient subsequent trials for extinction to take place. Participants in the UNP condition received two additional US-only trials during the ITIs following trials 2 and 6 (i.e., participants received a small cup containing a teaspoon with chocolate mousse). Each participant in the UNP condition received one unpaired US after a CS0 trial and the other after a CS- trial, to ensure complete uncoupling from the CS+ in all participants. Half of the participants in this condition received the CS0 unpaired trial first (on trial 2) and the CS- unpaired trial second (on trial 6); for the other half the order was reversed. The control condition did not receive USs during extinction.

*Reacquisition:* After extinction, all participants received four CS+ and four CS- trials.

After reacquisition, salivation was assessed on one additional CS+ and CS- trial. Half of the participants within each condition received the CS+ salivation trial first, and the other half received the CS- salivation trial first.

The instructions given during the three phases were pre-recorded. A trial started when a closed box (CS+ or CS-) was placed in front of the participant, and she was instructed to look at it. After ten seconds, expectancy and desire VAS were filled in, and the participant opened the box. In case of a CS+ trial, the US inside the box was consumed. In case of a CS- trial the empty box was closed again. The box was then removed from sight, and an inter-trial interval (ITI) of ten

seconds started, after which the next trial began. During salivation trials, dental rolls were inserted after expectancy and desire VAS were filled in, but before the boxes were opened and any chocolate mousse was consumed. Thus, a trial was halted during salivation measurements.

The order of presentation of the trials throughout all phases was randomized, with the restriction that no more than two consecutive trial types were the same. Further, half of the participants within each condition received the CS+ and the other half the CS- on the first extinction or reacquisition trial, because nonreinforced trials after acquisition and reinforced trials after extinction may alter responding on the following trial.

After the acquisition, extinction, and reacquisition phases were completed, participants filled in questionnaires on their idea about the study's hypothesis, CS preference, hunger, BIS-11, RS, liking of the chocolate mousse and time of pre-experimental food intake.

#### Data reduction and statistical analyses

The twenty extinction trials were averaged into five extinction blocks. Differential acquisition, extinction, and reacquisition of the desire to eat and US expectancy over time and across conditions were analyzed by using a repeated-measures ANCOVA for each phase of the experiment (acquisition, extinction, and reacquisition) This resulted in 3 (Condition: Control vs. OR vs. UNP)  $\times$  2 (CS-type: CS+ vs. CS-)  $\times$  5 / 5 / 4 (Acquisition Trial / Extinction Block / Reacquisition Trial) repeated-measures ANCOVAs, including CS-type (CS) and trial (T) / block (B) as within-subjects factors and condition (C) as between-subjects factor. Thus, differential responses were analyzed; i.e. responses to the CS+ were always compared with responses to the CS-. The total score of the BIS-11 was centered and included as covariate in the ANCOVAs to assess effects of impulsivity (I). When appropriate, additional analyses were performed to explore significant interactions.

Conditioned salivary responses were analyzed using a repeated-measures ANCOVA, with measurement type (baseline, CS+, CS-) as within-subjects variable, condition as between-subjects factor, and the centered score of the BIS-11 as covariate. CS preference (CS+ or CS-) was analyzed using a binomial test, and chi-square tests were conducted to test for differences in CS preference across conditions. Greenhouse-Geisser epsilon corrections are reported for all repeated-measures analyses whenever sphericity was violated.

## Results

### Participant characteristics

The participant characteristics did not differ across conditions (see Table 1).

**Table 1.** Participants characteristics per condition; means with standard deviations in parentheses.

	control	OR	UNP	<i>F</i> (2, 87)	<i>p</i>
<i>n</i>	30	30	30		
<i>Age</i>	19.20 (1.37)	20.50 (6.25)	19.77 (1.73)	0.87	.42
<i>BMI</i>	22.08 (2.83)	23.06 (2.79)	21.55 (3.84)	1.72	.18
<i>Baseline hunger</i>	53.60 (18.23)	51.17 (22.91)	49.33 (24.30)	0.29	.75
<i>Post hunger*</i>	43.83 (25.54)	41.50 (20.47)	50.67 (28.92)	1.10	.34
<i>BIS-11 total</i>	58.87 (8.73)	57.33 (8.30)	59.37 (8.73)	0.46	.64
<i>RS</i>	10.27 (5.06)	12.83 (5.48)	11.40 (3.45)	2.20	.12
<i>Liking mousse</i>	77.87 (17.35)	77.33 (23.19)	79.73 (16.12)	0.13	.88

\*hunger ratings changed significantly over time,  $F(1, 87) = 5.08$ ,  $p = .03$ ,  $\eta_p^2 = .06$ , and this change did not differ across conditions,  $F(2, 87) = 1.89$ ,  $p = .16$ .

### US expectancy

Participants learned to expect chocolate mousse when presented with the CS+: a differential acquisition of US expectancies was present (CS  $\times$  T),  $F(3.01, 252.71) = 77.53$ ,  $p < .001$ ,  $\eta_p^2 = .48$  (see Figure 1). Differential expectancy did not differ across conditions or levels of impulsivity (CS  $\times$  T  $\times$  C / I), nor by their interaction (CS  $\times$  T  $\times$  C  $\times$  I),  $F_s < 1$ . A significant differentiation was present on trial 5,  $F(1, 84) = 930.36$ ,  $p < .001$ ,  $\eta_p^2 = .92$ , with no differences across conditions,  $F < 1$ .

On the first extinction block, conditions differed in differential US expectancies,  $F(2, 84) = 4.57$ ,  $p = .01$ ,  $\eta_p^2 = .10$ : the differentiation was already larger for the OR condition vs. the control condition,  $F(1, 56) = 9.48$ ,  $p = .003$ ,  $\eta_p^2 = .15$ , while there was no significant difference in differentiation for the UNP vs. OR condition,  $F(1, 56) = 1.72$ ,  $p = .20$ ,  $\eta_p^2 = .03$ , and UNP vs. control condition,  $F(1, 56) = 2.71$ ,  $p = .11$ ,  $\eta_p^2 = .05$ . The significant difference across conditions on extinction block 1 was due to the manipulations, since the conditions did not differ in differential US expectancy ratings on the first two extinction trials (before any USs were provided, hence including the additional CS–US trial in OR),  $F_s < 1$ . US expectancies extinguished (CS  $\times$  B),  $F(2.52, 212.65) = 126.73$ ,  $p < .001$ ,  $\eta_p^2 = .60$ , with differences across conditions (CS  $\times$  B  $\times$  C),  $F(5.06, 212.65) = 8.95$ ,  $p < .001$ ,  $\eta_p^2 = .18$  (see Figure 1). Next, extinction was compared for each pair of conditions. As expected, the OR condition showed a significantly slower extinction performance

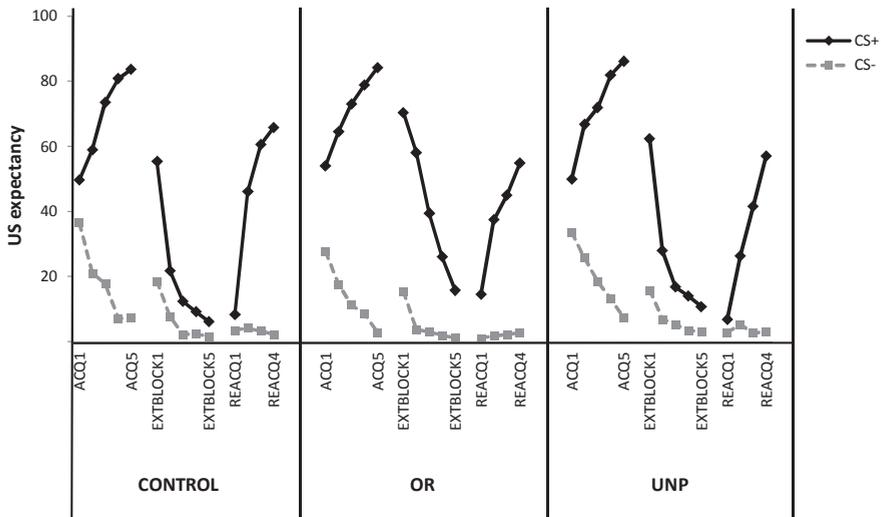


Figure 1. Mean US expectancy by CS-type, trial or block, condition, and phase of the experiment.

compared with both the control and UNP conditions,  $F(2.72, 152.02) = 14.30$ ,  $p < .001$ ,  $\eta_p^2 = .20$ ;  $F(2.72, 151.76) = 11.72$ ,  $p < .001$ ,  $\eta_p^2 = .17$  (control vs. UNP:  $F = 1.17$ , *ns*). On the last extinction block, a differentiation between CS+ and CS- expectancy scores was still present,  $F(1, 84) = 37.41$ ,  $p < .001$ ,  $\eta_p^2 = .31$ , that differed across conditions,  $F(2, 84) = 4.51$ ,  $p = .01$ ,  $\eta_p^2 = .10$ : differential expectancies in the OR vs. control condition were still significantly larger,  $F(1, 56) = 7.58$ ,  $p = .008$ ,  $\eta_p^2 = .12$ , and non-significantly larger than those in the UNP condition,  $F(1, 56) = 3.21$ ,  $p = .08$ ,  $\eta_p^2 = .05$  (control vs. UNP:  $F = 1.45$ , *ns*). This pattern of results shows that occasional reinforcements during extinction (but not unpaired USs) slow down extinction performance. Impulsivity did not moderate extinction ( $CS \times B \times I$ ;  $CS \times B \times C \times I$ ),  $F = 1.71$ , *ns*,  $F < 1$ .

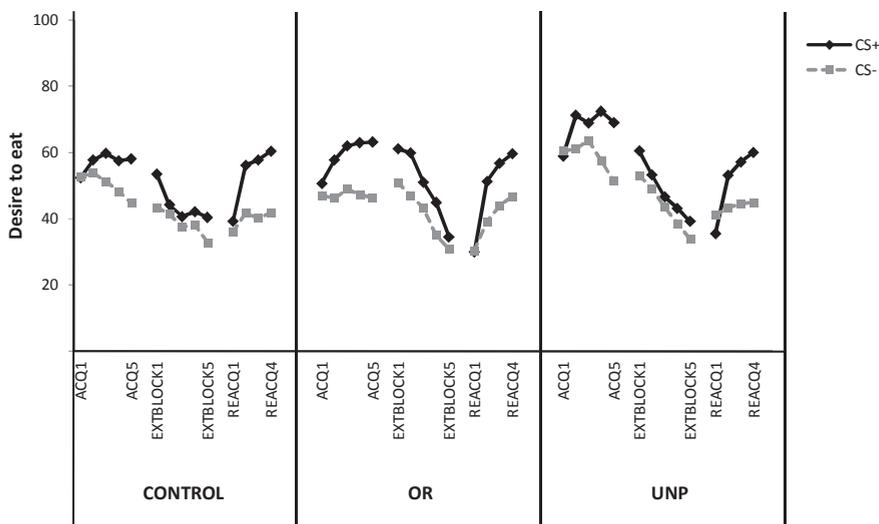
On reacquisition trial 1, the differentiation between CS+ and CS- expectancy scores was still present,  $F(1, 84) = 15.46$ ,  $p < .001$ ,  $\eta_p^2 = .16$ , with marginally significant differences across conditions,  $F(2, 84) = 2.71$ ,  $p = .07$ ,  $\eta_p^2 = .06$ : the control condition did not differ from the OR and UNP conditions,  $F(1, 56) = 2.75$ ,  $p = .10$ ,  $F < 1$ , while the differentiation was larger for the OR vs. UNP condition,  $F(1, 56) = 4.79$ ,  $p = .03$ ,  $\eta_p^2 = .08$ . Reacquisition of US expectancies was significant ( $CS \times T$ ),  $F(2.37, 198.94) = 140.68$ ,  $p < .001$ ,  $\eta_p^2 = .63$ , and differed across conditions ( $CS \times T \times C$ ),  $F(4.74, 198.94) = 4.29$ ,  $p = .001$ ,  $\eta_p^2 = .09$  (see Figure 1). In line with our hypotheses, both occasional reinforced trials during extinction,  $F(2.04, 114.42) = 6.75$ ,  $p = .002$ ,  $\eta_p^2 = .11$ , and unpaired USs,  $F(2.44, 136.41) = 3.73$ ,  $p = .02$ ,  $\eta_p^2 = .11$ , slowed down reacquisition relative to normal

extinction. Furthermore, reacquisition differed between the OR and UNP conditions,  $F(2.49, 139.25) = 2.83, p = .05, \eta_p^2 = .05$ . This could indicate occasional reinforced trials during extinction to be more effective in reducing the speed of reacquisition than unpaired USs during extinction, although the drawing of any conclusions regarding differences in reacquisition patterns between the OR vs. UNP conditions is complicated by the fact that expectancies differed on reacquisition trial 1. Impulsivity did not moderate reacquisition ( $CS \times T \times I; CS \times T \times C \times I$ ),  $F = 2.28, ns, F < 1$ . Thus, as expected, provision of unpaired USs and, possibly even more so, occasional reinforced trials during extinction reduced the speed of reacquisition of US expectancies.

### Desire to eat

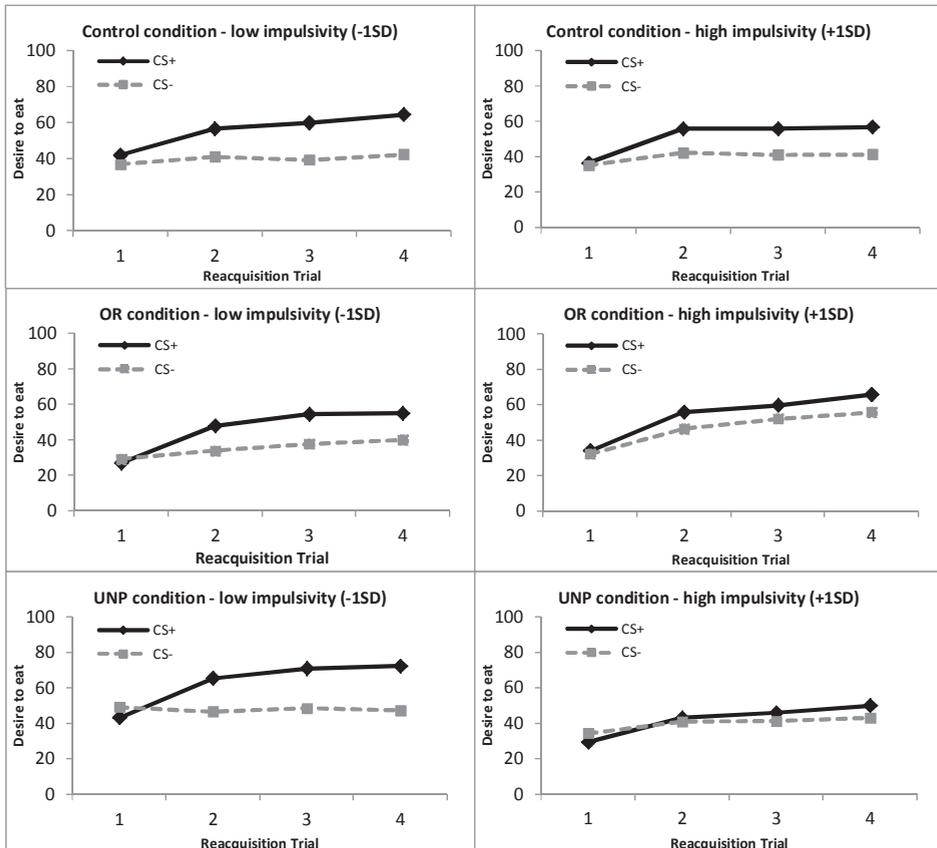
Participants developed a conditioned desire to eat, as shown by a significant  $CS \times T$  interaction,  $F(2.93, 246.33) = 14.98, p < .001, \eta_p^2 = .15$ , this acquisition being similar across conditions ( $CS \times T \times C$ ),  $F < 1$  (see Figure 2). Impulsivity did not moderate these interactions ( $CS \times T \times I; CS \times T \times C \times I$ ),  $F_s < 1$ . A significantly larger desire in response to the CS+ compared to the CS- was present on trial 5,  $F(1, 84) = 42.22, p < .001, \eta_p^2 = .34$ , with no differences across conditions,  $F < 1$ .

The differentiation was still present in the first block of the extinction phase,  $F(1, 84) = 30.64, p < .001, \eta_p^2 = .27$ , with no differences across conditions,  $F < 1$ . Overall, differential desires decreased during extinction ( $CS \times B$ ),  $F(2.56, 215.33) = 3.12, p = .03, \eta_p^2 = .04$ , and this extinction interacted with condition ( $CS$



**Figure 2.** Mean desire for chocolate mousse by CS-type, trial or block, condition, and phase of the experiment.

$\times B \times C$ ),  $F(5.13, 215.33) = 2.61, p = .03, \eta_p^2 = .06$  (see Figure 2). Next, extinction across each pair of conditions was examined. Conditioned desires extinguished similarly in the control vs. UNP condition,  $F < 1$ , but both differed from the OR condition,  $F(2.51, 140.42) = 4.83, p = .005, \eta_p^2 = .08$ ;  $F(2.71, 152.02) = 2.77, p = .05, \eta_p^2 = .05$ . To further examine these significant differences, analyses were conducted on differentiations between the CS+ and CS- scores on each block using a Bonferroni-corrected alpha of .0125. On the second extinction block, the differentiations in the control and UNP conditions were smaller than the differentiation in the OR condition, control vs. OR:  $F(1, 56) = 7.85, p = .007, \eta_p^2 = .12$ ; OR vs. UNP:  $F(1, 56) = 7.23, p = .009, \eta_p^2 = .11$ . On the subsequent blocks (3 – 5), differential desires appeared similar across these pairs of conditions, control vs. OR block 3–5:  $F(1, 56) = 2.32, p = .13, \eta_p^2 = .04, F(1, 56) = 4.27, p = .044, \eta_p^2 = .07$ ;  $F = 1.62, ns$ , OR vs. UNP block 3 – 5:  $F(1, 56) = 2.21, p = .14, \eta_p^2 = .04$ ;  $F(1,$



**Figure 3.** Relationships between impulsivity and mean desire for chocolate mousse during reacquisition by CS-type, trial, and condition. Low vs. high impulsivity reflect desire ratings 1 SD below vs. above the mean of the BIS-11.

56) = 3.30,  $p = .08$ ,  $\eta_p^2 = .06$ ;  $F < 1$ . On block 5, a differentiation between the CS+ and CS- was still present,  $F(1, 84) = 22.10$ ,  $p < .001$ ,  $\eta_p^2 = .21$ , that was similar across conditions,  $F < 1$ . Thus, overall, this pattern of results suggests a delayed extinction of conditioned desires when occasional reinforcements are given during extinction. The results further suggest that extinction of conditioned desires was successful to some extent, although it was not complete. Impulsivity did not moderate extinction performance (CS  $\times$  B  $\times$  I; CS  $\times$  B  $\times$  C  $\times$  I),  $F_s < 1$ .

On reacquisition trial 1, no differentiation was present anymore,  $F < 1$ , although there was a trend that the differentiation differed across conditions,  $F(2, 84) = 2.56$ ,  $p = .08$ ,  $\eta_p^2 = .06$ . Reacquisition was significant (CS  $\times$  T),  $F(2.33, 195.67) = 45.11$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , with no differences across conditions, (CS  $\times$  T  $\times$  C),  $F = 1.01$  (see Figure 2). Impulsivity moderated the reacquisition of the desire for chocolate mousse (CS  $\times$  T  $\times$  I),  $F(2.33, 195.67) = 5.08$ ,  $p = .005$ ,  $\eta_p^2 = .06$ : impulsivity was associated with a less pronounced reacquisition of conditioned desires, independent of condition (CS  $\times$  T  $\times$  C  $\times$  I),  $F = 1.40$ , *ns* (see Figure 3). On reacquisition trial 4, a significant differentiation between the CS+ and CS- was present,  $F(1, 84) = 60.11$ ,  $p < .001$ ,  $\eta_p^2 = .42$ , with no differences across conditions,  $F < 1$ . Higher impulsivity was associated with a smaller differentiation on this trial,  $F(1, 84) = 5.91$ ,  $p = .02$ ,  $\eta_p^2 = .07$ , independent of condition,  $F = 1.04$ .

### Salivation

Salivation data of one participant was missing. Salivation differed across measurements (baseline, CS+ and CS- reacquisition),  $F(2, 166) = 6.87$ ,  $p = .001$ ,  $\eta_p^2 = .08$ , independent of condition,  $F = 1.21$ , *ns*, impulsivity,  $F < 1$ , and their interaction,  $F = 1.13$ , *ns*. Salivation increased from baseline to CS+ ( $p = .001$ ) and from baseline to CS- ( $p = .02$ ), but salivation was similar for the CS+ and CS- ( $p = .27$ ). Thus, no clear evidence was found for a conditioned salivary response [grams M (SD) control: baseline 0.36 (0.30); CS+ 0.51 (0.31); CS- 0.50 (0.30); OR: baseline 0.44 (0.38); CS+ 0.48 (0.32); CS- 0.43 (0.34); UNP: baseline 0.39 (0.24); CS+ 0.51 (0.41); CS- 0.47 (0.37)].

### CS preference

The CS+ was preferred over the CS- by 74 participants (82.2%),  $p < .001$ . CS preference did not differ across conditions,  $c^2(1, N = 90) = 0.15$ ,  $p = .93$ .

## Discussion

In this study, the effects of different extinction procedures on the extinction and reacquisition of appetitive responses to food-associated cues were assessed. Additionally, it was examined whether impulsivity would affect conditioned responses. The results were partly in line with our hypotheses. Participants who received occasional reinforcements during extinction (OR condition) clearly showed a delayed extinction of US expectancies compared with participants who received normal extinction or unpaired presentations of the US during extinction (UNP condition). A comparable pattern was found for the desire to eat, although complete extinction of eating desires did not seem to be achieved in any of the conditions. Following the extinction procedures, participants received renewed CS–US pairings. In line with our hypotheses, a slower reacquisition of US expectancies was present in the OR and UNP conditions relative to the control condition. However, this pattern was not reflected in desire ratings: the conditions showed a similar reacquisition of conditioned desires to eat. Impulsivity did not moderate acquisition or extinction patterns, but was associated with a less pronounced reacquisition of the desire for chocolate mousse. Further, significant differences in salivation in response to the CS+ and CS– were not found. Finally, participants showed a clear conditioned preference for the CS+ on a forced-choice task.

The finding that in humans, extinction of US expectancies and conditioned desires is slower when the CS has been occasionally reinforced by an appetitive US during extinction is new, and in line with experiments conducted in rats showing a slower loss of responding to the CS+ during extinction (Bouton et al., 2004). Note that this altered extinction is specific to reinforcement of the CS–US bond and not due to the mere fact that chocolate mousse was ingested during extinction, since extinction patterns in the UNP condition were mostly similar to those in the control condition. Another new finding is the slower reacquisition of US expectancies in the OR and UNP conditions relative to the control condition, which is also in line with rat studies (e.g., Bouton et al., 2004; Rauhut et al., 2001). Thus, it seems that, like rats, human participants may learn to associate a previously occasionally reinforced appetitive CS with a decreased chance of subsequent reinforcement of the CS. Presentation of unpaired USs during extinction seems similarly effective in reducing the magnitude of return of US expectancies that occurs during reacquisition, possibly because USs become associated with extinction, increasing generalization from extinction to reacquisition (see Bouton et al., 2004 and Vervliet et al., 2010). Thus, judging from the present US expectancy data, occasional reinforcements and unpaired US presentations during extinction could be effective

in reducing reacquisition in dieters who have achieved (some extent of) extinction of a food CS.

Although it is thought that US expectancies provide information about an important component of Pavlovian conditioning (Boddez et al., 2013; Mitchell, De Houwer, & Lovibond, 2009), it has to be noted that the reacquisition pattern of conditioned desires did not support our hypothesis: reacquisition of conditioned desires was not slower for the OR and UNP conditions even though US expectancies showed this pattern. These apparently divergent findings are in line with findings of previous human appetitive conditioning studies. While US expectancies and desires often change in parallel during acquisition, extinction of conditioned desires seems to be more difficult to achieve than extinction of US expectancies (Papachristou et al., 2013; Van Gucht et al., 2008), and we previously reported similarly divergent response patterns during reacquisition (van den Akker et al., 2014). This suggests the presence of different response systems that are differentially sensitive to different phases of conditioning (Papachristou et al., 2013; Van Gucht et al., 2008). With regard to eating desires, it has been noted that the difficulty to extinguish conditioned appetitive motivation resembles findings in evaluative conditioning studies: conditioned evaluations often do not show sensitivity to extinction (De Houwer, Thomas, & Baeyens, 2001), and this seems to be the case as well for conditioned evaluations of food CSs (Papachristou et al., 2013; Van Gucht et al., 2008). In contrast, US expectancies have been proposed to reflect another response system related to preparatory reactions to food cues (Van Gucht et al., 2008). Another explanation for the response divergence might however be that in the present and previous experiments, extinction of US expectancies is often not complete either. Therefore, it cannot be ruled out that a small but significant differentiation in US expectancies that remains at the end of extinction causes the incomplete extinction of conditioned desires. Thus, it is possible that a complete extinction of expectancies would have resulted in an equally complete extinction of desires (but see Papachristou et al., 2013). Similarly, in case of reacquisition, it might be that the relatively slight reductions in returns of US expectancies during reacquisition were not sufficient to reduce the magnitude of reacquisition of conditioned desires. If US expectancies indeed need to be diminished more to achieve this, techniques that are able to further reduce a return of US expectancies during reacquisition might be crucial in diminishing this return of conditioned desires – for instance, more elaborate extinction techniques involving a greater number of occasional reinforcements and unpaired USs.

The present findings may have implications for increasing dieting success. Judging from the US expectancy data (i.e., a less rapid reacquisition in the OR and UNP conditions), the implication would be that dieters could, on the long-term,

benefit from occasional lapses in their diet, if these lapses are followed by adherence to their diet (i.e., nonreinforced food cues). However, in our study, occasional reinforced extinction did not slow down the reacquisition of eating desires, while desires/cravings for food are thought to be important predictors for actual eating behaviour and relapse (e.g., Rudak & Thomas, 2009). Additionally, unsuccessful dieters seem to more frequently eat high-calorie or ‘forbidden foods’ during their diets (Wing & Hill, 2001). This raises the question whether occasional lapsing can improve dieting success, and if so, whether perhaps the manner or extent of lapsing matters. It seems too early however to conclude from the present data that occasional snacking during a diet can increase dieting success. Another way for occasional reinforced extinction to increase dieting success might be by reducing overeating within one eating episode, for instance when individuals consider their diet “broken” after one bite of forbidden food and subsequently engage in disinhibited eating. Such overeating may be prevented if individuals learn to associate one small snack (the CS) with no further (over)eating (Bouton, 2011). Finally, the results also suggest it might be beneficial to provide USs unpaired from their CSs. One obvious issue with implementing unpaired procedures to reduce responding to CSs is that this seems only practically possible for food cues that do not entail the sight, smell, or taste of food, since these CSs are usually present when food is consumed. However, this does not mean unpaired procedures cannot be utilized. In fact, consuming (moderate amounts of) binge foods in non-binge situations has previously been recommended to more successfully break the exclusive bond between binge cues and binge eating (Jansen, 1998).

In this study, impulsivity did not seem to be related to a slower extinction of US expectancies. This finding is in contrast with two previous studies conducted in our lab in which a design was used very similar to the one in the present study (van den Akker et al., 2014). Slight differences with the previous designs were present: as opposed to the previous studies, no salivation measurements were conducted during the procedure, and slightly shorter total trial times were used (approximately three seconds). However, it is not clear how these alterations may counteract effects of impulsivity on extinction performance. Interestingly, impulsivity was associated with a reduced rate of reacquisition of conditioned desires to eat. This result is in contrast with a study reporting negative relationships between impulsivity and weight loss success (Nederkoorn et al., 2007), and with several addiction studies showing positive associations between impulsivity and risk of relapse (e.g., Doran, Spring, McChargue, Pergadia, & Richmond, 2004; Yoon et al., 2007). However, we have previously found impulsivity to moderate reacquisition of conditioned desires in precisely the manner reported here (van den Akker et al., 2014, study 2), and, in fact, some studies have associated higher impulsivity with

*lower* relapse rates after treatment and *greater* benefits from a weight reduction program in overweight children (Papachristou, Nederkoorn, Giesen, & Jansen, 2014; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010). The authors suggested that their impulsive participants might have benefitted more from certain aspects of the behaviour modification therapies that they had received, and one could speculate that the present extinction procedures have tapped into similar underlying constructs. Clearly, more research on the role of impulsivity in extinction and reacquisition of appetitive responses, and the relationship with clinical outcomes, is needed. Also, since only female students were included in the current study, it has yet to be examined whether the present findings would generalize to male and non-student populations.

In sum, provision of occasional reinforcements and unpaired USs during extinction seem promising techniques to reduce reacquisition, although beneficial effects on reacquisition were not evident for the desire to eat. Future studies should aim to find out what exactly causes the divergent patterns of appetitive motivation and US expectancies and how these relate to dieting success. Weight loss methods may be improved by including trainings that successfully reduce reacquisition of appetitive responses, while, ideally, increasing the loss of responding during extinction.

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# Chapter 6

## **How partial reinforcement of food cues affects the extinction and reacquisition of appetitive responses. A new model for dieting success?**

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## Abstract

Animals and humans can easily learn to associate an initially neutral cue with food intake through classical conditioning, but extinction of learned appetitive responses can be more difficult. Intermittent or partial reinforcement of food cues causes especially persistent behaviour in animals: after exposure to such learning schedules, the decline in responding that occurs during extinction is slow. After extinction, increases in responding with renewed reinforcement of food cues (reacquisition) might be less rapid after acquisition with partial reinforcement. In humans, it may be that the eating behaviour of some individuals resembles partial reinforcement schedules to a greater extent, possibly affecting dieting success by interacting with extinction and reacquisition. Furthermore, impulsivity has been associated with less successful dieting, and this association might be explained by impulsivity affecting the learning and extinction of appetitive responses. In the present two studies, the effects of different reinforcement schedules and impulsivity on the acquisition, extinction, and reacquisition of appetitive responses were investigated in a conditioning paradigm involving food rewards in healthy humans. Overall, the results indicate both partial reinforcement schedules and, possibly, impulsivity to be associated with worse extinction performance. A new model of dieting success is proposed: learning histories and, perhaps, certain personality traits (impulsivity) can interfere with the extinction and reacquisition of appetitive responses to food cues and they may be causally related to unsuccessful dieting.

**Keywords:** appetitive conditioning, dieting success, unsuccessful dieting, partial reinforcement, impulsivity, extinction

## Introduction

As obesity prevalence continues to rise, so do attempts to lose weight by restricting dietary intake (Hill, 2002). In a U.S. sample, as many as 60% of overweight and 70% of obese women reported to be currently trying to lose weight (Bish et al., 2005). However, successful long-term weight loss is rare, and weight loss practices have even been linked to binge eating, weight gain and the development of obesity (e.g., Field et al., 2003; Jeffery et al., 2000; Neumark-Sztainer et al., 2006; Stice, Presnell, Shaw, & Rohde, 2005). Learning models can help explain why successful long-term weight loss is so difficult (Bouton, 2011; Jansen, 1998). After conditioned stimuli (CSs) have become associated with food intake (unconditioned stimulus; US), they will elicit conditioned responses (CRs). Exposure to a CS can induce (strong) desires for food, and may promote food consumption (e.g., Boggiano, Dorsey, Thomas, & Murdaugh, 2009; Jansen, 1998).

Conditioning phenomena could also explain why some dieters are able to adhere to their diets more successfully than others. Intermittent reinforcement of conditioned food cues (i.e., the alternation of intake and restriction in response to food cues) has long been known to result in persistent conditioning effects in animals. For instance, rats that do not always receive a food US when presented with a CS (e.g., on 50% of the trials) are known to perform worse in an extinction training in which the CS is never followed anymore by the US, compared with rats that had received a 100% contingency conditioning procedure (e.g., Bouton, Woods, & Todd, 2014; Haselgrove, Aydin, & Pearce, 2004). Thus, paradoxically, although the reinforcement schedule is leaner in rats receiving partial (e.g., 50% contingency) instead of continuous (100% contingency) reinforcement, extinction is more difficult. This difficulty to extinguish conditioned responses after partial reinforcement is known as the partial reinforcement extinction effect (PREE). It is thought that the PREE occurs because, in case of partial reinforcement, the animal has received reward under conditions of nonreinforcement: extinction is harder to achieve because a nonreinforced CS signals possible US availability on the next trial (e.g., Amsel, 1962; Capaldi, 1994). Consequently, reward is expected after nonreinforced CS trials during extinction and appetitive responses are more persistent. Further, it can be argued that original learning with either continuous or partial reinforcement might result in differential response patterns when the CS-US contingency is again reinforced after extinction, i.e. during a reacquisition phase. Reacquisition after extinguished responses to a continuous schedule is often rapid (e.g., Ricker & Bouton, 1996); however, one might expect that the return of appetitive responses during reacquisition after extinction is less pronounced

after partial reinforcement because a reinforced CS does not predict (as strongly) that the subsequent trial will be reinforced.

It seems likely that there are intra- and inter-individual differences in the extent to which food cues are reinforced, and thus, the extent to which partial reinforcement is practiced. For instance, an individual might consume breakfast at a relatively similar timepoint every day while less consistently eating a snack in the afternoon, alternating 'eating' and 'not eating' on a day-to-day basis for some cues. Over time, the predominant learning schedule for inconsistently reinforced food cues essentially reflects partial reinforcement schedules. Additionally, across individuals, it seems likely that overall patterns of reinforcement differ: some may practice partial reinforcement to a greater extent than others. For instance, some individuals may show a relatively inconsistent eating pattern, reinforcing and nonreinforcing different sets of cues each day (e.g., Kirk & Hill, 1997). When an individual starts a diet, extinction is presumably practiced because he or she is attempting to refrain from eating (US) in response to previously reinforced cues (CS). The PREE would predict that this extinction is more difficult to achieve for those who previously practiced a greater degree of partial reinforcement. A more difficult extinction of conditioned responses would theoretically result in a greater difficulty to refrain from eating in response to those cues: during extinction of previously partially reinforced cues, a dieter's body keeps expecting to receive food in response to such cues (i.e., they experience PREEs). Thus, the dieter could experience heightened conditioned cravings for foods even after a period in which he or she has suppressed responses to the cues. However, when a dieter has successfully extinguished these responses and thus has overcome the PREE, one could expect that a history of partial reinforcement could be beneficial for long-term weight maintenance. Since returns of appetitive responses after extinction ("relapse") are thought to considerably thwart dieting efforts (Bouton, 2011), a history of partial reinforcement could decrease chances for a full-blown relapse because they may slow down reacquisition. To gain insight into the underlying mechanisms behind individual differences in dieting success, examining causes of potential differences in the extinction and reacquisition of appetitive responses could prove valuable.

Apart from learning histories, personality characteristics could also affect dieting success. Impulsivity has been especially associated with increased cue reactivity, overeating, and obesity (Guerrieri, Nederkoorn, & Jansen, 2008; Tetley, Brunstrom, & Griffiths, 2010). Importantly, impulsivity has been found to distinguish successful from less successful dieters – impulsivity has been related to less weight loss during a weight loss treatment (e.g., Nederkoorn, Jansen, Mulken, & Jansen, 2007), less successful self-reported dieting (e.g., van Koningsbruggen, Stroebe, &

Aarts, 2013), and in the lab, restrained eaters (dieters) only overate when they were also impulsive (Jansen et al., 2009). Also, it seems that impulsiveness increases the risk for relapse in addicts (e.g., Doran, Spring, McChargue, Pergadia, & Richmond, 2004), and evidence suggests that treatment outcome and maintenance could be improved by targeting impulsivity (Houben & Jansen, 2011; Houben, Wiers, & Jansen, 2011; Verbeken, Braet, Goossens, & van der Oord, 2013). It is possible that a relationship between impulsivity and unsuccessful dieting could be explained by differences in the learning and ‘unlearning’ of conditioned responses to rewarding cues between more and less impulsive individuals. For instance, different aspects of impulsivity have been theoretically associated with an increased speed of acquisition of appetitive responses, although empirical tests have been inconclusive (Corr, 2001, 2002; Corr, Pickering, & Gray, 1995; Dawe, Gullo, & Loxton, 2004; Gorenstein & Newman, 1980; Papachristou, Nederkoorn, Beunen, & Jansen, 2013; Patterson & Newman, 1993; van den Akker, Jansen, Frentz, & Havermans, 2013). Further, one specific aspect of impulsivity, rash impulsiveness or the inability to inhibit predominant approach responses (as measured by the BIS-11) (Dawe et al., 2004; Patton, Stanford, & Barratt, 1995), could be associated with impaired extinction. The underlying neural structure of rash impulsiveness is the orbitofrontal cortex (OFC): worse functioning of the OFC has been related to higher rash impulsiveness in healthy individuals (see Dawe et al., 2004; Horn, Dolan, Elliott, Deakin, & Woodruff, 2003). Investigations in rodents, monkeys, and humans have resulted in the conclusion that the OFC is necessary for integrating changing information about a reward and providing new estimations about expected outcomes, that is, learning when reward contingencies change (e.g., Butter, 1969; Gallagher, McMahan, & Schoenbaum, 1999; McDannald, Jones, Takahashi, & Schoenbaum, 2014; Rolls, 2000, 2004; Schoenbaum & Esber, 2010; Schoenbaum, Roesch, Stalnaker, & Takahashi, 2009). A relatively poor functioning OFC in rash impulsive individuals could therefore result in less correct estimates of expected outcomes when CS-US contingencies are altered during extinction, i.e. resulting in extinction deficits. The present studies investigate whether a measure of rash impulsiveness influences the acquisition and extinction of appetitive responses.

In sum, dieters who previously practiced intermittent reinforcement of food cues might be less successful in restricting their food intake through difficulties in achieving extinction (i.e., they might experience a PREE), while simultaneously being at reduced risk for relapse once extinction has been achieved. However, relatively few human appetitive conditioning studies involving food rewards have been conducted (e.g., Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008), and none examined effects of partial reinforcement on conditioned responses to

food cues. The present two studies were designed to test the hypothesis that an appetitive partial reinforcement schedule causes a PREE in healthy humans and slows down a return of appetitive responses when CSs are reinforced again after extinction. Since impulsivity has theoretically been associated with a possibly faster acquisition of conditioned appetitive responses and slower extinction, the influence of impulsivity on the different phases of conditioning was also investigated.

## STUDY 1

### Methods and materials

#### Participants

Thirty-two participants took part in the study. Three participants did not develop a differential US expectancy, suggesting they were not aware of the CS–US contingency. They were replaced by three other participants ensuring full counterbalancing. All participants were undergraduate female students who were proficient in Dutch and indicated a liking for chocolate. Participants were instructed to have a small meal two hours prior to participation but to refrain from calorie intake thereafter. To reduce demand characteristics participants were told the study's aim was to investigate the memory of taste. Participants received either € 7,50 or course credit for participation. A local ethical committee approved the study.

#### Measurements

*Desire and US expectancy:* 100mm-Visual Analogue Scales (VAS) were used to assess subjective desire for chocolate mousse (*'How strong is your desire for chocolate mousse at this moment?'*) and expectancy to taste chocolate mousse (*'How strong do you expect to receive chocolate mousse at this moment?'*). Ratings ranged from 0 (*no desire at all / certainly expect not to taste chocolate mousse*) to 100 (*very strong desire / certainly expect to taste chocolate mousse*). The order of presentation of these two questions was counterbalanced.

*Salivation:* Salivation was measured using dental rolls (Hartmann, nr 2, 10×35 mm) which the participant placed and removed herself. Two dental rolls were placed between the cheek and lower gum on the left and right side. They were removed after precisely one minute. The dental rolls were kept in a sealed plastic bag and their weight was registered before and after the saliva was collected, using a weighing scale accurate to 0.01 g (Mettler Toledo, PB3002).

*CS preference:* After the experiment, participants indicated their CS preference (CS+ or CS-) ('If you were allowed to take one of the boxes home, which one would you pick?').

*Hunger:* To control for hunger, participants filled in a VAS ('How hungry are you at this moment?') ranging from 0 (*not hungry at all*) to 100 (*extremely hungry*) before and after the conditioning procedure.

*Chocolate mousse liking:* To control for differences in the liking of chocolate mousse, participants filled in a VAS ('How much did you like the chocolate mousse?') ranging from 0 (*not at all*) to 100 (*extremely*).

*Barrett Impulsivity Scale-11 (BIS-11; Patton, Stanford et al. 1995):* The BIS-11 was used to measure impulsivity. The BIS-11 is a self-report questionnaire and consists of 30 items. Each statement can be rated on a 4-point scale, ranging from *rarely/never* to *always/almost always*. Total scores were calculated, a higher score indicating higher impulsiveness. The BIS-11 has good internal consistency and is well validated (Patton et al., 1995; Stanford et al., 2009). The internal consistency of the total BIS-11 score in the current studies was good (Cronbach's alpha of study 1: .79; study 2: .90).

*Revised Restraint Scale (RS; Polivy, Herman, & Howard, 1988):* To control for differences in dietary restraint (i.e. the intention to restrict food intake) the 10-item RS was used. Scores range from 0–35, a higher score indicating increased intentions to restrain intake. The RS is thought to be a reliable measure of dieting (Lowe & Thomas, 2009).

All questionnaires were administered in Dutch.

## Stimuli

*US:* A small portion of chocolate mousse (approximately 2 g, Almhof) served in a small cup with a teaspoon served as US. During the experiment, the USs were kept in a cooler and out of sight of the participants.

*CS:* Two children's jewelry boxes served as CSs, and contained the US only in case of a CS+ trial. One box depicted an elephant ('Elmer the Patchwork Elephant'), had coloured squares and yellow linings, and the other depicted fish ('The Rainbow Fish') and was blue<sup>1</sup>. Which box served as CS+ and CS- was counterbalanced. The CS+ box was also used as CS0 (CS+ box but no US) in the partial reinforcement condition and during extinction.

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<sup>1</sup> The characters depicted on the boxes are based on children's books.

## Design and procedure

Participants were seen individually between 11 AM and 6 PM. For both studies, testing times were distributed equally across the conditions. Participants gave written consent after arrival in the laboratory, and filled in a hunger VAS. A baseline salivation measurement was then conducted. After that, the participants were shown the jewelry boxes and were informed that they would be repeatedly asked to open them during the experiment. They were then explicitly instructed that one of these boxes sometimes contained something they would eat, whereas the other box would never contain anything. This was done because there is currently a wide consensus that explicit contingency learning is an important component of conditioning (Boddez et al., 2013), and that it might even be necessary for conditioning to occur (Lovibond & Shanks, 2002). After this, the conditioning procedure started.

Participants were randomly assigned to a continuous reinforcement (CRF) condition or a partial reinforcement (PRF) condition (to be shown later). The instructions given during the experiment were pre-recorded. A trial started when a closed box was placed in front of the participant. After 10 seconds, desire and US expectancy VAS were filled in. The participant then opened the box, and in case of a CS+ trial, she ate the chocolate mousse that was inside the box. In both the CS+ and CS- trials, she closed the box again, followed by an inter-trial interval (ITI) of 10 seconds, after which the next trial started. The order of the presentation of the trials was random with the restriction that no more than two consecutive trials were of the same trial type (CS+, CS0 or CS-). Further, two of the same trial types were never spaced apart by more than four other trial types. At baseline, and at the last acquisition, extinction, and reacquisition trials, salivation was measured. Trials were halted during salivation measurements. These measurements were conducted after participants had filled in the desire and expectancy VAS, but before the lids of the boxes were opened. When the cotton roles were removed again, participants took a sip of water to rinse their mouths. The order of the salivation measurements (CS+ or CS- first) at the end of acquisition was counterbalanced. After the acquisition, extinction, and reacquisition phase were completed, participants filled in questionnaires on their idea about the study's hypothesis, CS preference, hunger, BIS-11, RS, liking of the chocolate mousse and time of pre-experimental food intake.

## Acquisition, extinction, and reacquisition

*CRF:* During acquisition, participants in the CRF condition received 6 CS+ trials and 6 CS- trials.

*PRF*: During acquisition, participants in the PRF condition were given a 50% reinforcement schedule. Participants received 6 CS+ trials, 6 nonreinforced CS0 trials, and 6 CS- trials. Trial durations were kept similar for the CRF and PRF conditions to achieve similar associative strengths across the conditions (Subtract R method; Bouton & Sunsay, 2003).

During extinction, participants received 12 CS0 trials. No CS- trials were included after the acquisition phase as an attempt to limit the length of the procedure and to avoid high levels of boredom in participants. After extinction, all participants received 4 CS+ trials to test for differences in reacquisition.

### Statistical analyses and data reduction

The twelve extinction trials were averaged into four blocks of three trials. Differential acquisition of the desire to eat and US expectancy across conditions were analyzed by using a 2 (Condition: CRF vs. PRF) x 2 (CS-type: CS+ vs. CS-) x 6 (Acquisition trial) repeated-measures ANCOVA, including CS-type (CS) and trial (T) as within-subjects factors and condition (C) as between-subjects factor. Analyses were performed on US expectancy and desire for chocolate mousse ratings given during CS+ and CS- trials. Because no CS- trials were included after the acquisition phase, analyses on extinction and reacquisition were performed on CS0 (extinction) and CS+ (reacquisition) scores only. Extinction and reacquisition were analyzed by separate 2 (Condition: CRF vs. PRF) x 4 (Extinction block [B] or Reacquisition trial) repeated-measures ANCOVAs. The total score of the BIS-11 was centered and included as covariate in the ANCOVAs to assess effects of impulsivity (I) on responses during conditioning, extinction and reacquisition. If necessary, additional analyses were performed to explore significant interactions.

Acquisition of a salivary response was also analyzed using repeated-measures ANCOVA, with measurement type (baseline, CS+, CS-) as within-subjects variable, condition as between-subjects factor, and the centered score of the BIS-11 as covariate. Significant interactions were examined using pairwise comparisons. CS preference (CS+ or CS-) was analyzed using binomial tests. Chi-square Likelihood Ratio tests were used to assess differences in CS preference across conditions. Greenhouse-Geisser epsilon corrections are reported for all repeated-measures analyses whenever sphericity was violated. Partial eta squared ( $\eta_p^2$ ) is reported as a measure of effect size.

## Results

### Participant characteristics

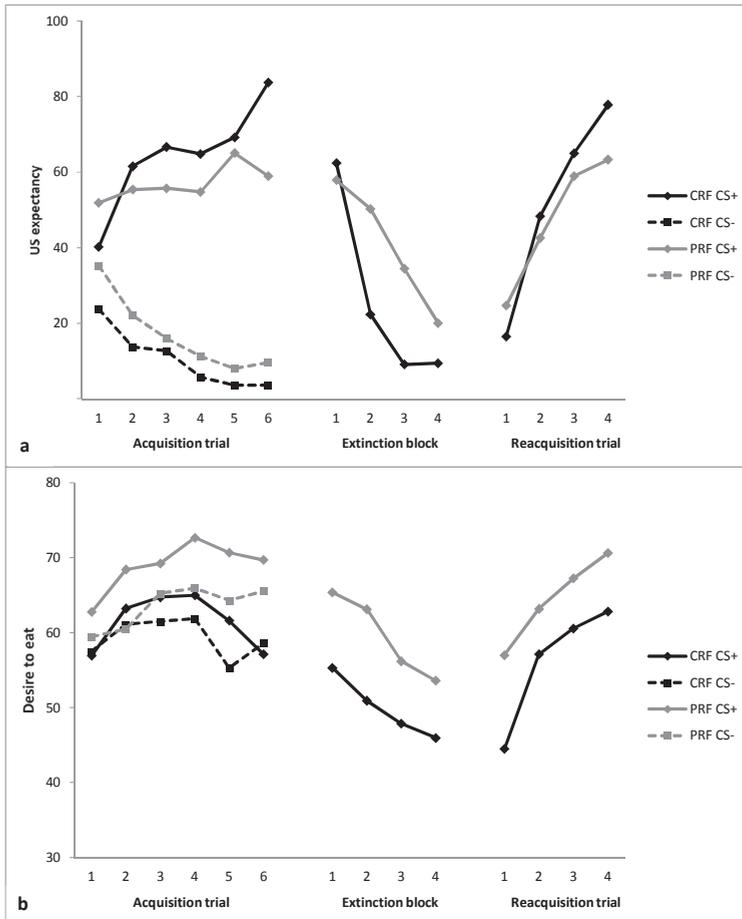
No significant differences across conditions were found for age, BMI, hunger, BIS-11, RS, and liking of chocolate mousse (see Table 1, Study 1).

**Table 1.** Participant characteristics per study and across conditions, means with standard deviations in parentheses.

	CRF	PRF	<i>F</i> (1, 30)	<i>p</i>
<b>Study 1</b>				
<i>n</i>	16	16		
<i>Age</i>	19.6 (1.7)	19.4 (1.0)	0.06	.80
<i>BMI</i>	22.9 (5.2)	21.4 (2.7)	1.05	.32
<i>Baseline hunger</i>	42.6 (20.3)	51.6 (22.5)	1.41	.24
<i>Post hunger</i>	42.2 (21.0)	51.9 (21.1)	1.69	.20
<i>BIS-11 total</i>	58.8 (9.8)	58.1 (7.1)	0.06	.54
<i>RS</i>	12.5 (4.9)	10.9 (4.2)	1.03	.81
<i>Chocolate mousse liking</i>	77.4 (14.2)	80.2 (10.6)	0.39	.32
<b>Study 2</b>				
<i>n</i>	24	24		
<i>Age</i>	20.1 (1.9)	20.1 (1.6)	0.00	> .99
<i>BMI</i>	22.7 (3.7)	22.8 (2.8)	0.02	.90
<i>Baseline hunger</i>	48.1 (21.8)	52.8 (17.9)	0.67	.42
<i>Post hunger</i>	45.7 (31.2)	41.5 (19.4)	0.31	.58
<i>BIS-11 total</i>	58.0 (11.2)	58.5 (11.7)	0.02	.88
<i>RS</i>	12.2 (5.5)	14.1 (5.4)	1.49	.23
<i>Chocolate mousse liking</i>	77.8 (20.1)	79.4 (14.7)	0.09	.76

### US expectancy

A differential acquisition of US expectancies (i.e., US expectancy is higher over time in response to the CS+ vs. CS-) was present, as indicated by a significant CS × T interaction,  $F(3.85, 107.80) = 18.79, p < .001, \eta_p^2 = .40$ , with no significant differences across conditions (CS × T × C),  $F(3.85, 107.80) = 1.45, p = .22, \eta_p^2 = .05$  (see Figure 1a). On trial 6 a significant differentiation was present,  $F(1, 28) = 135.93, p < .001, \eta_p^2 = .83$ ; differential expectancy was larger in the CRF condition than the PRF condition (CS × C),  $F(1, 28) = 7.18, p = .012, \eta_p^2 = .20$ , and larger (though only marginally significant) in higher impulsives vs. lower impulsives (CS × I),  $F(1, 28) = 3.50, p = .07, \eta_p^2 = .11$ . Impulsivity influenced conditioned responses over

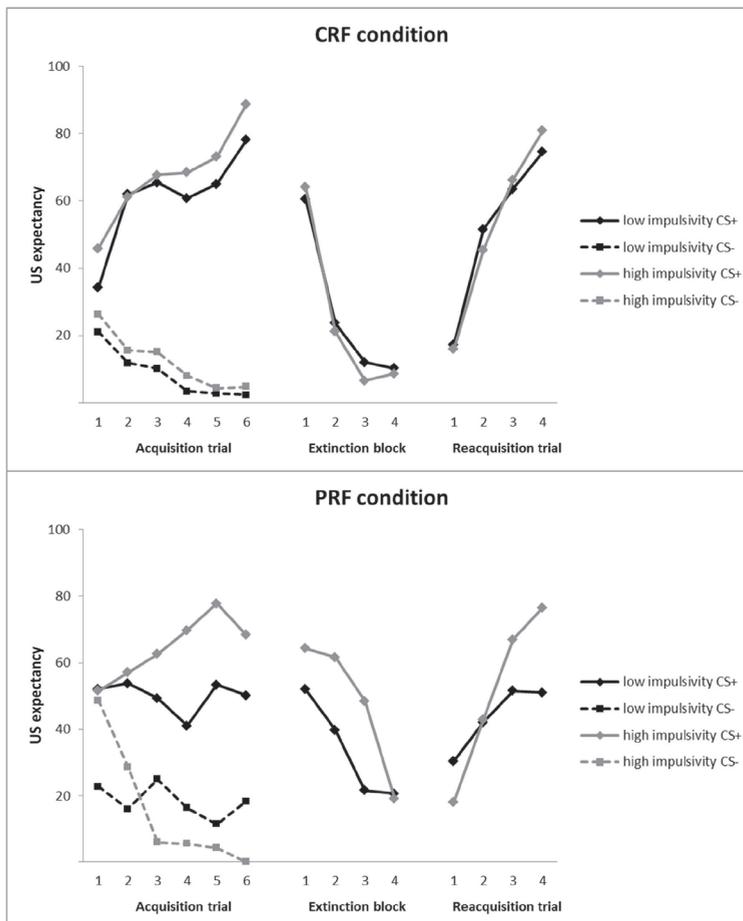


**Figure 1.** Mean US expectancy and desire for chocolate mousse, by CS-type, trial, condition, and phase of the experiment (study 1).

time, as evidenced by a significant CS  $\times$  T  $\times$  I interaction,  $F(3.85, 107.80) = 2.85$ ,  $p = .029$ ,  $\eta_p^2 = .09$ . Condition had a significant effect on this interaction, as evidenced by a CS  $\times$  T  $\times$  C  $\times$  I interaction,  $F(3.85, 107.80) = 2.54$ ,  $p = .046$ ,  $\eta_p^2 = .08$ . Follow-up tests showed that impulsivity did not affect responses within the CRF condition,  $F < 1$ , but did within the PRF condition (CS  $\times$  T  $\times$  I),  $F(5, 70) = 3.85$ ,  $p = .004$ ,  $\eta_p^2 = .22$ . These results suggest impulsivity to be related to larger US expectancies specifically within the PRF condition (see Figure 2)<sup>2</sup>.

<sup>2</sup> The differentiation on trial 1 did not differ significantly across conditions or levels of impulsivity,  $F$ 's  $< 1$ , nor by their interaction,  $F(1, 28) = 1.52$ ,  $p = .23$ ,  $\eta_p^2 = .05$ .

From the last acquisition trial to the first extinction block, the decrease in US expectancy in response to the CS+ was already larger for the CRF (vs. PRF) condition ( $T \times C$ ),  $F(1, 28) = 5.22, p = .03, \eta_p^2 = .16$ . There was an overall decrease in US expectancies throughout extinction,  $F(2.38, 66.67) = 116.25, p < .001, \eta_p^2 = .81$ , and as expected, this decrease was more pronounced for the CRF condition ( $T \times C$ ),  $F(2.38, 66.67) = 16.51, p < .001, \eta_p^2 = .37$ . (see Figure 1a). Using a Bonferroni-corrected alpha of .0125, pairwise comparisons suggested a facilitated extinction in the CRF condition: a smaller nondifferential US expectancy was found in the CRF condition vs. the PRF condition for block 2 ( $p < .001$ ) and block 3,  $p < .001$  (block 1:  $p = .28$ ; block 4:  $p = .03$ ). While impulsivity did not moderate extinction scores overall ( $T \times I$ ),  $F(2.38, 66.67) = 1.97, p = .14, \eta_p^2 = .07$ , the  $T \times C \times I$  interac-



**Figure 2.** Effects of impulsivity on mean US expectancy, by CS-type, trial, condition, and phase of the experiment. Low vs. high impulsivity reflect US expectancy scores 1 SD below vs. above the mean of the BIS-11 (study 1).

tion was significant,  $F(2.38, 66.67) = 2.45, p = .032, \eta_p^2 = .11$ . Follow-up analyses revealed no effects of impulsivity on extinction within the CRF condition ( $T \times I$ ),  $F < 1$ , while impulsivity was associated with differential extinction patterns within the PRF condition,  $F(3, 42) = 2.55, p = .028, \eta_p^2 = .21$ : within this condition, the more impulsive participants showed slower extinction (see Figure 2).

On the first reacquisition trial, there was no significant difference between the conditions in US expectancy,  $F < 1$ . Reacquisition of US expectancies was present,  $F(1.97, 55.07) = 61.19, p < .001, \eta_p^2 = .69$ , with a non-significant trend that is in line with our hypotheses suggesting a more rapid reacquisition in the CRF condition than in the PRF condition ( $T \times C$ ),  $F(1.97, 55.07) = 2.52, p = .09, \eta_p^2 = .08$  (see Figure 1a). The  $T \times I$  interaction was marginally significant,  $F(1.97, 55.07) = 2.98, p = .06, \eta_p^2 = .10$ , suggesting a moderating role of impulsivity in reacquisition: impulsivity was related to a more rapid reacquisition (see Figure 2). This interaction was independent of condition ( $T \times C \times I$ ),  $F(1.97, 55.07) = 1.14, p = .33, \eta_p^2 = .04$ . In line with this, both participants in the CRF condition and those with higher impulsivity showed significantly greater reacquisition scores on the last reacquisition trial,  $F(1, 28) = 4.20, p = .050, \eta_p^2 = .13, F(1, 28) = 4.84, p = .036, \eta_p^2 = .15$ . Thus, participants who received CRF and those who were more impulsive showed evidence of a more rapid reacquisition of US expectancies.

### Desire to eat

Acquisition of differential desire for chocolate mousse was not significant ( $CS \times T$ ), with no differences between conditions, ( $CS \times T \times C$ ),  $F_s < 1.04$ , or across levels of impulsivity ( $CS \times T \times I$ ),  $F(3.30, 92.49) = 1.69, p = .17, \eta_p^2 = .06$ . Thus, no evidence was found indicating a robust acquisition of the desire for chocolate mousse. Since a conditioned desire to eat cannot be extinguished if not first acquired, no statistical tests on extinction and reacquisition performance were conducted (see Figure 1b).

### Salivation

One participant was excluded from salivation analyses because she scored  $> 3$  SD above the mean on at least one of the measures used to assess acquisition (baseline, CS+, CS-) A main effect of time point was found (Baseline vs. CS+ vs. CS-),  $F(2, 54) = 4.86, p = .011, \eta_p^2 = .15$ : Bonferroni-corrected pairwise comparisons showed a significant increase from baseline to CS+ ( $p = .032$ ), while both the increase from baseline to CS- ( $p = .26$ ), and the difference between CS+ and CS- ( $p = .33$ ) was not. Interactions with condition and impulsivity were non-significant, as was the 3-way interaction,  $F_s < 1$ . The increase in responding to the CS+ but not CS- could be regarded as tentative evidence for a conditioned

salivation effect. However, strong evidence for acquisition of conditioned salivary responses would have taken the form of significantly higher salivation to CS+ than CS-. Because this was not found, statistical tests on extinction and reacquisition of salivary response were not conducted (see Table 2).

### CS liking

CS liking data of three participants were missing. At the end of the procedure, the CS+ was preferred above the CS- by 90% of the participants ( $n = 26$ ), binomial test,  $p < .001$ . Thus, participants showed evidence of conditioned positive evaluations of the CS+. Condition did not affect CS preference,  $\chi^2(1) = 0.31, p = .58$  (CS+ choice: CRF: 13 or 86.7%; PRF: 13 or 92.6%).

**Table 2.** Salivation in grams, by CS-type and condition at the end of the different phases of the experiment, means with standard deviations in parentheses (study 1).

	CRF condition (n = 15)	PRF condition (n = 16)
<i>Baseline</i>	0.37 (0.26)	0.27 (0.11)
<i>Acquisition</i>		
CS+	0.57 (0.35)	0.37 (0.18)
CS-	0.46 (0.27)	0.35 (0.21)
<i>Extinction</i>	0.44 (0.29)	0.29 (0.22)
<i>Reacquisition</i>	0.58 (0.33)	0.31 (0.16)

## Discussion

The US expectancy data were in line with the hypotheses. Participants receiving continuous or partial reinforcement learned to expect to eat chocolate mousse in the presence of a stimulus predicting the US. When the CS+ was no longer followed by the US during extinction, participants who received partial reinforcement were slower to extinguish their expectancies, compared with participants in the CRF condition. This reflects a PREE. Furthermore, participants in the CRF vs. PRF condition showed a more rapid reacquisition. However, these effects may have been caused by differences in acquisition levels or by nonassociative processes (e.g., differences in arousal).

Impulsivity had an effect on the acquisition, extinction, and reacquisition of US expectancies. More impulsive individuals showed a larger differential acquisition of expectancies in specifically the PRF condition, a more pronounced PREE, and a generally more rapid reacquisition of expectancies. Again, nonassociative

processes as well as differences in acquisition levels could be responsible for the patterns observed during extinction and reacquisition.

Conditioned positive evaluations of the CS+ were found, although this might be explained by an increased number of exposures to the CS+ vs. the CS- box. Further, no conditioned salivary response was found. Similarly, no reliable acquisition of conditioned desires was detected, which is in contrast to studies that used relatively similar conditioning procedures (e.g., Van Gucht et al., 2008). Before drawing any preliminary conclusions, the experiment was repeated with some adaptations to the design, including the use of a stronger, more salient US and larger sample size.

## **STUDY 2**

### **Introduction**

The findings of Study 1 were generally in favor of our hypotheses; however, the study's design could benefit from some improvements. Therefore, a second study was conducted, including the following changes: first, the number of acquisition trials was reduced to five; second, the US size was slightly increased to facilitate conditioning (Morris & Bouton, 2006); third, the desire question (VAS) was slightly altered to better direct the participants' attention towards the presented CS; fourth, CS- trials were included throughout all phases of the experiment to control for nonassociative processes. Because previous appetitive food conditioning studies in humans have generally not achieved successful extinction of the desire for food, a pilot study including these changes to the design was conducted first. The pilot data (unpublished) showed extinction to be complete within 12 trials following continuous reinforcement.

### **Methods and materials**

#### **Participants**

Forty-eight participants took part in this study. One participant was excluded from the study sample because she had a BMI of 15 and was considered substantially underweight. She was replaced by another participant to ensure complete counterbalancing.

### Measurements and stimuli

All measurements and stimuli were identical to those used in study 1 except for a few minor changes. The question stated on the desire-VAS was changed to 'When presented this box, how strong is your desire for chocolate mousse right now' (Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010). Furthermore, the US size was increased from ~2 g to ~3.5 g (i.e., one heaped teaspoon).

### Design and procedure

The design of study 2 was largely similar to the design used in study 1 except for the changes as discussed earlier. The order of salivation measurements (CS+ or CS- first) was counterbalanced across phases of the experiment. The order of the expectancy and desire VAS and which box served as CS+ or CS- was randomized across participants.

### Statistical analyses and missing data

Data analyses were identical to analyses in study 1, except for the analyses of extinction and reacquisition data since CS- trials were now included in these conditioning phases. Differential extinction and reacquisition of the desire to eat and US expectancies were analyzed by using 2 (Condition: CRF vs. PRF) x 2 (CS-type: CS+ vs. CS-) x 5 resp. 4 resp. 4 (Acquisition trial resp. Extinction block resp. Reacquisition trial) repeated-measures ANCOVAs, including CS-type and trial/block as within-subjects factors, condition as between-subjects factor, and the centered score of the BIS-11 as covariate.

For one participant, data was missing for one desire-VAS during reacquisition. The value of this score was estimated using the Multiple Imputation (MI) method (Schafer & Graham, 2002).

## Results

### Participant characteristics

No significant differences across conditions were found for age, BMI, hunger, BIS-11, RS, and liking of chocolate mousse (see Table 1, Study 2).

### US expectancy

Differential acquisition of US expectancy was present, as evidenced by a significant CS x T interaction,  $F(3.13, 137.72) = 33.81, p < .001, \eta_p^2 = .44$ , with a non-significant trend towards a larger differentiation in the CRF condition (CS x T x C),  $F(3.13, 137.72) = 2.16, p = .09, \eta_p^2 = .05$  (see Figure 3). This resulted in a significant

differentiation on trial 5,  $F(1, 44) = 365.96$ ,  $p < .001$ ,  $\eta_p^2 = .89$ , this differentiation being larger in the CRF condition than in the PRF condition,  $F(1, 44) = 23.89$ ,  $p < .001$ ,  $\eta_p^2 = .35$ . Impulsivity did not have an effect on this differentiation,  $F(1, 44) = 1.47$ ,  $p = .23$ ,  $\eta_p^2 = .03$ , and did not moderate conditioned responses over time, neither overall (CS  $\times$  T  $\times$  I),  $F < 1$ , nor by condition (CS  $\times$  T  $\times$  C  $\times$  I),  $F(3.13, 44) = 2.03$ ,  $p = .11$ ,  $\eta_p^2 = .04$ .

From the last acquisition trial to the first extinction block, the CRF already showed a greater change in differential US expectancies,  $F(1, 44) = 18.84$ ,  $p < .001$ ,  $\eta_p^2 = .30$ . Differential US expectancy decreased significantly during extinction (CS  $\times$  B),  $F(2.15, 94.77) = 70.55$ ,  $p < .001$ ,  $\eta_p^2 = .62$ , with significant differences across conditions (CS  $\times$  B  $\times$  C),  $F(2.15, 94.77) = 11.57$ ,  $p < .001$ ,  $\eta_p^2 = .21$  (see Figure 3). Follow-up analyses per condition and using a Bonferroni-corrected alpha of .017 indicated better extinction performance in the CRF condition com-

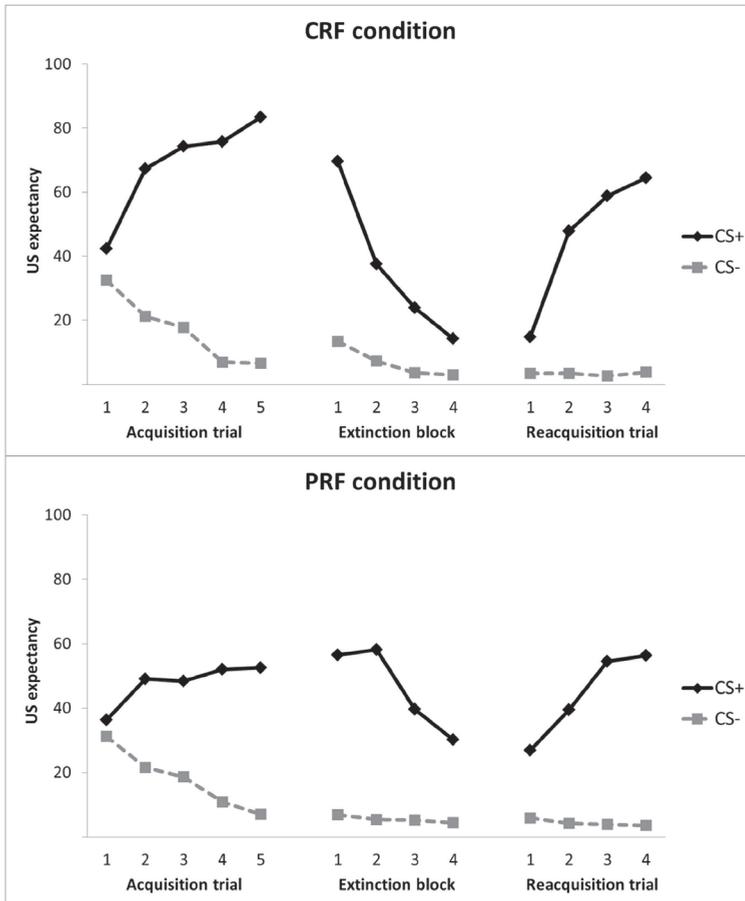
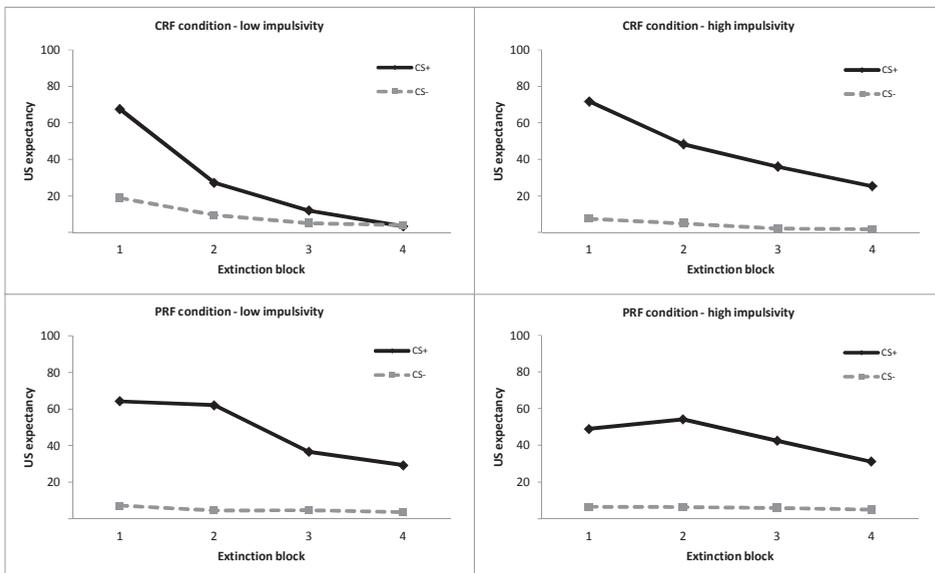


Figure 3. Mean US expectancy, by CS-type, trial, condition, and phase of the experiment (study 2).

pared with the PRF condition. While participants in the CRF condition already showed clear extinction during the second extinction block,  $F(1, 22) = 50.12$ ,  $p < .001$ ,  $\eta_p^2 = .70$ , participants in the PRF condition did not show evidence for a decrease in expectancies until block 3 (compared with the first extinction block),  $F(1, 22) = 18.51$ ,  $p < .001$ ,  $\eta_p^2 = .46$  (block 2:  $F < 1$ ). Additionally, the difference between CS+ and CS- expectancy scores was still higher in the PRF condition than in the CRF condition during block 4,  $F(1, 44) = 7.48$ ,  $p = .009$ ,  $\eta_p^2 = .15$ . Thus, these results indicate both a slower and less complete extinction in the PRF condition, compared with the CRF condition, clearly reflecting a PREE.

Impulsivity appeared to moderate overall extinction scores (CS  $\times$  B  $\times$  I),  $F(2.15, 94.77) = 3.33$ ,  $p = .037$ ,  $\eta_p^2 = .07$ , independent of condition (CS  $\times$  B  $\times$  C  $\times$  I),  $F < 1$  (see Figure 4). Follow-up analyses per block (CS  $\times$  B) and using a Bonferroni-corrected alpha of .0125 suggest a slower extinction of US expectancies during the second half of extinction for participants who are more impulsive (block 1:  $p = .95$ ; block 2:  $p = .21$ ; block 3:  $p = .009$ ; block 4:  $p = .009$ ). Thus, higher impulsivity is related to overall worse extinction performance. Since BMI has been related to deficits in working memory which might be associated with learning (extinction) deficits (Lasselin et al., 2013; Maayan, Hoogendoorn, Sweat, & Convit, 2011), the correlation between the BIS-11 and BMI was calculated ( $r = .24$ ;  $p = .1$ ), and BMI was added to the model. BMI did not interact with differential extinction,  $F < 1$ ,



**Figure 4.** Effects of impulsivity on mean US expectancy during extinction, by CS-type, trial, and condition. Low vs. high impulsivity reflect US expectancy scores 1 SD below vs. above the mean of the BIS-11 (study 2).

nor did it result in a very different CS  $\times$  B  $\times$  I interaction,  $F(2.12, 88.99) = 2.59$ ,  $p = .078$ ,  $\eta_p^2 = .06$ . Thus, it seems that the slower extinction by participants with higher impulsivity was not explained by their higher BMI.

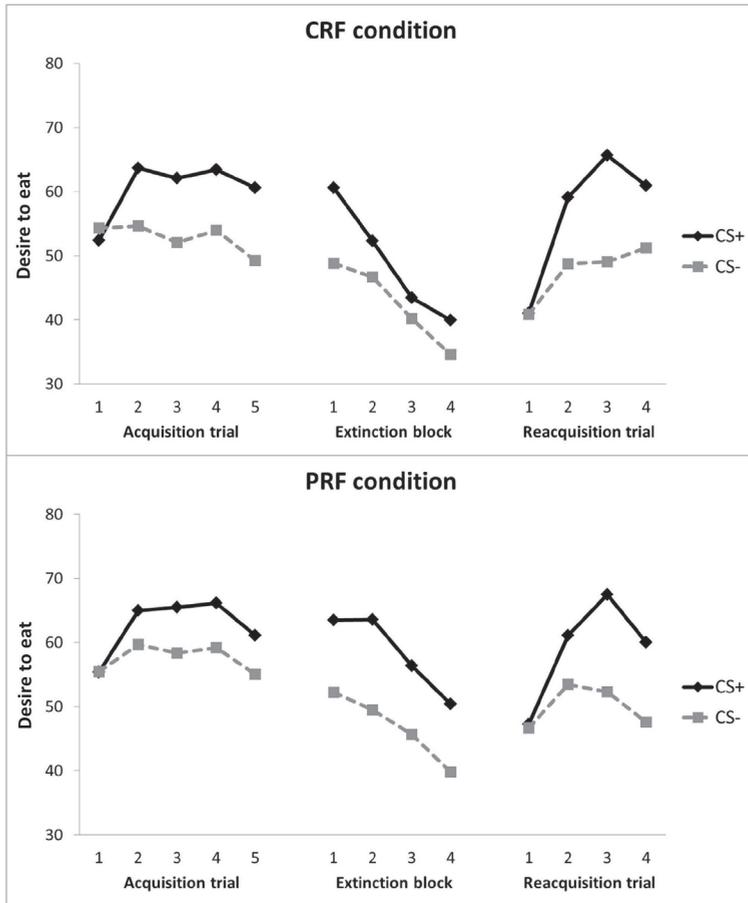
A significant CS+ vs. CS- differentiation was still present on the first reacquisition trial,  $F(1, 44) = 24.16$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , with no differences across conditions,  $F(1, 44) = 2.10$ ,  $p = .15$ ,  $\eta_p^2 = .05$  (see Figure 3). Reacquisition of expectancies was significant (CS  $\times$  T),  $F(2.25, 99.18) = 49.80$ ,  $p < .001$ ,  $\eta_p^2 = .53$ . For the CRF condition evidence was found for a more rapid reacquisition compared with the PRF condition (CS  $\times$  T  $\times$  C),  $F(2.25, 99.18) = 2.76$ ,  $p = .06$ ,  $\eta_p^2 = .06$ . Impulsivity did not moderate speed of reacquisition; neither overall (CS  $\times$  T  $\times$  I),  $F(2.25, 99.18) = 1.74$ ,  $p = .18$ ,  $\eta_p^2 = .04$  nor by condition (CS  $\times$  T  $\times$  C  $\times$  I),  $F(2.25, 99.18) = 1.54$ ,  $p = .22$ ,  $\eta_p^2 = .03$ .

### Desire to eat

Differential acquisition of the desire for chocolate mousse was present, as shown by a significant CS  $\times$  T interaction,  $F(2.95, 129.85) = 5.04$ ,  $p = .003$ ,  $\eta_p^2 = .10$ , with no significant differences across conditions (CS  $\times$  T  $\times$  C),  $F < 1$  (see Figure 5). Impulsivity did not moderate these interactions (CS  $\times$  T  $\times$  I; CS  $\times$  T  $\times$  C  $\times$  I),  $F_s < 1$ . The differentiation resulted in a significantly higher desire in response to the CS+ compared to the CS- on trial 5,  $F(1, 44) = 10.65$ ,  $p = .002$ ,  $\eta_p^2 = .20$ , with no differences across conditions,  $F < 1$ .

A differentiation was still present on block 1,  $F(1, 44) = 40.37$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , with no differences across conditions,  $F < 1$ . A significant overall extinction of conditioned desires was found (CS  $\times$  B),  $F(2.41, 106.12) = 3.89$ ,  $p = .017$ ,  $\eta_p^2 = .08$ , as well as a significant CS  $\times$  B  $\times$  C interaction,  $F(2.41, 106.12) = 3.86$ ,  $p = .018$ ,  $\eta_p^2 = .08$ . Follow-up analyses indicated a significant CS  $\times$  T interaction within the CRF condition,  $F(3, 66) = 7.04$ ,  $p < .001$ ,  $\eta_p^2 = .24$ , while no such interaction was found for the PRF condition,  $F(2.05, 45.04) = 1.19$ ,  $p = .31$ ,  $\eta_p^2 = .05$ , indicating an extinction of desire within the CRF condition but not in the PRF condition (see Figure 5). On the last extinction block, a differentiation is present,  $F(1, 44) = 21.39$ ,  $p < .001$ ,  $\eta_p^2 = .33$ , that is not significantly different for the two conditions,  $F(1, 44) = 2.42$ ,  $p = .13$ ,  $\eta_p^2 = .05$ . Thus, overall, these findings point towards a PREE; conditioned desires are resistant to extinction after partial reinforcement but less so after continuous reinforcement. Impulsivity did not influence extinction overall (CS  $\times$  T  $\times$  I), nor by condition, (CS  $\times$  T  $\times$  C  $\times$  I),  $F_s < 1$ .

On the first reacquisition trial, no significant differentiation was present, with no differences across conditions,  $F_s < 1$ . Reacquisition of desire ratings was significant (CS  $\times$  T),  $F(3, 132) = 11.97$ ,  $p < .001$ ,  $\eta_p^2 = .21$ , with no differences across conditions (CS  $\times$  T  $\times$  C),  $F < 1$  (see Figure 5). Impulsivity showed a marginally

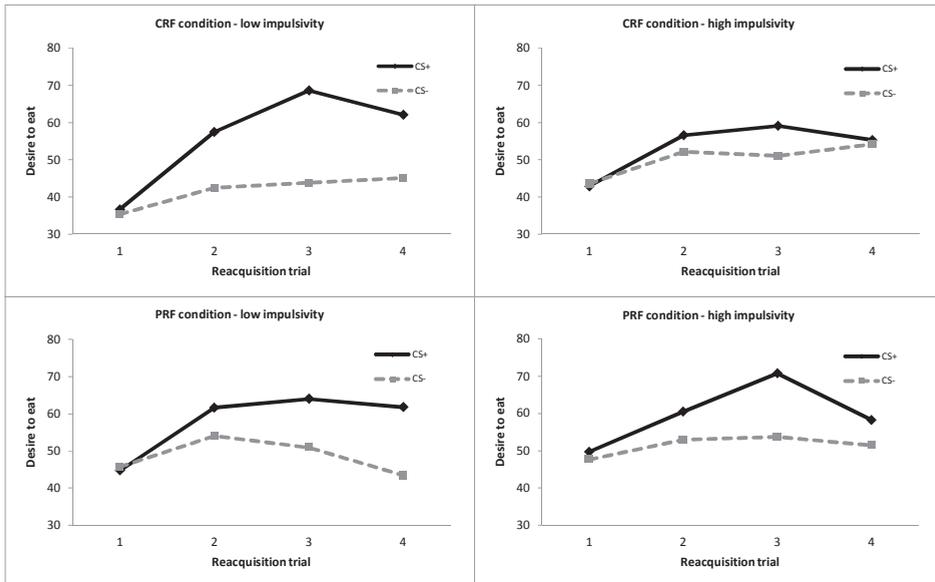


**Figure 5.** Mean desire for chocolate mousse, by CS-type, trial, condition, and phase of the experiment (study 2).

significant interaction with reacquisition over time ( $CS \times T \times I$ ),  $F(3, 132) = 2.46$ ,  $p = .066$ ,  $\eta_p^2 = .05$ , independent of condition ( $CS \times T \times C \times I$ ),  $F(3, 132) = 1.02$ ,  $p = .39$ ,  $\eta_p^2 = .02$  (see Figure 6). Further analyses showed that differential desire on the last reacquisition trial was smaller in high impulsive vs. low impulsive participants,  $F(1, 44) = 6.19$ ,  $p = .017$ ,  $\eta_p^2 = .12$ , suggesting that impulsivity hindered the reacquisition of conditioned desires.

### Salivation

Two participants were excluded from analyses because they scored  $> 3$  SD above the mean on at least one of the measures used to assess acquisition. Analysis of salivation during baseline, CS+ and CS- exposure revealed a significant main effect,  $F(2, 84) = 4.17$ ,  $p = .019$ ,  $\eta_p^2 = .09$ . Bonferroni-corrected pairwise com-



**Figure 6.** Effects of impulsivity on mean desire for chocolate mousse during reacquisition, by CS-type, trial and condition. Low vs. high impulsivity reflect desire scores 1 SD below vs. above the mean of the BIS-11 (study 2).

parisons suggested an increase in salivation from baseline to CS+ ( $p = .034$ ) but not from baseline to CS- ( $p = .18$ ), and there were no differences between CS+ and CS- salivation ( $p > .99$ ). Once again, the increase in salivation to CS+ but not CS- from baseline might provide weak evidence of conditioned salivation. Condition did not moderate the overall interaction,  $F < 1$ , nor did impulsivity,  $F(2, 84) = 2.41$ ,  $p = .1$ ,  $\eta_p^2 = .05$ . Because the difference in salivation between CS+ and CS- did not reach significance, analyses on extinction and reacquisition were not performed (see Table 3).

### CS liking

The CS+ was preferred over the CS- by 37 participants (77%), binomial test,  $p < .001$ . There was a trend towards participants in the CRF condition choosing the CS+ more often,  $\chi^2(1) = 3.04$ ,  $p = .08$  (CRF: 21 participants or 88%; PRF: 16 participants or 67%).

## Discussion

In this second study, a successful acquisition of a conditioned desire for chocolate mousse was demonstrated. Importantly, some of the main findings of study 1

**Table 3.** Salivation in grams, by CS-type and condition at the end of the different phases of the experiment, means with standard deviations in parentheses (study 2).

	<b>CRF condition (n = 23)</b>	<b>PRF condition (n = 23)</b>
<i>Baseline</i>	0.33 (0.19)	0.32 (0.18)
<i>Acquisition</i>		
CS+	0.41 (0.29)	0.39 (0.21)
CS-	0.40 (0.22)	0.35 (0.23)
<i>Extinction</i>		
CS+	0.30 (0.26)	0.25 (0.15)
CS-	0.28 (0.17)	0.26 (0.17)
<i>Reacquisition</i>		
CS+	0.36 (0.24)	0.32 (0.22)
CS-	0.36 (0.19)	0.35 (0.24)

were replicated and extended by demonstrating a partial reinforcement extinction effect that was reflected in both US expectancies and the desire for food, and which could not be explained by differences in arousal across conditions. Similar to study 1, a more rapid reacquisition of US expectancies after continuous versus partial reinforcement was demonstrated. Further, impulsivity again appeared to be related to worse extinction performance with regard to US expectancies, although in the present study this effect was not specific to the PRF condition. Only in study 2, impulsivity was related to a less complete recovery of conditioned desires for chocolate mousse when CSs were again reinforced after extinction. Finally, a preference for the CS+ over the CS- was again clearly demonstrated in the forced-choice task.

## General Discussion

One aim of the two studies reported here was to examine whether partial reinforcement of food cues would result in a partial reinforcement extinction effect (PREE) in humans and whether it would slow down a return of conditioned responses when the CS-US contingency is again reinforced after extinction. A further aim was to assess whether impulsivity moderated conditioned appetitive responses during each conditioning phase. As argued in the introduction, effects of partial reinforcement schedules and an impulsive personality on appetitive responses during different phases of conditioning may help us to understand inter-individual differences in dieting success.

The acquisition of US expectancies was successful in both studies. In the second study, an acquisition of conditioned desires for chocolate mousse was also demonstrated; after repeated pairings of an initially neutral stimulus (a specific box) with the intake of food, participants reported a greater desire for this food when exposed to the intake-associated box (CS+) compared with a control box (CS-). This replicates findings of previous appetitive conditioning studies. Extinction of conditioned responses to food cues was slowed down by a partial reinforcement schedule, and some evidence was found for a slower extinction with higher levels of impulsivity. Reacquisition of US expectancies was reduced after acquisition with partial reinforcement. Finally, a conditioned preference for the CS+ was found, as well as weak evidence for a conditioned salivary response: across the studies, salivation in response to the CS+ was significantly higher than baseline, whereas this difference was non-significant for the CS- (see also van den Akker et al., 2013). Closer inspection of the salivation patterns suggest that strong carryover effects (i.e., measuring CS+ or CS- salivation first) may have contributed to the lack of a clear difference between CS+ and CS-. Additionally, effects on salivation seem to be very small and the current studies might not have had sufficient power to detect such small effects.

Partial reinforcement in humans has previously only been investigated outside the food domain (e.g., Abad, Ramos-Álvarez, & Rosas, 2009; Pittenger & Pavlik, 1988). A new and interesting finding is that continuous and partial reinforcement schedules had differential effects on extinction after appetitive conditioning to food rewards. First, participants in the CRF versus PRF condition showed a better extinction of US expectancies. This extinction was more rapid and more complete. Second, extinction of the conditioned desire for chocolate mousse showed a comparable pattern: after partial reinforcement extinction was not reached while continuous reinforcement did lead to extinction, though the differentiation between the CS+ and CS- in the latter group seemed to have returned towards the end of the extinction phase. These findings demonstrate partial reinforcement extinction effects in the food domain in humans and are in line with findings of studies conducted in animals (e.g., Haselgrove et al., 2004). It may be noted that the present conditioning procedure was not exclusively Pavlovian. Although provision of the US was not within the participant's control (in line with Pavlovian learning principles), the procedure still involved instrumental learning components: participants had to open a box to obtain the food US. However, the PREE has also been reported for instrumental procedures (Mackintosh, 1974). Further, instrumental learning is thought to involve Pavlovian conditioning of cues that are embedded in the task (Bouton, 2007), and these would elicit Pavlovian CRs as measured by the current outcome measures. Therefore, a possible influence of instrumental

learning does not seem to be a problem for the general perspective. The present results also provide some insight into the relationship between US expectancies and conditioned desires during extinction: the resulting heightened US expectancies in the PRF condition went hand in hand with a clear resistance to extinction of conditioned desires, whereas the better extinction of expectancies in the CRF condition occurred in parallel with a better extinction of conditioned desires. This suggests that extinction of US expectancies and desires could be more narrowly related than has previously been suggested (Van Gucht et al., 2010).

Another new finding is that impulsivity predicted a worse extinction of expectations to receive a food US, the strongest evidence for this being found in study 2. A worse extinction of reward expectancies in higher (rash) impulsive individuals might be explained by learning deficits caused by a relatively poor functioning OFC (see introduction). Previous experiments reporting comparable extinction deficits in humans are scarce. A few studies reported a decreased ability to modulate response behaviour during extinction and reversal learning (e.g., when a CS is first associated with reward and then with punishment) in healthy impulsive participants (Avila & Parcet, 2000; Franken, van Strien, Nijs, & Muris, 2008; Gullo, Jackson, & Dawe, 2010; but see Papachristou et al., 2013). However, since the findings of the two studies reported here were somewhat inconsistent, we suggest future studies have yet to determine whether rash impulsiveness is indeed related to extinction deficits.

Besides the effects of partial reinforcement procedures and impulsivity on extinction, these variables also appeared to influence reacquisition performance. In line with our hypothesis, participants in the PRF versus CRF condition showed a less rapid return of US expectancies. As argued in the introduction, a slower reacquisition may be the result of previously partially reinforced cues not predicting as strongly that the subsequent trial will be reinforced. Alternatively, one could argue that the nonreinforced trials during acquisition with partial vs. continuous reinforcement resulted in a greater similarity between the acquisition and extinction 'contexts' (Capaldi, 1994). Since a return of responding after extinction may be weakened if extinction has been performed in a context more similar to the acquisition context (Bouton, 2002), this could explain why reacquisition is less rapid after partial reinforcement. While these effects on US expectancies seemed robust, no comparable effects were found for conditioned desires. Moreover, impulsivity seemed to affect reacquisition, although its interaction with measures of reacquisition was not consistent across the two studies. Future studies should replicate the present findings and attempt to match final levels of acquisition and extinction performance in order to conclude that reacquisition is indeed more rapid

when preceded by CRF versus PRF, and that impulsivity is related to differences in reacquisition.

The present studies provide unique evidence that partial reinforcement of food cues and, possibly, impulsiveness are related to worse extinction of appetitive responses to food cues. Further, it could be that partial reinforcement is associated with a less rapid reacquisition. These findings might have clinical implications. Cue exposure with response prevention is a treatment that aims to extinguish conditioned appetitive responses by repeated exposure to a conditioned cue (CS+) with response prevention, i.e., not eating, to prevent reinforcement. This extinction training is sometimes used to treat individuals with eating and/or weight disorders (Boutelle et al., 2011; Jansen, Broekmate, & Heymans, 1992; Jansen, Havermans, & Nederkoorn, 2011). The current data seem to predict that partially reinforced food cues will be more difficult to extinguish during cue exposure treatment. Similarly, our data suggest that dieters who attempt to extinguish responses to more partially (relative to more continuously) reinforced cues could experience more difficulty adhering to their diets. On the other hand, once extinction is achieved, previously partially reinforced food cues may reduce the strength of returns of appetitive responses (rapid reacquisition), improving long-term weight loss maintenance (for circumstantial evidence regarding a link between conditioned reactions to food cues and dieting success, see Jansen, Stegerman, Roefs, Nederkoorn, & Havermans, 2010; see also Polivy, Herman, & Coelho, 2008). It is of clinical interest to examine in future studies whether and to what extent weight loss success and/or maintenance can be attributed to specific learning histories and whether impulsivity plays a role.

In sum, the two studies combined are new in demonstrating a partial reinforcement extinction effect after appetitive conditioning involving food rewards in healthy humans. This PREE was reflected in US expectancies and in the desire for food. Another new but preliminary finding was that impulsivity seemed to be related to a slower extinction of conditioned expectations to receive food. It is proposed that dieters who previously practiced partial reinforcement of food cues experience PREEs during a diet, which could make (shorter-term) adherence to the diet more difficult. These individuals might however be at reduced risk for some forms of relapse once their responses have been successfully extinguished. Gaining more insight into the causes of individual differences in extinction and returns of appetitive responses might ultimately improve the successfulness of treatments aimed at achieving short and long-term weight loss. Future research should aim to find out whether and in what ways short and long term dieting success can be predicted by differences in prior reinforcement schedules, and

further clarify the roles of partial reinforcement and impulsivity in the acquisition, extinction, and reacquisition of appetitive responses to food cues.

## **Acknowledgements**

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# Chapter 7

## **Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity**

van den Akker, K., Nederkoorn, C., & Jansen, A. Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity. *Under review.*

## Abstract

Studies on human appetitive conditioning using food rewards can benefit from including psychophysiological outcome measures. The present study tested whether skin conductance can function as a measure of differential responding in an appetitive conditioning paradigm including an acquisition and extinction phase, and examined which time window during a trial is most sensitive to conditioning effects. As a secondary aim, the effects of ambiguous vs. non-ambiguous contingency instructions on conditioned responses (skin conductance, US expectancies, chocolate desires, and CS evaluations) were assessed. Results indicated differential skin conductance responses in an anticipatory time window and during unexpected omission of the US in early extinction. Interestingly however, anticipatory responses were only found for participants who received ambiguous contingency instructions. Ambiguous instructions also slowed the extinction of US expectancies but did not influence chocolate desires and CS evaluations. It is concluded that skin conductance can function as a sensitive measure of differential responding in appetitive conditioning, though its sensitivity might depend on the specific task context.

**Keywords:** appetitive conditioning, food conditioning, electrodermal responses, contingency instructions, ambiguity

## Introduction

The prevalence of overweight and obesity has reached epidemic proportions. Currently, more than two-thirds of all U.S. adults are either overweight or obese (Ogden, Carroll, Kit, & Flegal, 2014). Experts agree that the changed food environment is largely responsible for this (Swinburn, Egger, & Raza, 1999), since its abundant food cues can easily elicit appetitive responses such as food cravings that promote overeating. Pavlovian learning has been proposed to play an important role in the development of these appetitive responses: after repeated pairings of a stimulus (e.g., the sight and smell of food or a certain context) with food intake, the stimulus becomes a predictor (food cue) for intake that promotes appetitive responses and food intake (Jansen, 1998; Jansen, Havermans, & Nederkoorn, 2011).

In line with a learning-based account, conditioning studies have shown that after a few pairings of a neutral stimulus (e.g., a box) with food intake (e.g., eating a piece of chocolate; unconditioned stimulus or US), this stimulus (conditioned stimulus+ or CS+) elicits conditioned appetitive responses (CRs), relative to a control stimulus not followed by intake (CS-). These responses generally diminish when the CS+ is no longer followed by the US during extinction (e.g., Jansen, Schyns, Bongers, & van den Akker, 2016; van den Akker, Havermans, Bouton, & Jansen, 2014; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008). CRs that have been examined in these human appetitive conditioning studies often include psychological (self-reported US expectancies, cravings or desires to eat, and CS evaluations) and sometimes behavioural responses (food consumption or choice, and computer tasks) (Bongers, van den Akker, Havermans, & Jansen, 2015; van den Akker, Jansen, Frentz, & Havermans, 2013; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008). There are limitations, however, to relying solely on self-report and behavioural measures. For example, their assessment may alter responses on subsequent measurements (Gawronski, Gast, & De Houwer, 2015; Lipp & Purkis, 2006), and self-report measures in particular can be sensitive to experimental demand (e.g., Lipp, 2006). In addition, verbal/cognitive and behavioural measures likely do not cover all indices of (appetitive) learning, since multiple response systems are thought to be involved in conditioning (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Delamater & Oakeshott, 2007).

Psychophysiological measurement of conditioned appetitive responding may overcome at least some of these limitations. Although several psychophysiological measures may be suitable for measuring differential responding in appetitive conditioning (Blechert, Testa, Georgii, Klimesch, & Wilhelm, 2016; Franken, Huijding, Nijs, & van Strien, 2011; Meyer, Risbrough, Liang, & Boutelle, 2015; O'Doherty, Dayan, Friston, Critchley, & Dolan, 2003), one particularly promising, easy-to-use,

and noninvasive measure is skin conductance. Skin conductance measures activity of the sympathetic nervous system which is thought to reflect arousal (Dawson, Schell, & Filion, 2007). Such arousal can originate from various cognitive and emotional processes (Critchley, 2002). Skin conductance is heightened during exposure to the sight and smell of palatable food and other appetitive substances (e.g., Carter & Tiffany, 2001; Nederkoorn, Smulders, & Jansen, 2000), and it is widely used as a measure of differential responding in fear conditioning studies, in which it may primarily index explicit learning about the CS–US contingencies (Hamm & Weike, 2005). In the appetitive field, several conditioning studies have examined skin conductance, reporting a successful acquisition of conditioned skin conductance responses to reward-associated CSs (e.g., Glautier, Drummond, & Remington, 1994; Klucken et al., 2015; but see Field & Duka, 2001). The USs that were used in these studies rarely involved *food intake*, however. One study that used a food US reported differential skin conductance responses during exposure to a food-associated CS+ (a shape; Andreatta & Pauli, 2015). However, this CS+ (but not the CS–) was always accompanied by a picture of the food US. Since food pictures are potent CSs on their own that elicit appetitive responses (Boswell & Kober, 2016), it is impossible to determine whether differential responding was due to presentation of the existing cue (food picture) or due to the newly conditioned cue – i.e., it is unclear whether differential skin conductance responses reflected conditioning effects.

Skin conductance can be measured in different time windows during a conditioning trial (Boucsein, 2012; Prokasy & Kumpfer, 1973). In fear conditioning studies, it is often measured directly after presentation of a CS (first-interval response or FIR), or, in case of longer CS–US intervals, in the period prior to US delivery (second-interval response or SIR; Lovibond, Saunders, Weidemann, & Mitchell, 2008). In addition to measuring skin conductance during an anticipation period, one may also observe differential responding after unexpected omission of a shock US (i.e., on a non-reinforced CS+ trial after CS offset; Dunsmoor & LaBar, 2012; Spoormaker et al., 2011). This has been termed “third-interval omission response” (TOR) or “offset SCR” (skin conductance response), and possibly reflects “surprise” or “relief” upon unexpected omission of the aversive US (Rescorla & Wagner, 1972; Spoormaker et al., 2011). In appetitive conditioning, measuring skin conductance responses during an expectancy mismatch (e.g., during extinction) could provide an additional measure of learning, possibly reflecting “surprise” about the non-occurrence of the US.

Conditioned responses (including skin conductance) are likely not solely based on physical pairings between a CS and a US. Studies have shown that contingency instructions can have a big impact on responding as well. For example,

verbal instructions about the CS–US contingency (e.g., that the CS+ predicts a shock) can establish conditioned fear responses in the absence of actual CS–US pairings (e.g., Raes, De Houwer, De Schryver, Brass, & Kalisch, 2014), and information suggesting a reversal of CS–US contingencies after conditioning (e.g., informing participants that the CS+ is no longer followed by a shock) can reverse fear responses (e.g., Mertens & De Houwer, 2016). In many conditioning studies, contingency instructions are provided prior to acquisition, guiding a participant's attention towards the CS–US relationship (e.g., “one of these boxes will sometimes contain something to eat, whereas the other box will never contain anything”). This is done because US expectancies are likely necessary for the development of conditioned (appetitive) responses (Hogarth & Duka, 2005; van den Akker et al., 2013). The precise wording of the contingency instruction might however impact subsequent learning. Specifically, using an ambiguous contingency instruction like “the box will *sometimes* contain chocolate” (which may be used to account for the fact that the stimulus is not followed by the US during extinction) could result in a pattern of responding similar to that induced by a partial reinforcement schedule, in which the CS–US contingency is less than 100%, thereby leading to an attenuated CR during acquisition (e.g., interfering with a successful acquisition of differential skin conductance responses; Dunsmoor, Bandettini, & Knight, 2007), and a slowed extinction (i.e., the partial reinforcement extinction effect; e.g., van den Akker et al., 2014). In the present study, we investigated the effects of a subtle difference in the wording of contingency instructions on conditioning by omitting the word *sometimes* in one condition.

The primary aim of the present study was to examine whether skin conductance can be used as a measure of conditioned responding in a differential appetitive conditioning paradigm, and to examine which time window provides the most sensitive measure for differential responding – after CS onset (FIR), right before the US is imminent (SIR), or after CS offset (TOR). In addition, the influence of an ambiguous contingency instruction (either including the word *sometimes* or not) on conditioned responses (US expectancies, desires for chocolate, CS evaluations, and skin conductance) was examined. It was expected that skin conductance would be heightened in response to CS+ vs. CS– trials after acquisition, and especially in the time window when the US was imminent. It was also hypothesized that an US omission response in CS+ vs. CS– trials would occur when the US was unexpectedly not provided, particularly in early extinction when US omission would be most surprising. Finally, it was expected that relatively ambiguous instructions (ambiguous condition) would attenuate both the acquisition and extinction of conditioned responses, compared with a condition in which the word “sometimes” was omitted (non-ambiguous condition).

## Methods and materials

### Participants

Sixty-four participants took part in the study. Of these, four participants were excluded: three because they were not aware of the contingency between the CS and US, and one due to technical errors. These participants were replaced by four additional participants to ensure full counterbalancing. Participants were eligible to participate in the study if they were undergraduate female students, right-handed, aged between 17 and 25 years, and had indicated to like chocolate. It was ensured that none of the participants had previously participated in an appetitive conditioning study. All participants were instructed to have a small meal (such as a sandwich) two hours prior to participation and to refrain from calorie intake thereafter. As a cover story, participants were told the study was about attention and taste perception. Participants received either a monetary reward (€ 7,50) or course credit for participation. The study was approved by the local ethical committee.

### Measures

*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 (leaving the right hand to answer VAS). 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.

*US expectancy and desire for chocolate*: computerized Visual Analogue Scales (VAS) were used to assess expectancy to receive chocolate (*'To what extent do you expect to receive chocolate at this moment?'*) and subjective desire for chocolate (*'When looking at this picture, how strong is your desire for chocolate at this moment?'*). Ratings were scored from 0 (*certainly not expect to receive chocolate / no desire at all*) to 100 (*certainly expect to receive chocolate / very strong desire*).

*CS evaluations*: Evaluations for the CS+ and CS- were assessed using two VAS (*'How pleasant do you find this picture?'*). Ratings ranged from 0 (*not pleasant at all*) to 100 (*extremely pleasant*).

*Hunger*: To be able to control for possible group differences in hunger, participants filled in a VAS (*'How hungry are you at this moment?'*) ranging from 0 (*not hungry at all*) to 100 (*extremely hungry*).

*US liking*: US liking was assessed using a VAS (*'How much did you like the chocolate?'*) ranging from 0 (*did not like it at all*) to 100 (*liked it very much*).

## Stimuli

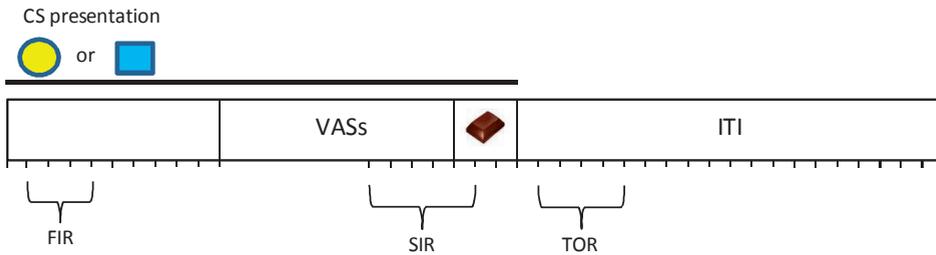
Two geometrical shapes (a blue rectangle and a yellow square) were used as conditioned stimuli. These were displayed on a computer screen in front of the participant. Which shape served as CS+ and CS- was counterbalanced between participants. A small piece of Belgian milk chocolate (approximately 1.3 – 1.5 grams, Rousseau chocolate) functioned as US.

## Procedure

After arrival, participants were seated at a table, in front of a computer screen. The participant was informed that two electrodes would be attached to her fingers, but that these would not be painful. After giving informed consent, participants were explained how to fill in a VAS. Next, the electrodes were attached to the participant's left hand, and the experimenter explained that the participant would sometimes be asked to eat something. The participant was instructed to sit still and keep her left hand still throughout the procedure, while using her right hand to pick up the food and to answer VAS. Next, participants were shown the two geometrical shapes and, depending on the participant's condition, she received one of two instructions. In the ambiguous condition, the participant was instructed that after seeing one of the two shapes, she would sometimes receive something to eat. After seeing the other shape, she would never receive anything to eat. Participants were asked to repeat this information once. In the non-ambiguous condition, the word "sometimes" was simply omitted. Next, the computer screen was turned on, and the participant completed a computerized hunger VAS. After this, the conditioning procedure started, which was similar for all participants.

During acquisition, participants received five CS+ trials and five CS- trials (see below). Immediately following acquisition the extinction phase started, consisting of twelve CS+ (no US) and twelve CS- trials. Trials were presented in a semi-randomized order, with no more than two consecutive trials being of the same trial type. Whether extinction started with a CS+ or CS- trial was counterbalanced across participants. Trial sequences were similar to prior studies to allow concurrent measurement of expectancy and desire VASs (e.g., van den Akker, van den Broek, Havermans, & Jansen, 2016).

A trial proceeded as follows: participants were shown one of the shapes (CS+ or CS-) on the computer screen for 10 seconds, accompanied by the instruction to look at the picture (see Figure 1). Next, an expectancy VAS appeared below the CS. The trial proceeded when participants clicked a button indicating they had finished filling in the question. After a two-second delay, the desire-for-chocolate VAS was presented. After the participant had completed this question, the VAS disappeared, and the CS remained present for another three seconds. During this



**Figure 1.** Overview of a conditioning trial and the three examined time windows. “VASs” indicate administration of the US expectancy and desires VASs. ITI is the inter-trial interval. Each small line reflects one second in the conditioning trial. Chocolate (the US) was given on CS+ trials during acquisition only. FIR (first-interval response), SIR (second-interval response), and TOR (third-interval omission response) represent the three time windows during which responses were analyzed.

period, in case of a CS+ trial, participants received the US. After the three seconds, the CS disappeared, and the inter-trial interval started (ranging from 17–23 seconds). After this, the next trial started. Online markers were used to note when a participant took a deep breath, moved, or talked, to be able to remove any skin conductance responses caused by these actions.

After completion of both the acquisition and extinction procedure, participants were presented with the two shapes and completed CS evaluation VASs. Next, they indicated when they had last eaten, wrote down their suspicions about the study’s hypothesis, and the participant’s age and study year were assessed. Finally, their height and weight were measured.

#### Data reduction and response definition

Ledalab V3.4.8 was used for preprocessing and for extraction of skin conductance data (Benedek & Kaernbach, 2010). The data were first downsampled to 10 Hz (by averaging every 50 samples), and artifacts were manually identified and corrected using a spline interpolation. The data were smoothed by means of convolution with a Hanning window, and continuous decomposition analysis (CDA) was used to obtain skin conductance responses. CDA uses deconvolution to decompose the skin conductance data into its tonic and phasic components, resulting in phasic activity with a zero baseline. CDA is especially advantageous for analysis of overlapping skin conductance responses (i.e., superposition effects), and has been used before for analyzing (fear) conditioning data (e.g., Baeuchl, Meyer, Hoppstädter, Diener, & Flor, 2015; Cacciaglia et al., 2013). The sum of the amplitudes of all skin conductance responses with onsets within a time window was used as dependent variable (AmpSum). A minimum response amplitude criterion of 0.01 microSiemens was used. Responses were discarded and replaced by the overall individual mean when they were directly preceded by the participant sighing,

talking, or moving, or when no responses were recorded due to technical issues (1.34% of all responses; ambiguous CS+ 1.22%; CS- 0.61%; non-ambiguous CS+ 1.83%; CS- 1.70%) (Weike, Schupp, & Hamm, 2007). The data were range-corrected by dividing each skin conductance score by the participant's individual maximal conditioned response (e.g., Cacciaglia et al., 2013), and normalized using a square root transformation.

Three time windows were analyzed based on prior research and visual inspection of the data (Boucsein, 2012; Prokasy & Ebel, 1967; see Figure 1):

*First-interval response (FIR)*: FIR magnitudes were measured in a time window spanning from 1 – 4 following CS onset.

*Second-interval response (SIR)*: In previous studies using a relatively long delay between CS onset and the US, a 5s-time window before US delivery has been examined, yielding a more sensitive measure of differential responding (Lovibond et al., 2008). In the current study, a time window was analyzed spanning from 4s before US occurrence to 1s after. Note that although this window includes a portion of the US period (1 second), it is not contaminated by US occurrence due to the slowness of the skin conductance signal.

*Third-interval omission response (TOR)*: To assess whether skin conductance responses were increased at CS+ vs. CS- offset, a time window was analyzed spanning from 1–5s after stimulus offset. This time window was only examined during extinction (i.e., when no further USs were provided).

### Statistical analyses

Differential acquisition and extinction of desire for chocolate, US expectancy, and skin conductance over trials and across conditions were analyzed using repeated-measures ANOVAs for each phase of the experiment (acquisition and extinction), and, for the skin conductance data, for each time window (FIR, SIR, and TOR). This resulted in 2 (Condition: ambiguous vs. non-ambiguous) x 2 (CS-type: CS+ vs. CS-) x 5 / 12 (Acquisition Trial / Extinction Trial) repeated-measures ANOVAs, including CS-type (CS) and Trial (T) as within-subjects factors and Condition (C) as between-subjects factor. CS evaluations after extinction were analyzed using 2 (CS-type: CS+ vs. CS-) x 2 (Condition: ambiguous vs. non-ambiguous) repeated-measures ANOVAs as well. Greenhouse-Geisser epsilon corrections are reported for repeated measures ANOVAs when sphericity was violated.

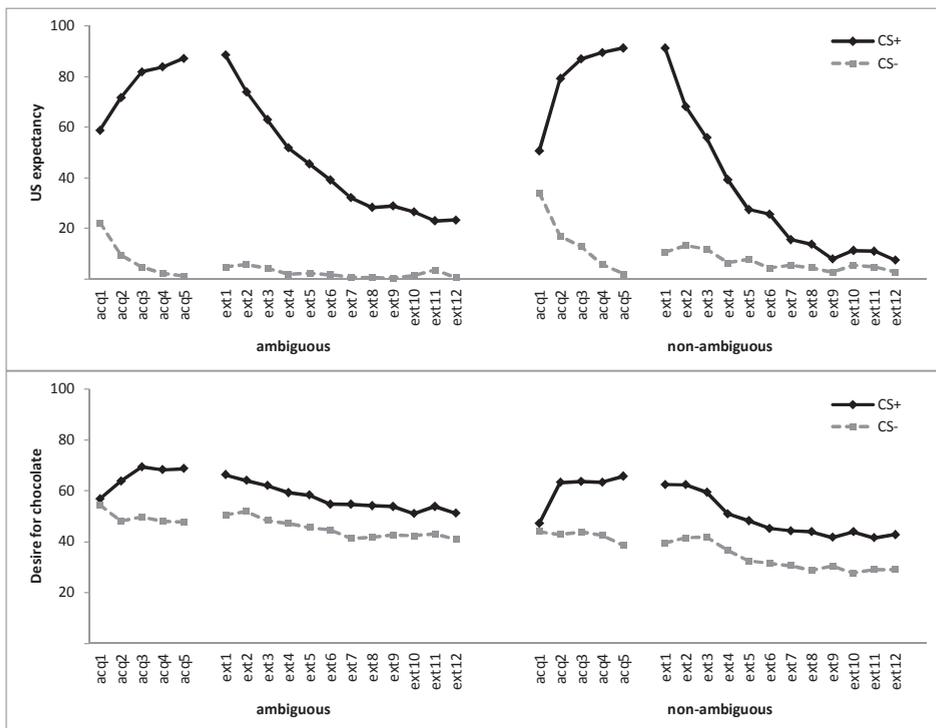
## Results

### Participant characteristics

Conditions ( $n = 32$  per condition) did not differ in age (overall  $M = 19.56$ ;  $SD = 1.50$ ), baseline hunger (overall  $M = 52.11$ ;  $SD = 21.49$ ), or US liking (overall  $M = 74.16$ ;  $SD = 18.11$ ),  $F < 1$ . They did, however, differ in BMI,  $t(62) = 2.14$ ,  $p = .04$  (ambiguous:  $M = 22.52$ ;  $SD = 3.45$ ; non-ambiguous:  $24.91$ ;  $SD = 5.32$ ). Including centered BMI score as covariate in the analyses did not change the pattern of results. Therefore, in the reported analyses, BMI was not included.

### US expectancy and desire for chocolate

Participants acquired US expectancies when presented with the CS+ vs. CS-, as evidenced by a significant CS  $\times$  T interaction,  $F(2.30, 142.63) = 82.54$ ,  $p < .001$ ,  $\eta_p^2 = .57$  (see Figure 2). Conditions differed in the course of acquisition (CS  $\times$  T  $\times$  C),  $F(2.30, 142.63) = 3.07$ ,  $p = .04$ ,  $\eta_p^2 = .05$ , which seemed to be due to



**Figure 2.** Mean US expectancy and desire for chocolate ratings, per condition, CS-type, and trial. “acq” refers to acquisition (5 trials); “ext” refers to extinction (12 trials).

greater differential US expectancies in the ambiguous condition already on the first acquisition trial,  $F(1, 62) = 6.11, p = .02, \eta_p^2 = .09^1$ . On the last acquisition trial, a significant differentiation in US expectancies was present,  $F(1, 62) = 1308.71, p < .001, \eta_p^2 = .96$ , and equally so for both conditions,  $F < 1$ .

Differential US expectancies extinguished (CS x T),  $F(4.49, 278.52) = 86.71, p < .001, \eta_p^2 = .58$  (see Figure 2). Although the course of extinction did not differ across conditions, (CS x T x C),  $F(4.49, 278.52) = 1.37, p = .24, \eta_p^2 = .02$ , on the last extinction trial, differential expectancies were still greater in the ambiguous vs. non-ambiguous condition,  $F(1, 62) = 10.83, p = .002, \eta_p^2 = .15$ . Follow-up analyses suggested that expectancies extinguished in the non-ambiguous,  $F(1, 31) = 1.99, p = .17, \eta_p^2 = .06$ , but not in the ambiguous condition,  $F(1, 31) = 27.99, p < .001, \eta_p^2 = .47$ . This suggests that, in line with expectations, the ambiguous instruction slowed down extinction.

A differential desire for chocolate was acquired (CS x T),  $F(2.41, 149.58) = 15.27, p < .001, \eta_p^2 = .20$ , resulting in a significantly larger desire in response to the CS+ vs CS- on the last acquisition trial,  $F(1, 62) = 49.89, p < .001, \eta_p^2 = .45$  (see Figure 2). Conditions did not differ in the course of acquisition nor in final acquisition levels,  $F_s < 1$ . Differential desires were still present on the first extinction trial,  $F(1, 62) = 49.93, p < .001, \eta_p^2 = .45$ , with no differences across conditions,  $F(1, 62) = 1.71, p = .20, \eta_p^2 = .03$ . Chocolate desires extinguished to some extent (CS x T),  $F(7.03, 435.64) = 2.41, p = .02, \eta_p^2 = .04$  (see Figure 2). On the last extinction trial, a differentiation between the CS+ and CS- was still present,  $F(1, 62) = 24.11, p < .001, \eta_p^2 = .28$ . The course of extinction and final extinction levels were similar for the conditions,  $F_s < 1$ .

In sum, differential US expectancies and chocolate desires were successfully acquired, and they extinguished to some extent. This overall pattern is similar to findings of previous studies. Further, our manipulation affected the extinction of US expectancies: extinction was less complete in the ambiguous vs. non-ambiguous condition.

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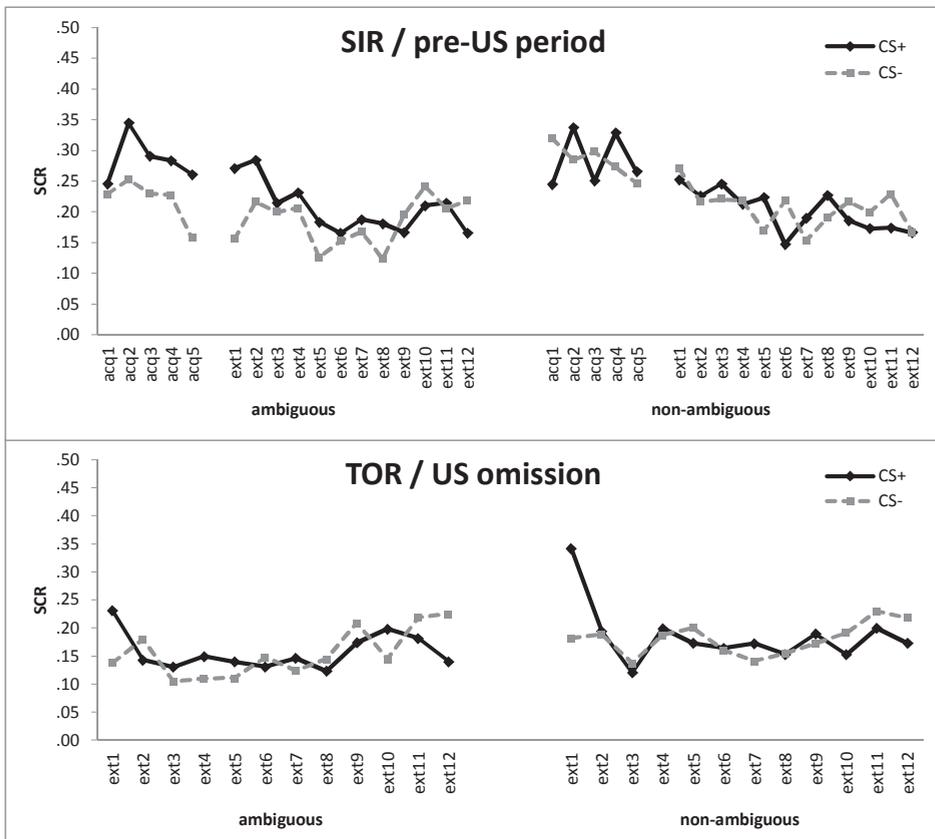
1 Closer inspection of the data suggested that these baseline differences may have been caused by random group differences in the type of trial that participants received first during acquisition. Twenty participants in the ambiguous condition received the CS+ first, whereas fifteen participants in the non-ambiguous condition did. Tests showed that receiving the CS+ first had a strong positive effect on the differentiation on trial 1,  $F(1, 62) = 25.59, p < .001, \eta_p^2 = .29$ , and when adding the type of first trial (CS+ or CS-) as covariate in the analysis the CS x T x C interaction became non-significant,  $F < 1$ .

## CS evaluations

After extinction, evaluations for the CS+ were significantly higher than for the CS-,  $F(1, 62) = 25.64, p < .001, \eta_p^2 = .29$ , with no differences across conditions,  $F < 1$  (ambiguous: CS+  $M = 55.03, SD = 16.38$ ; CS-  $M = 37.63, SD = 17.96$ ; non-ambiguous: CS+  $M = 52.78, SD = 20.80$ ; CS-  $M = 33.94, SD = 21.75$ ).

## Skin conductance

*FIR*: FIR magnitudes did not increase over time in response to CS+ vs. CS- onset (CS x T),  $F < 1$ , with no differences across conditions (CS x T x C),  $F(3.29, 203.87) = 1.50, p = .21, \eta_p^2 = .02$ . In line with this, no significant differentiations were present on the last acquisition trial or on the first extinction trial,  $F_s < 1$ , as well as no interactions with condition,  $F_s < 1$  (data not shown).



**Figure 3.** Skin conductance data for second-interval responses (SIR) and third-interval omission responses (TOR), per condition, CS-type, and trial. “acq” refers to acquisition (5 trials); “ext” refers to extinction (12 trials). “SCR” represents the mean range-corrected and square root transformed sum of amplitudes within the response window.

*SIR*: The CS+ vs. CS- differentiation did not change over time,  $F(3.46, 214.42) = 1.14, p = .34, \eta_p^2 = .02$ , irrespective of condition,  $F < 1$ . However, and in line with visual inspection of the data, there was a main effect of CS-type,  $F(1, 62) = 4.61, p = .036, \eta_p^2 = .07$ , indicating larger responses to the CS+ vs. CS-, and a significant CS x C interaction,  $F(1, 62) = 4.30, p = .04, \eta_p^2 = .07$  (see Figure 3). Follow-up analyses suggested overall increased skin conductance to the CS+ in the ambiguous condition,  $F(1, 31) = 10.08, p = .003, \eta_p^2 = .25$ , but not in the non-ambiguous condition,  $F < 1$ . In line with this, on the last acquisition trial, the ambiguous condition showed a significant CS+ vs. CS- differentiation,  $F(1, 31) = 4.25, p = .048, \eta_p^2 = .12$ , whereas the non-ambiguous condition did not,  $F < 1$  (although the overall CS x C interaction on this trial did not reach significance,  $F(1, 62) = 1.46, p = .23, \eta_p^2 = .02$ ).

On the first extinction trial, *SIR* magnitudes differed significantly between conditions,  $F(1, 62) = 5.91, p = .018, \eta_p^2 = .09$ . Follow-up analyses indicated a differentiation in the ambiguous,  $F(1, 31) = 9.47, p = .004, \eta_p^2 = .23$ , but not in the non-ambiguous condition,  $F < 1$  (see Figure 3). The acquired differentiation in the ambiguous condition rapidly extinguished: on extinction trial 2, it was not significant anymore,  $F(1, 31) = 1.48, p = .23, \eta_p^2 = .05$ . However, over the course of extinction, the reduction in differential skin conductance scores in the ambiguous condition did not reach significance (CS x T),  $F = 1.10, ns$ .

*TOR*: a *TOR* to the CS+ (vs. CS-) was found on the first extinction trial,  $F(1, 62) = 14.83, p < .001, \eta_p^2 = .19$ , with no significant differences across conditions,  $F = 1.03, ns$  (see Figure 3). This US omission response disappeared quickly, as no differentiation was present anymore on the second extinction trial,  $F < 1$ . In line with this, extinction of the omission response was marginally significant (CS x T),  $F(8.63, 535.05) = 1.75, p = .08, \eta_p^2 = .03$ , and there was no significant CS+ vs. CS- differentiation on the last extinction trial,  $F(1, 62) = 2.73, p = .10, \eta_p^2 = .04$ . The course of extinction and final extinction levels did not differ across conditions,  $F_s < 1$ .

In sum, the results suggest that the time window shortly before US occurrence (*SIR*) and the time window after expected US occurrence in extinction (*TOR*), but not the time window right after CS onset (*FIR*), provide sensitive time windows to detect differences between the two CS-types. Evidence for increased *SIR* magnitudes to the CS+ was only found in participants who had received ambiguous instructions about the CS-US contingency. Furthermore, acquired differential skin conductance responses extinguished rapidly when CS-US pairings were discontinued during extinction.

## Discussion

The aims of the present study were to 1) examine whether skin conductance is a measure of differential responding in appetitive conditioning, and if so, which time window is most sensitive to distinguish between the CS+ and CS–, and 2) investigate whether inclusion of the ambiguous word *sometimes* in a contingency instruction attenuates acquisition and extinction. Results suggested differential skin conductance responses when the US was imminent (i.e., SIR), though only for participants who received an ambiguous contingency instruction. In contrast, no differential responses were found for the time window following CS onset (i.e., FIR). Further, evidence was found for an US omission response (i.e., TOR). Extinction of these differential skin conductance responses was very rapid: they were non-significant by the second extinction trial. Finally, the ambiguous contingency instruction was related to a worse extinction of US expectancies.

These findings indicate that skin conductance can function as a sensitive measure of differential responding in appetitive conditioning involving food rewards: acquisition of differential responses was found in an anticipatory time window when the US was imminent, and an US omission response was present when the US unexpectedly did not occur in early extinction. Specifically, regarding the pre-US time window, the CS+ elicited greater skin conductance responses than the CS– after acquisition, and only in participants who received an ambiguous contingency instruction – though the overall change in differential skin conductance over the course of acquisition did not reach significance. The finding that the pre-US vs. CS onset time window is better able to distinguish CS+ and CS– trials in case of longer CS–US intervals seems in line with unpublished pilot data of previous work in fear conditioning (Lovibond et al., 2008). It is likely that participants learn about the temporal delay between CS onset and the occurrence of the US, and as a result show anticipatory skin conductance responses shortly before the US is expected. Finally, the omission response reported here may reflect “surprise” when the US did unexpectedly not occur during extinction (e.g., Spoormaker et al., 2011). The finding that this response was only present on the first extinction trial suggests that it may only occur in appetitive conditioning when non-occurrence of the US is very surprising. Thus, future studies that use a similar appetitive conditioning paradigm may wish to 1) examine skin conductance in the pre-US period, 2) take into account ambiguity of the CS–US relationship, and 3) examine the US omission response.

The unexpected finding that acquisition of skin conductance responses was only found in participants who received ambiguous contingency instructions is interesting and merits further discussion. One explanation of this finding is that

participants in the ambiguous condition might have been thinking more extensively about whether or not the US was going to occur as possible US occurrence became more imminent, whereas for participants in the non-ambiguous condition, the outcome seemed certain and no such cognitive effort was required. Given that electrodermal responding is sensitive to a multitude of psychological processes (Critchley, 2002), this could have resulted in differential skin conductance responses only in the ambiguous condition. Note, however, that this finding seems in contrast with prior human conditioning studies using aversive USs. In these studies, participants showed *smaller* skin conductance responses to stimuli that indicated ambiguity or uncertainty of US occurrence, compared with stimuli that signaled certain US occurrence (Dunsmoor, Bandettini, & Knight, 2007; Grupe & Nitschke, 2011) – although a recent study reported equally heightened skin conductance responses for such stimulus types when the temporal occurrence of the US was predictable (Davies & Craske, 2015). One obvious difference between our and these prior studies is the type of US used (appetitive vs. aversive), but it is not immediately clear how this may account for the contrasting findings. Thus, although the current data point towards interesting modulations in anticipatory skin conductance responses induced by contingency instruction ambiguity, additional studies are needed to investigate what processes may underlie the current findings and why they seem to differ with outcomes of prior studies conducted in the fear domain.

Finally, apart from its effects on anticipatory skin conductance responses, contingency instruction ambiguity was related to a worse extinction of US expectancies. This might be best explained by a verbally induced partial reinforcement extinction effect (Haselgrove, Aydin, & Pearce, 2004; van den Akker, Havermans, Bouton, & Jansen, 2014). This finding, combined with the additional effects of contingency instruction ambiguity on skin conductance responses in the present study, suggests that subtle changes in contingency instructions can have a substantial impact on responding. Researchers therefore may wish to take into account subtleties in their exact framing of contingency instructions when designing their studies.

In sum, we found evidence for skin conductance to be a sensitive measure of differential responding in appetitive conditioning involving food rewards in two time windows: when the US was imminent, and during unexpected omission of the US in early extinction. Interestingly however, differential anticipatory responses were only found for participants who had received an ambiguous contingency instruction, suggesting that the sensitivity of this anticipatory measure might be dependent on the specific task context. Apart from their effects on skin conductance, verbal contingency instructions also affected US expectancies –

as expected, ambiguous instructions slowed their extinction. Future (appetitive) conditioning studies may wish to further examine and/or take into account effects of contingency instruction ambiguity.

## **Acknowledgements**

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# Chapter 8

## General discussion



This dissertation aimed to address some important gaps in human food conditioning research. First, it was examined whether appetitive conditioning occurs under more real-life circumstances by using more naturalistic stimuli as CSs and by conducting the experiment outside the laboratory (**Chapter 2 and 3**). Second, mechanisms of extinction and techniques to improve long-term extinction were investigated (**Chapter 4 and 5**). Third, two individual difference factors were studied: learning history and impulsivity (**Chapter 2, 5, and 6**). Finally, it was tested whether salivation (**Chapter 2, 5, and 6**) and skin conductance (**Chapter 7**) were sensitive to detecting differential responses to the CS+ vs. CS-. Below, the main findings are first summarized and then discussed in more detail. In addition, important remaining empirical questions are outlined and clinical implications are discussed.

## Summary of the findings

In **Chapters 2 and 3**, studies are described that examine conditioning under more naturalistic circumstances. In one study (**Chapter 2**) a virtual environment (e.g., a gallery) was repeatedly paired with the intake of a small amount of milkshake (the US). After acquisition, participants reported increased US (eating) expectancies, desires for milkshake, and CS liking when presented with the milkshake-associated environment (CS+), relative to an environment not paired with milkshake intake (CS-). Some evidence was also found for the elicitation of conditioned physiological reactivity: salivation to the CS+, but not the CS-, was heightened compared with baseline – although the difference between the CS+ and CS- was non-significant. Finally, in one subgroup of participants (the more impulsive ones), a greater intake in the CS+ vs. CS- was found.

In the study described in **Chapter 3**, we attempted to further strengthen the link with real-life by not only using naturalistic stimuli (specific times of day) but by also conducting the experiment *outside* the laboratory. Ecological momentary assessment was used to pair one specific time of day (CS+) with the US (eating handmade Belgian chocolates), and to assess US expectancies and eating desires in response the CS+ and CS- time of day during an acquisition and extinction phase. Results showed that whereas differential US expectancies were successfully acquired, eating desires were not. However, exploratory analyses revealed an interesting finding: it seemed that a part of the participants (approximately half) acquired differential eating desires. Once acquired, it appeared difficult to extinguish eating desires – mirroring findings of laboratory studies. Closer inspection of the data showed that the “learners” also developed greater differential US

expectancies and missed fewer opportunities to learn about the CS–US relationship (i.e., they missed fewer prompts). This could suggest that eating desires *can* be learned in real-life, but this may be more difficult than in the laboratory.

Prior studies suggest that extinction of eating desires is relatively difficult to achieve. In **Chapter 4**, it was tested whether US expectancies might mediate the extinction of eating desires. In addition, CS evaluations were assessed to gain more insight into their potential relationship with eating desires. Participants first completed a differential acquisition procedure, in which a stimulus (a box) was repeatedly paired with a food US (chocolate), whereas another box was never paired with chocolate. After this, half of the participants were instructed that none of the boxes would contain chocolate anymore, while the other did not receive this instruction. This was immediately followed by an extinction phase. It was found that instructed extinction reduced US expectancies but had no impact on eating desires.

The study described in **Chapter 4** had an additional aim – to examine whether a reduced amount of eating expectancy violation would result in worse longer-term extinction learning. That is, when US expectancies have been disconfirmed after acquisition, the non-occurrence of the US during extinction is rather unsurprising (expectancy violation is low), and relatively little extinction learning may occur. In this study, extinction learning was tested by assessing spontaneous recovery and re-extinction on a subsequent test day. However, findings indicated that the extinction instruction did not adversely affect responding – extinction of desires was incomplete, and similarly so for both conditions. Finally, partial evidence was found for a link between eating desires and evaluations: differential evaluations were successfully acquired but they only partly mirrored changes in eating desires throughout our conditioning phases. In addition, correlations between eating desires and evaluations were inconsistent.

In **Chapter 5**, we studied two extinction techniques aimed at reducing rapid reacquisition. After an acquisition phase, participants received one of three extinction procedures: normal extinction, occasional reinforced extinction (some CS–US pairings were reinforced), and provision of unpaired USs (some USs were provided during the inter-trial intervals). After this, a reacquisition phase took place, during which the CS–US contingency was again fully reinforced. Next, salivation to, and preference for, the CSs were assessed. In line with expectations, both occasional reinforced extinction and unpaired USs during extinction (compared with normal extinction) resulted in less rapid reacquisition of US expectancies. The reacquisition of eating desires was however unaffected by either procedure. In line with previous reports, the extinction of eating desires was not complete in any of the conditions. Participants also indicated a conditioned preference for the CS+ vs.

CS–, and only partial evidence for a conditioned salivary response was found. Finally, higher levels of impulsivity were related to a less rapid reacquisition of eating desires. We conclude that occasional USs during extinction (paired or unpaired from the CS) is a promising technique that might help reduce relapse in dieters.

In **chapter 6**, we studied two potential sources of inter-individual variability in appetitive conditioning: learning history and impulsivity. In two studies, the effects of partial vs. continuous reinforcement during acquisition were examined on the extinction and reacquisition of appetitive responses to food cues. In addition, it was examined whether impulsivity moderated conditioned responses. In addition, salivation was repeatedly measured, and CS preference was assessed. As expected, we found that partially vs. continuously reinforced acquisition lead to a slower extinction of US expectancies (**study 1 & 2**), and, once successfully acquired, eating desires (**study 2**). In fact, after partial reinforcement, eating desires were resistant to extinction – no evidence for extinction was found after partial reinforcement whereas a partial extinction was present after continuous reinforcement. These findings clearly reflect a partial reinforcement extinction effect (PREE). Also in line with expectations, reacquisition of US expectancies was more rapid after continuous reinforcement, though eating desires were similarly reacquired across conditions. Impulsivity was related to a slower extinction of US expectancies (**study 1: CRF condition & study 2**), and in one study, to a less rapid reacquisition of eating desires (**study 2**). Finally, a preference for the CS+ vs. CS– was found and only partial evidence for a conditioned salivary response.

In **Chapter 7**, we examined whether skin conductance is sensitive to detect differences between a food-associated CS+ and CS–. Participants completed an acquisition and extinction phase, and three time windows were examined: after CS onset, when the US was imminent, and after CS offset (extinction only). In addition, the effects of contingency instruction ambiguity were examined: prior to acquisition, participants received either an ambiguous or non-ambiguous instruction regarding the CS–US contingency. Next to skin conductance, US expectancies, eating desires, and CS evaluations were also measured. Evidence for an acquisition of differential anticipatory skin conductance responses were found in the time window immediately prior to US occurrence (but not right after CS onset) – though interestingly, this was only the case for participants who had received the ambiguous contingency instruction. In addition, results indicated a heightened response during US omission in early extinction (i.e., during an expectancy mismatch). Both responses extinguished rapidly. Finally, US expectancies were also affected by the type of instruction: extinction of expectancies was slowed. Eating desires and CS evaluations were not affected by the type of instruction, and in line with previous studies, both failed to (completely) extinguish.

## General discussion

### Learning to desire food in naturalistic situations

Experts have argued that in principle, *any* stimulus in the natural environment can become associated with food consumption through repeated pairings – including the sight and smell of food, specific environments, emotions, rituals, and cognitions (Bouton, 2011; Jansen, Nederkoorn, & Havermans, 2011). Until recently however, this assumption remained untested – prior studies have typically used arbitrary stimuli (e.g., trays, geometrical shapes) as CSs. Therefore, in one study (**Chapter 2**), we investigated appetitive conditioning using more naturalistic stimuli (virtual environments). The findings suggest that virtual environments, much like arbitrary stimuli, can become to function as conditioned stimuli: after repeated pairings, a milkshake-associated environment elicited conditioned responses, including heightened US expectancies and desires for milkshake. This is in line with a few recent laboratory studies that have also attempted to condition more naturalistic cues to food intake. Replicating and extending our current findings, these studies have found evidence for appetitive conditioning to virtual environments presented on a computer screen (Astur, Carew, & Deaton, 2014), to emotions (Bongers & Jansen, 2015), and to edible objects (Blechert et al., 2016), and collectively, the studies provide strong support for classical conditioning as mechanism underlying cue and context-elicited appetitive responses to naturalistic food cues.

Ultimately, we want to explain, predict, and change behaviour in free-living humans. However, given the numerous differences between laboratory studies and the real-life environment, it may be that laboratory findings do not completely generalize to real-life. Therefore, in a second study (**Chapter 3**), we attempted to further strengthen the link with real-life conditioning by utilizing not only ecologically valid CSs (certain times of day) but also by conducting the experiment outside the laboratory. Results indicated that whereas US expectancies were successfully acquired, chocolate desires were not. However, exploratory analyses indicated that a subsample of participants had successfully acquired differential chocolate desires, and interestingly, these acquired desires did not seem to (fully) extinguish – mirroring findings of laboratory studies. Closer inspection of the data suggested that a successful acquisition of differential chocolate desires co-occurred with more CS–US pairings and stronger US expectancies – suggesting these factors may contribute to a successful acquisition of eating desires. This could provide preliminary evidence that the acquisition of differential eating desires under more naturalistic circumstances *is* possible, supporting the ecological validity of our

conditioning paradigm, and suggesting that classical conditioning contributes to (or has an influence on) cue-elicited food desires in daily life. On the other hand, our findings also suggest that eating desires are more difficult to acquire in real-life compared with the laboratory, in which eating desires are usually easily established after a similar amount of CS–US pairings (Bongers et al., 2015; Papachristou et al., 2013; Van Gucht, Vansteenwegen, Beckers, et al., 2008). The precise causes for these differential patterns for laboratory vs. real-life conditioning are presently unknown. Clearly, more research is needed on what might cause an attenuated conditioning in real-life, and the specific circumstances under which individuals do or do not acquire conditioned desires to eat.

### **Mechanisms of extinction: evidence for multiple systems?**

Prior findings suggest that eating desires and US expectancies generally change in parallel during acquisition. However, during *extinction*, these responses appear to diverge: US expectancies reduce while eating desires tend to remain heightened (Papachristou et al., 2013; Van Gucht et al., 2013; Van Gucht et al., 2010; Van Gucht, Vansteenwegen, Beckers, et al., 2008). Van Gucht and colleagues explained this divergence by proposing that US expectancies and eating desires might stem from separate response systems that are differentially sensitive to extinction. Specifically, US expectancies might stem from a response system that prepares the organism for the incoming US, while eating desires could stem from another system that is based on mere activation of the US representation in memory – a system that might also underlie evaluative responses (Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002; Baeyens, Eelen, Crombez, & Van den Bergh, 1992). Extinction may have more impact on responses that are based on a system that prepares an organism for the incoming US than on responses that are based on a hedonic/evaluative system (Van Gucht et al., 2010; Van Gucht, Vansteenwegen, Beckers, et al., 2008). This is of importance: if eating desires are truly resistant to extinction, this suggests that techniques other than extinction are necessary to successfully reduce desires.

Our findings indeed consistently show that a complete extinction of eating desires is relatively difficult to achieve – acquired eating desires did not fully extinguish in any of our studies (**Chapter 3, 4, 5, 6, and 7**). This was the case even after increasing the number of extinction trials (**Chapter 5**), when extinction took place on two different sessions (**Chapter 4**), and (possibly) when extinction was spread out over a 12-day period (**Chapter 3**). We also excluded an important alternative explanation for the apparent resistance of eating desires to extinction. Specifically,

and in line with findings of conditioning studies in addiction (e.g., Field & Duka, 2001), we proposed that a non-complete extinction of US expectancies might be causally related to the failure to extinguish eating desires (i.e., lingering US expectancies may cause heightened eating desires during extinction). We experimentally tested this by disconfirming US expectancies after acquisition (i.e., instructed extinction) – and found that this had no effect on eating desires (**Chapter 4**). The data reported in **Chapter 7** is consistent with this finding. In this study, a cognitive manipulation (ambiguous vs. non-ambiguous contingency instructions) only influenced the extinction of US expectancies, but had no influence on eating desires. Taken together, our findings seem in line with the idea that US expectancies and eating desires stem from different response systems that are differentially sensitive to extinction (and to verbal contingency instructions). It is interesting to note that some food cue exposure studies (in which individuals are exposed to e.g. the sight and smell of food for brief periods of time) also found that manipulating eating expectancies does not affect eating desires (e.g., Hardman, Scott, Field, & Jones, 2014; see also Boswell & Kober, 2015, Supporting Information) – thus, it may be that eating desires elicited by de novo conditioned and well-established food cues are relatively insensitive to current US expectancies.

Our studies also provide some insight into the responses that might share a common mechanism with eating desires vs. US expectancies. Regarding eating desires, one may expect their patterns to mirror those of CS evaluations, as these responses may be both based on activation of the US representation in memory (Van Gucht et al., 2010; Van Gucht, Vansteenwegen, Beckers, et al., 2008). Regarding US expectancies, one could expect strong relationships with skin conductance responses, as skin conductance may primarily reflect cognitive contingency learning (Sevenster et al., 2012; Soeter & Kindt, 2010; Weike, Schupp, & Hamm, 2007). We found partial evidence for this. On the one hand, eating desires and evaluations were both unaffected by differential contingency instructions in two studies: instructed extinction and contingency instruction ambiguity had no influence on both eating desires and CS evaluations, whereas US expectancies and skin conductance both showed sensitivity to the type of contingency instruction received (**Chapter 4 and Chapter 7**). On the other hand, closer inspection of the data in **Chapter 4** suggested partially divergent patterns between eating desires and evaluations: desires and evaluations did not change in parallel during the experimental sessions, and they did not consistently correlate with each other. The data reported in **Chapter 7** suggested differential patterns for US expectancies and skin conductance as well – both responses seemed differentially affected by differential contingency instructions. Thus, while eating desires and evaluations may be more related to each other than to US expectancies and skin conduc-

tance, eating desires/evaluations and US expectancies/skin conductance do not seem homologous either. The precise relationships between these measures await further investigation.

## Countering eating desires: is extinction ineffective?

A complete extinction of eating desires was not present in any of our studies – despite various attempts to achieve this (e.g., more extinction trials, more extinction days). However, it is important to highlight that eating desires often extinguished at least *partially* throughout our studies. This suggests that extinction (and its clinical equivalent: cue exposure therapy) is at least partly effective in decreasing eating desires. In fact, closer inspection of the data described in **Chapter 5** (in which a larger amount of extinction trials was used) suggested that approximately half of the participants who acquired eating desires had fully extinguished their desires by the 20<sup>th</sup> (last) extinction trial – despite showing *greater* acquisition levels. In contrast, the other half of the participants showed little evidence for any extinction. Although the causes for this large inter-individual variability in extinction performance are presently unclear, this may suggest that cued eating desires are not insensitive to extinction per se, but for some individuals relatively extensive extinction trainings are required to effectively reduce desires.

Still, the finding that at least in some individuals, acquired eating desires are difficult to extinguish (and can easily return after extinction, see **Chapter 4**) suggests that including techniques other than extinction may be beneficial for reducing eating desires more rapidly and/or more permanently. If eating desires and conditioned evaluations indeed share a common mechanism (activation of the US representation in memory), then interventions that address the positive valence of a CS might also be effective in decreasing eating desires. For example, counterconditioning (pairing the CS+ with a negatively valenced US after acquisition) has been shown to eliminate both conditioned eating desires and positive evaluations, this effect persisting after one week (Van Gucht et al., 2013; Van Gucht et al., 2010). Other potentially effective methods could include US devaluation (i.e., diminishing the value of the US; Baeyens, Eelen, Van den Bergh, & Crombez, 1992; Leer, Engelhard, Altink, & van den Hout, 2013), and cognitive reappraisal of the CS (Blechert et al., 2015). Highlighting the possible benefit of targeting evaluations in reducing appetitive responses, CS evaluations have been found to be predictive for food choice (Veling, Aarts, & Stroebe, 2013) and alcohol intake (Houben, Nederkoorn, Wiers, & Jansen, 2011). Similarly, more negative evaluations about an aversive CS+ after extinction are predictive for returns of fear responses

(Dirikx, Hermans, Vansteenwegen, Baeyens, & Eelen, 2007; Zbozinek, Hermans, Prenoveau, Liao, & Craske, 2014).

## Improving dieting success by reducing risk of relapse

Even when appetitive responses have been successfully reduced during extinction, they can suddenly return – as shown by conditioning phenomena such as rapid reacquisition (Bouton, 2011). These returns of responses theoretically result in an increased chance for relapse, and may partly explain why long-term successful dieting is so difficult (Jansen, Schyns, Bongers, & van den Akker, 2016). Techniques that effectively reduce the magnitude of these returns of responses in the lab may also prove effective in reducing relapse in dieters and individuals with eating psychopathology.

One interesting technique is *occasional reinforced extinction* (i.e., occasionally reinforcing the CS–US contingency during extinction). In **Chapter 5**, we indeed found evidence for occasional reinforced extinction to effectively reduce reacquisition in humans – occasional reinforced extinction (relative to normal extinction) resulted in a slower reacquisition of US expectancies. In contrast, conditions did not differ in the reacquisition of eating desires. A similar pattern (an attenuated reacquisition of US expectancies but not eating desires) was found for participants who received unpaired USs during extinction (i.e., receiving occasional USs during extinction in the inter-trial intervals) – though unpaired USs did not slow down extinction. The mechanism behind this might be similar to the mechanism underlying occasional reinforced extinction: the USs may have become associated with extinction, and when encountered during reacquisition, this lead to a slowed return of responses. Thus, these techniques seem effective in diminishing the return of at least some types of conditioned responses – in line with findings in rodents (Bouton et al., 2004; Woods & Bouton, 2007). Given these encouraging findings, we suggest future studies may directly examine the effectiveness of these techniques in (pre)clinical populations.

Occasional reinforced extinction may be implemented in two ways. First, if one aims to reduce relapse caused by one “lapse” in the diet (e.g., eating crisps in the evening again once after a period of successful restriction/extinction), one could deliberately occasionally reinforce this event during extinction. Second, eating large amounts of food (including eating binges) may be prevented as well using occasional reinforced extinction, by learning to associate eating one small snack with no additional intake (Bouton, 2011). Incorporating *unpaired* USs may be possible as well for some types of food cues. For example, if a dieter exclusively

consumes crisps in the evening when watching television, he or she may benefit from eating crisps in some other contexts. A similar approach may be used to diminish eating binges: by eating (moderate amounts of) binge food in non-binge contexts, the exclusive bond between a CS and a binge may be broken more successfully (Jansen, 1998).

One may also attempt to heighten *eating expectancy violation*. In **Chapter 4**, after acquisition, participant's eating expectancies were either verbally disconfirmed or not disconfirmed prior to extinction. By verbally disconfirming expectancies, expectancy violation should be minimal during extinction (the non-occurrence of the US is unsurprising), which may attenuate extinction learning (Craske et al., 2014; Rescorla & Wagner, 1972). The implication for cue exposure therapy would be that one should avoid cognitive interventions that may diminish US expectancies prior to an exposure session (e.g., informing the patient that no eating will occur during the session), and design cue exposure sessions in a way that maximizes eating expectancy violation. However, we found no evidence for the extinction instruction to hamper extinction learning, suggesting that it may not be necessary to focus on maximizing eating expectancy violation during cue exposure sessions. Alternatively, it may also be that a stronger manipulation is necessary to achieve attenuated conditioned responding (e.g., more sessions, larger differences in violation), or that effects would be visible on other indices of appetitive responding. Given that expectancy violation is thought to play a very important role in exposure therapy for anxiety disorders (Craske et al., 2014), further research on the role of eating expectancy violation in extinction is warranted.

Research into additional techniques that may strengthen extinction learning and reduce returns of appetitive responses can also help develop more successful weight loss interventions and optimize cue exposure therapy. There are various techniques that seem promising, including for example counterconditioning (Van Gucht et al., 2013), the use of retrieval cues (Dibbets & Maes, 2011), and exposure in multiple contexts (Vansteenwegen et al., 2007). One further empirical question that our findings raise is exactly how the different responses we measure in the laboratory translate to eating behaviour in real-life. For example, does an attenuated return of US expectancies but not eating desires still result in a reduced risk of relapse? While eating desires are thought to play a very important role in motivating intake (e.g., Fedoroff, Polivy, & Peter Herman, 2003; Jansen, Havermans, & Nederkoorn, 2011), it is not clear yet how exactly US expectancies may relate to eating – though in human fear conditioning, US expectancy is considered a valid measure (Boddez et al., 2013).

## Individual differences in conditioning

Individual differences in food cue reactivity and dieting success might be partly explained by individual differences in which responses to food are acquired and extinguished. We tested two potential factors that may explain inter-individual variability in reactivity: an impulsive personality and learning history (specifically, schedules of reinforcement).

It was tested whether one measure of impulsivity (the Barratt Impulsiveness Scale-11 or BIS-11; Patton et al., 1995) moderated conditioned responses across four studies – in one study, only acquisition was studied (**Chapter 2**), and in three studies, acquisition, extinction, and reacquisition were examined (**Chapter 5 and 6**). Regarding acquisition, we did not find consistent evidence for impulsivity to moderate responding. In one study, impulsivity was related to greater intake in the CS+ vs. CS–, suggesting that heightened impulsivity might be associated with an increased susceptibility to (over)eat in response to a CS+. This is an interesting finding, and might reflect an increased proneness to react to cravings in the higher impulsives (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009). However, this finding was not replicated in another study – this study even reporting a *decreased* intake to the CS+ vs. CS– in more impulsive individuals (Bongers et al., 2015). Only partial evidence was found for our hypothesis that impulsivity slows down extinction – in one study impulsivity slowed down extinction of US expectancies (**Chapter 6; study 2**), in another study, it slowed down extinction of US expectancies only in one experimental condition (**Chapter 6; study 1**), and in a third study, it did not interact with extinction (**Chapter 5**). Finally, impulsivity was related to a slower – rather than more rapid – reacquisition of eating desires in two studies (**Chapter 6; study 2 and Chapter 5**); in the third study, reacquisition of eating desires could not be examined because they were not successfully acquired (**Chapter 6; study 1**). Taken together, associations between impulsivity and appetitive learning in our studies were inconsistent, only its interaction with reacquisition being quite consistent across two studies. However, this finding seems in sharp contrast with several studies linking impulsivity to a greater chance of relapse (Doran, Spring, McChargue, Pergadia, & Richmond, 2004; Yoon et al., 2007), and with a study suggesting impulsivity interferes with weight loss (Nederkoorn et al., 2007). There are also a few reports, however, linking impulsivity with a *reduced* risk of relapse after treatment (Papachristou, Nederkoorn, Giesen, & Jansen, 2014; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010). One intriguing possibility is that those treatments and the current extinction procedure targeted similar underlying mechanisms that the impulsives (who may need it the most) benefitted most from. This possibility awaits empirical tests.

Of note, it may be that impulsivity would show more consistent relationships with appetitive learning under different circumstances. For example, one may argue that aspects of impulsivity not measured in our studies are more strongly related to differences in learning (e.g., reward sensitivity). However, an appetitive conditioning study conducted in our laboratory examined different aspects of impulsivity and did not find evidence for this (Papachristou et al., 2013). It may also be that the food US (e.g., one spoon of chocolate mousse) used in the studies was too small – for example, a previous study has shown that extraverts (relative to introverts) only show better appetitive conditioning when stronger, but not weaker, sexual USs were used (Paisey & Mangan, 1988). Another possibility is that the relatively simple paradigm that we used minimized chances to detect effects of impulsivity on responding. It has been argued that individuals may react similarly to unambiguous and simple (“strong”) situations, which limits variability in responding across participants. In contrast, using “weak” situations (situations that involve some ambiguity or complexity) may be more likely to reveal meaningful individual differences. These “weak” situations may also more closely resemble real-life circumstances (Beckers et al., 2013; Lissek, Pine, & Grillon, 2006). Finally, we have mostly relied on self-report measures, and it may be that impulsivity effects would have been reflected in other types of measures (behavioural, physiological). In sum, future studies may uncover the precise role of impulsivity (and other individual differences) in different phases of learning by studying the different facets of impulsivity, by including stronger USs, by using a more ambiguous paradigm, and by including different types of outcome measures.

Inter-individual variability in responding is likely not solely explained by stable predisposing factors. Another interesting potential source of variability is learning history – specifically, the extent to which food cues have been reinforced in the past. The findings reported in **Chapter 6** clearly indicate that humans can experience a PREE after partially reinforced acquisition: extinction of eating desires and US expectancies was worse after partial reinforcement. In addition, the reacquisition of US expectancies (but not eating desire) was slowed. Based on these findings, we proposed that individual differences in dieting success may be partly explained by different learning histories: dieters who have previously practiced partial reinforcement schedules experience a greater difficulty in restricting their intake due to a slower extinction (i.e., they may experience PREEs). However, if an individual has managed to stick to his or her diet long enough, he or she may be able to overcome the PREE, and even be at lower risk of relapse. Further research on the unique influences of learning histories (such as schedules of reinforcement) on appetitive responding may help elucidate why some individuals diet more suc-

cessfully than others, and possibly, the effectiveness of treatments can ultimately be improved by taking into account learning histories.

One promising individual difference factor not examined in this dissertation is *weight status*. Overweight and obesity have been associated with greater food cue reactivity and cue-elicited overeating (Ferriday & Brunstrom, 2011; Jansen et al., 2003; Tetley, Brunstrom, & Griffiths, 2009), and one possibility is that this heightened food cue reactivity is partly the result of a predisposition to form associations between stimuli and food intake more readily and/or more strongly. One recent study indeed reported evidence for a successful acquisition of a swallowing response in overweight individuals to a CS+ (vs. CS-) associated with the delivery of chocolate milk (US), whereas normal-weight controls did not successfully acquire this response (Meyer, Risbrough, Liang, & Boutelle, 2015). This finding is in contrast, however, with several other findings relating obesity to associative learning *deficits*, including when food rewards are used as USs (e.g., Coppin, Nolan-Poupart, Jones-Gotman, & Small, 2014; Zhang et al., 2014). To gain more insight into the role of weight status in appetitive learning, we recently conducted a study in which we compared overweight/obese ( $n = 45$ ; BMI  $M = 33.8$ ;  $SD = 4.4$ ) with normal-weight ( $n = 34$ ; BMI  $M = 22.4$ ;  $SD = 1.58$ ) women on a differential appetitive conditioning task involving an acquisition and extinction phase (van den Akker, Schyns, & Jansen, in prep). The number of trials in each phase was variable: acquisition vs. extinction ended when a performance criterion was reached (acquisition: CS+ vs. CS- differentiation  $> 50$ ; extinction: differentiation  $< 20$ ). We examined US expectancies, eating desires, CS evaluations, and skin conductance. The results showed that the overweight/obese group acquired less differential US expectancies, lower eating desires, and they did not develop differential CS evaluations – despite having received (non-significantly) more acquisition trials. However, the course of extinction – although difficult to examine due to the differences in acquisition – did not differ across the groups. When writing this discussion, skin conductance responses have not yet been analyzed. Still, these results provide evidence suggesting overweight/obese individuals are worse at discrimination learning on an appetitive conditioning task using food as rewards. One intriguing possibility is that this worse discrimination learning may translate to *overgeneralization*, since worse discrimination learning is thought to be one aspect of overgeneralization. Overgeneralization is related to (fear) psychopathology – for example, anxiety disorder patients are thought to overgeneralize their fear to various stimuli, including those never actually paired with an aversive US (Hermans, Baeyens, & Vervliet, 2013; Lissek et al., 2010). As a result, these patients experience fear in response to various situations, promoting anxiety and avoidance. If obese individuals are prone to overgeneralization in an appetitive

paradigm, this would have interesting implications. For example, a person who repeatedly consumes crisps in the evening while watching a certain TV show may learn this eating to be very specific to those precise circumstances (evening time while watching a specific TV show). This specific context is expected to promote food cue reactivity. In contrast, a person who overgeneralizes may experience food cue reactivity to a wider range of stimuli – e.g., evening time, or watching TV *in general*, resulting in a greater amount of craving-eliciting cues. This provides a mechanism for studies linking higher BMI with more frequent food cravings (Chao, Grilo, White, & Sinha, 2014), and might be consistent with recent evidence suggesting that overgeneralization may be caused by executive function deficits (Lenaert, van de Ven, Kaas, & Vlaeyen, 2016): there is strong evidence for such deficits in obesity (Smith, Hay, Campbell, & Trollor, 2011), and hence, they may translate to overgeneralization.

In sum, differences in certain traits (impulsivity, weight status) may impact appetitive responses throughout different conditioning phases, although their specific influences require further investigation. In addition, we have shown that differences in learning histories (different reinforcement schedules) can influence conditioned appetitive responses as well: partial reinforcement led to a slower extinction of eating desires and US expectancies and to a less rapid reacquisition of US expectancies. There are several other factors that can potentially alter conditioned appetitive responses – such as certain genetic polymorphisms (Klucken et al., 2015; Klucken et al., 2013), gender (Klucken et al., 2009), and dieting status (Astur et al., 2015). Of note, the current studies have not addressed influences of differential *states* in explaining individual variability in responding – for example, food deprivation may potentiate conditioned appetitive responses (e.g., through elevated ghrelin levels; Astur et al., 2014; St-Onge, Watts, & Abizaid, 2016; see also Robinson & Berridge, 2013), as might selective restriction of e.g. chocolate (Polivy, Coleman, & Herman, 2005). We have attempted, though, to control for baseline hunger levels throughout the studies. Research into the influences of traits, states, and learning histories are important, since they may help explain why some dieters are successful and others are not. Ultimately, research into these aspects can help design optimized (and personalized) treatments.

## Psychophysiological measurements

Relying solely on self-report and behavioural measures has limitations. We examined two psychophysiological measures of differentially conditioned responding: salivation and skin conductance.

Salivary responses to the conditioned stimuli were assessed across four studies using the cotton role method (**Chapter 2, 5, and 6**). In three studies, a significant increase in salivation was found from baseline to CS+, no significant increase from baseline to CS-, and no significant difference between CS+ and CS- (**Chapter 2 and 6**). A fourth study found significant increases from baseline to both the CS+ and CS-, and also no difference between CS+ and CS- (**Chapter 5**). Taken together, although the findings provide some evidence for conditioned salivary responding to the CS+, they also suggest that salivation (as measured by the cotton role method) might not be very useful as measure of differential responding in appetitive conditioning.

Skin conductance seemed a more promising measure (**Chapter 7**). We examined three time windows during a conditioning trial – after CS onset (first interval response), immediately prior to US occurrence (second interval response), and during US omission in extinction (third interval omission response). We found evidence for differential responding in two of these time windows – in the pre-US and the US omission window. The finding that differential anticipatory responses were found only for a time window immediately preceding the possible occurrence of the US (but not after CS onset) seems in line with unpublished pilot data of previous work in fear conditioning, in which anticipatory reactions were also strongest when the US was imminent (Lovibond, Saunders, Weidemann, & Mitchell, 2008). It seems plausible to assume that participants have learned about the temporal delay between the CS and US, and as a result, show differential responding only when the US was imminent. Apart from this anticipatory response, we also found evidence for a differential response at CS offset. This may reflect “surprise” when the US was unexpectedly omitted during early extinction, and is in line with findings of fear conditioning studies (Spoormaker et al., 2011). Another interesting finding was that differential skin conductance responses were only present for participants who received an ambiguous contingency instruction. Since skin conductance can be influenced by various cognitive processes (Critchley, 2002), this finding may be explained by participants in the ambiguous condition thinking more extensively about whether or not the US was going to occur as possible US occurrence became more imminent. Taken together, future studies that utilize a similar appetitive conditioning paradigm may wish to 1) examine the time window when the US is imminent, 2) take into account ambiguity of the CS–US relationship, and 3) examine responses after CS offset. In addition, the findings raise the question what skin conductance responses reflect in appetitive learning paradigms, since they did not seem to consistently track US expectancies (Hamm & Weike, 2005).

Regarding the psychophysiological measurement of appetitive learning, a next step would be to identify more emotional/motivational measures of conditioned

appetitive responding. It would be interesting to see whether such a measure would mirror eating desires in conditioning paradigms. One such potential measure is the startle response – several studies suggest that startle is modulated in response to appetitive vs. neutral stimuli (Lipp, Cox, & Siddle, 2001; Sabatinelli, Bradley, & Lang, 2001). Another candidate is facial EMG. Facial EMG reactivity is thought to reflect an individual's evaluation of a stimulus, and it seems sensitive to appetitive conditioning effects (Armel, Pulido, Wixted, & Chiba, 2009). Finally, swallowing activity may provide a suitable measure for appetitive responding (Meyer et al., 2015; Nederkoorn, Smulders, & Jansen, 1999).

## Clinical implications

The finding that US expectancies and eating desires can be acquired and (at least partially) extinguished suggests a role for Pavlovian learning processes in responses to food cues. This suggests that the clinical analogue of extinction – cue exposure therapy – might effectively reduce food cue reactivity and overeating. In cue exposure therapy, obese individuals and/or those with eating psychopathology are repeatedly exposed to stimuli associated with food intake – such as the sight or smell of food, environments, and emotions. Although studies indeed suggest cue exposure therapy to effectively reduce US expectancies, cravings, overeating, and eating psychopathology (Boutelle et al., 2014; Jansen, Broekmate, & Heymans, 1992; Jansen, Van Den Hout, De Loof, Zandbergen, & Griez, 1989; Martinez-Mallén et al., 2007; Schyns, Roefs, Mulkens, & Jansen, 2016; Toro, Cervera, Feliu, Garriga, Jou, Martinez, & Toro, 2003), there is also room for improvement: evidence for its long-term effectiveness is mixed (Boutelle et al., 2014; Jansen et al., 1992). Focusing on strengthening extinction learning and reducing magnitudes of returns of responses may increase the (long-term) effectiveness of cue exposure therapy. The data reported in this dissertation suggest that occasionally consuming a US (but not attempting to heighten the violation of eating expectancies) in cue exposure therapy may improve its long-term outcomes. It is likely best however to incorporate a number of techniques into cue exposure therapy in order to maximize its effectiveness. In addition, our findings suggest that additional methods might need to be incorporated that specifically target eating desires, since their complete extinction seems difficult to achieve. A number of potentially effective techniques to optimize exposure treatment for anxiety disorders have been discussed by Craske and colleagues (2014), and can be applied to the appetitive field. In fact, we have recently translated these techniques to develop a novel cue exposure therapy protocol (van den Akker, Schyns, & Jansen,

2016), and conducted an 8-session RCT to test the effects of this optimized cue exposure treatment in overweight participants. The results of this trial are very promising – both at post-treatment and at 3-month follow-up, participants in the cue exposure (vs. control) intervention showed successful weight loss and a lower intake of a high-calorie food that was included in exposure therapy (Schyns, van den Akker, Roefs, Houben, & Jansen, in prep). This supports the notion that applying findings of conditioning studies can optimize cue exposure treatments.

### **Some remarks**

One important limitation of most of the studies reported in this dissertation is that (sensitive) measurements were limited to self-report (mostly US expectancies, eating desires, and CS evaluations). Relying solely on self-report measures has its limitations, since these measures can be especially sensitive to experimental demand, and their measurement can alter subsequent assessments. We have started, however, to investigate additional measures of appetitive responding (see **Chapter 7**), and will continue to do so in our next studies. It is important to note that we do not think that our conditioning effects (e.g., eating desire patterns) are primarily due to experimental demand. Although one may raise this argument regarding the acquisition of eating desires, it is more difficult to see how experimental demand would result in a difficulty to extinguish eating desires, especially when US expectancies were verbally disconfirmed.

Ultimately, laboratory conditioning studies should model real-life situations, as we wish to explain, predict and change behaviour in free-living humans. However, and as described in this dissertation, we only found partial evidence for an acquisition of eating desires when conditioning occurred in “real-life”. This may suggest that there are important differences between the laboratory and real-life that may need to be taken into account when translating laboratory findings to real-life circumstances. However, this does not suggest that appetitive conditioning has no important role in eating and dieting behaviour. For example, the finding that acquisition in real-life occurred at least in a part of the sample is encouraging. In addition, findings showing that cue exposure therapy is effective in decreasing appetitive responses (e.g., Schyns, Roefs, Mulkens, & Jansen, 2016), and those suggesting that a successful extinction of responses may occur after successful dieting (Jansen et al., 2010), indicate that extinction of appetitive responses occurs after repeated CS-alone presentations – in line with a learning-based account. Nevertheless, it is worth investigating the precise differences between condition-

ing in real-life vs. the laboratory, as this may clarify how laboratory findings exactly translate to real-life.

Finally, it may be noted that our participant samples consisted of exclusively normal-weight female students. Although the basic learning processes that we investigated are expected to apply to various populations, there might also be important differences across individuals in the manner in which appetitive responses to food are acquired and extinguished – which our previous and recent studies seems to suggest. As such, we do not know to what extent our findings generalize to populations for whom they might be most relevant – (unsuccessful) dieters, overweight and obese individuals, and individuals with eating disorders.

## **Conclusions**

We conclude that 1) Eating desires can be easily acquired in the laboratory. In real-life, their acquisition seems more difficult. 2) In the laboratory, eating desires extinguish partly during extinction, but their complete extinction is difficult to achieve. 3) US expectancies have no mediating role in the extinction of eating desires. 4) Occasional reinforced extinction might be a promising technique to reduce eating binges and relapse in unsuccessful dieters and binge eaters. 5) Impulsivity and learning histories can be sources of inter-individual variability in appetitive responding. 6) Skin conductance might provide a measure of differential responding in appetitive conditioning. 7) Cue exposure therapy can benefit from more insight into the learned components of appetitive responding to food cues.



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# Summary



Heightened cue-elicited appetitive reactions (e.g., desires to eat) can promote (over)eating, unsuccessful dieting, and weight gain. Although it is thought that Pavlovian conditioning plays an important role in cue-elicited responses, only few studies have examined appetitive conditioning using food as rewards in humans. This dissertation attempts to address some important questions in appetitive conditioning research in the food domain. All studies in this dissertation used a differential appetitive conditioning paradigm, in which an initially neutral stimulus (CS+) is repeatedly paired with high-calorie food (US) and responses are compared with a stimulus not paired with food (CS-).

**Chapter 1** provides an introduction to appetitive conditioning in the food domain. The role of Pavlovian learning in food cue reactivity, overeating and (un)successful dieting is outlined. Next, an overview of prior appetitive conditioning studies is provided. Some important remaining questions are raised, and an outline of the dissertation is given.

**Chapters 2 and 3** describe two studies aimed at examining whether appetitive conditioning to food cues can be established under more naturalistic circumstances. In one study (**Chapter 2**), participants learned to associate a virtual environment (CS+) with the intake of a small amount of milkshake (US), and another virtual environment with no milkshake (CS-). US expectancies, milkshake desires, salivation, CS liking, and milkshake intake during a bogus taste test were measured. After six CS-US pairings, participants reported greater US expectancies and desires for milkshake when presented with the CS+ vs. CS-. They also indicated a greater liking for the CS+, but on a choice test, did not prefer the CS+ over the CS-. In addition, some evidence for a conditioned salivary response was found: salivation increased from baseline to the CS+ (but not CS-), though differences between the CS+ and CS- were not significant. Finally, a subsample of the participants (those with higher impulsivity) consumed more milkshake in the CS+ vs CS-. In another study (**Chapter 3**), the link with real-life was strengthened by implementing conditioning outside the laboratory. Using ecological momentary assessment, participants reported their US expectancies and eating desires on two specific times of day. At one time of day, participants consumed chocolates over the course of five days (acquisition). This was followed by a period during which no more chocolate was consumed (extinction, twelve days). It was found that although differential US expectancies increased over the course of acquisition, eating desires did not. However, exploratory analyses suggested a successful acquisition of differential eating desires in a subgroup of individuals. This acquisition co-occurred with stronger US expectancies and more opportunities to learn about the CS-US contingency. Finally, extinction of eating desires in this subsample was incomplete. Overall, these findings suggest that appetitive condi-

tioning is possible in more naturalistic situations, supporting the ecological validity of our paradigm. However, the results also suggest that conditioning may be more difficult to achieve in real-life vs. the laboratory.

**Chapters 4 and 5** examine how (long-term) extinction of eating desires might be successfully achieved. In **Chapter 4**, a two-session study is described in which eating expectancies were verbally disconfirmed in one condition after acquisition (instructed extinction) to test whether US expectancies mediate the extinction of eating desires. In addition, it was examined whether instructed vs. normal extinction would be related to worse extinction learning (examined on a second session after a 24 hour delay) because omission of the US during extinction is not surprising (i.e., expectancy violation is low). CS evaluations were also measured at the start and end of each session to examine relationships with US expectancies and eating desires. It was found that instructed extinction lead to an almost-immediate and complete reduction in US expectancies, but it had no effects on the extinction of eating desires on session 1, nor did it improve extinction learning on session 2. Some evidence was found that eating desires are associated more closely with conditioned evaluations than with US expectancies. In **Chapter 5**, a study is described that examined whether occasional reinforcement of the CS–US association and the provision of unpaired USs during extinction attenuate rapid reacquisition. These techniques were compared with normal extinction. Findings indicated a slower return of US expectancies during reacquisition after both techniques (relative to normal extinction), but no less rapid reacquisition of eating desires. It is concluded that 1) US expectancies do not mediate the extinction of eating desires, 2) cue exposure therapy may not need to focus on maximizing the violation of eating expectancies, and 3) occasional USs during a diet and during cue exposure therapy may help improve long-term outcome.

**Chapters 2, 5, and 6** report four studies investigating two potential sources of inter-individual variability in appetitive conditioning: an impulsive personality and learning history (specifically, schedules of reinforcement). It was hypothesized that impulsivity was associated with a stronger (re)acquisition and slower extinction. Furthermore, we tested the differential influences of partial (vs. continuous) reinforcement of food cues during acquisition on extinction and reacquisition, and expected that partial reinforcement would slow down both the extinction and reacquisition of appetitive responses. Results showed that impulsivity did not consistently moderate responding during acquisition, although findings of one study suggested that higher impulsives are more vulnerable to overeating in response to a CS+ (**Chapter 2**). Partial evidence was found for impulsivity to slow down the extinction of US expectancies (**Chapter 6**). Furthermore, impulsivity was unexpectedly related to a slower reacquisition of eating desires in two

experiments (**Chapter 5 and 6**) Thus, impulsivity may explain some individual differences in appetitive conditioning (and unsuccessful dieting), though its precise role warrants further investigation. In another study (**Chapter 6**), we investigated the effects of partial vs. continuous reinforcement on extinction and reacquisition of conditioned responses. As expected, partial (vs. continuous) reinforcement of food cues resulted in a slower extinction of US expectancies and eating desires, and a less rapid reacquisition of US expectancies. It was proposed that schedules of reinforcement may affect (long-term) dieting success by interacting with the extinction and reacquisition of appetitive responses.

**Chapters 2, 5, 6, and 7** report data on two psychophysiological measures we assessed during conditioning: salivation and skin conductance. Salivation was measured using the cotton role method, and assessed at baseline and during presentations of the CS+ and CS- (**Chapters 2, 5, and 6**). Skin conductance was measured in one study (after CS onset, during the pre-US period, and during CS offset; **Chapter 7**). In addition, in this study, participants received an ambiguous or non-ambiguous contingency instruction, and it was expected that the non-ambiguous contingency instruction would lead to stronger differential responses and a quicker extinction (skin conductance, desires, US expectancies, CS evaluations). Regarding salivation, some evidence was found for a conditioned salivary response – salivation generally increased from baseline to CS+ (but not CS-), but no differences were found between the CS+ and CS- in any of the studies. In contrast, evidence for an acquisition of differential skin conductance responses were found in an anticipatory time window when the US was imminent (but not after CS onset), and after CS offset. However, unexpectedly, acquisition of skin conductance responses was only present for participants who received the more ambiguous contingency instruction. The type of contingency instruction did not affect any other responses, except for the extinction of US expectancies: extinction was slower after the ambiguous contingency instructions. We conclude that salivation is not a very useful measure for appetitive conditioning. Skin conductance seems to be more sensitive to detecting differences between the CS+ and CS-, although successful acquisition may depend on the contingency instructions given prior to conditioning.



# Samenvatting



Verhoogde cue-geïnduceerde appetitieve responsen (zoals trek) kunnen (over)eten, onsuccesvol lijnen en gewichtstoename bevorderen. Men denkt dat Pavloviaanse conditionering een belangrijke rol speelt bij cue-geïnduceerde responsen, maar appetitieve conditionering met voedselbeloningen in mensen is slechts in enkele studies onderzocht. Het doel van deze dissertatie is om meer inzicht te krijgen in een aantal belangrijke openstaande vragen in appetitief conditioneringsonderzoek. In alle beschreven studies in deze dissertatie werd gebruik gemaakt van een differentieel appetitief conditioneringsparadigma, waarin een initieel neutrale stimulus (CS+) herhaald is gepaard met hoog calorisch voedsel (US) en responsen na blootstelling aan de CS+ werden vergeleken met responsen na blootstelling aan een stimulus die nooit is gepaard met voedsel (CS-).

**Hoofdstuk 1** geeft een introductie weer over appetitief conditioneringsonderzoek op het gebied van voedsel. De rol van Pavloviaans leren in cue reactiviteit, overeten en (on)succesvol lijnen wordt hierin beschreven. Vervolgens wordt een overzicht gegeven van eerdere appetitieve conditioneringsstudies. Een aantal belangrijke resterende vragen wordt benoemd, gevolgd door een overzicht van de inhoud van deze dissertatie.

**Hoofdstukken 2 en 3** beschrijven twee studies die als doel hadden om te testen of appetitieve conditionering kan worden bewerkstelligd in meer natuurlijke omstandigheden. In een van deze studies (**Hoofdstuk 2**) leerden participanten om een virtuele omgeving (CS+) te associëren met de inname van een kleine hoeveelheid milkshake (US) en een andere omgeving met géén milkshake (CS-). US verwachtingen, trek in milkshake, speekselproductie, aangenaamheid van de CSen en milkshake-inname tijdens een nep-smaakttest werden gemeten. De resultaten lieten zien dat participanten na zes CS-US paringen hogere US verwachtingen en trek in milkshake rapporteerden. Verder vonden ze de CS+ aangenamer dan de CS-, alhoewel ze de CS+ niet significant vaker verkozen boven de CS-. Verder werd gedeeltelijk bewijs gevonden voor een geconditioneerde speekselrespons: de speekselproductie van participanten was hoger bij de CS+ (maar niet bij de CS-) vergeleken met een baseline meting, hoewel verschillen tussen de CS+ en CS- niet significant waren. Tenslotte consumeerde een subgroep van de participanten (degenen die hoger scoorden op impulsiviteit) meer milkshake in de CS+ dan in de CS-. In een andere studie (**Hoofdstuk 3**) werd getracht de link met de "echte" wereld verder te versterken door het conditioneringsparadigma te implementeren buiten het lab. *Ecological momentary assessment* werd gebruikt om verwachtingen en trek van participanten te meten op twee verschillende tijdstippen. Op één van deze tijdstippen consumeerden participanten chocolade gedurende vijf dagen (acquisitie). Dit werd gevolgd door een periode waarin zij geen chocolade meer consumeerden (extinctie, twaalf dagen). De resultaten lieten zien dat differentiële

US verwachtingen tijdens acquisitie toenamen, terwijl trek dit patroon niet vertoonde. Exploratieve analyses suggereerden echter dat een succesvolle acquisitie van trek plaatsvond in een subgroep van de participanten. Deze acquisitie ging gepaard met sterkere US verwachtingen en meer mogelijkheden om de CS-US relatie te leren. De extinctie van trek in deze subgroep was niet compleet. De resultaten van de twee studies suggereren dat appetitieve conditionering mogelijk is in meer natuurlijke situaties. Dit ondersteunt de ecologische validiteit van ons paradigma. Echter, onze resultaten tonen ook aan dat conditionering in de “echte” wereld mogelijk moeilijker te bewerkstelligen is dan in het lab.

In de **hoofdstukken 4 en 5** wordt bekeken hoe extinctie van trek (op de lange termijn) succesvol zou kunnen worden bewerkstelligd. In **Hoofdstuk 4** wordt een studie beschreven die uit twee sessies bestaat en waarin eet-verwachtingen verbaal werden ontkracht na acquisitie in een van de condities (geïnstrueerde extinctie), om te testen of eet-verwachtingen de extinctie van trek mediëren. Daarnaast werd onderzocht of geïnstrueerde vs. normale extinctie zou leiden tot slechter extinctie-leren (gemeten tijdens een tweede sessie die precies 24 uur na de eerste plaatsvond), omdat omissie van de US tijdens extinctie niet verrassend is. Tevens werden aan het begin en het eind van elke sessie CS evaluaties gemeten om de associaties met US verwachtingen en trek te onderzoeken. De resultaten lieten zien dat geïnstrueerde extinctie leidde tot een nagenoeg onmiddellijke en complete reductie van US verwachtingen. Dit had echter geen invloed op trek tijdens sessie 1, en leidde niet tot beter extinctie-leren zoals gemeten tijdens sessie 2. Gedeeltelijk bewijs werd gevonden voor een nauwere samenhang tussen trek en evaluaties dan tussen trek en verwachtingen. In **Hoofdstuk 5** wordt een studie beschreven waarin onderzocht is of het af en toe bekrachtigen van de CS-US associatie en het geven van ongepaarde USen tijdens extinctie de gewoonlijk rappe reacquisitie van geconditioneerde reacties kan tegengaan. Deze technieken werden vergeleken met normale extinctie. De resultaten toonden aan dat US verwachtingen langzamer terugkeerden tijdens reacquisitie na beide technieken (vergeleken met normale extinctie), maar een langzamere terugkeer van trek werd niet gevonden. Wij concluderen dat 1) US verwachtingen niet de extinctie van trek mediëren, 2) cue exposure therapie niet hoeft te focussen op het ontkrachten van eet-verwachtingen, en 3) het af en toe consumeren van USen tijdens een lijnpoging en tijdens cue exposure therapie positieve effecten zou kunnen hebben op de lange termijn.

In **hoofdstukken 2, 5 en 6** staan vier studies beschreven waarin twee potentiële bronnen van inter-individuele variabiliteit in appetitieve conditionering zijn bestudeerd: een impulsieve persoonlijkheid en leergeschiedenis (specifiek: de mate van bekrachtiging van de CS-US relatie). Wij verwachtten dat impulsiviteit geas-

socieerd zou zijn met een sterkere (re)acquisitie en een tragere extinctie. Verder werd bestudeerd wat de gevolgen zijn van het continue vs. partieel bekrachtigen van stimuli tijdens acquisitie op extinctie en reacquisitie. Hier verwachtten wij dat partiele bekrachtiging de extinctie en reacquisitie van appetitieve responsen zou vertragen. De resultaten lieten geen consistente verbanden zien tussen impulsiviteit en geconditioneerde reacties tijdens acquisitie, alhoewel meer impulsieve participanten in één studie vatbaarder leken voor overeten bij blootstelling aan een CS+ (**Hoofdstuk 2**). Er werd gedeeltelijk bewijs gevonden dat impulsiviteit de extinctie van US verwachtingen vertraagt (**Hoofdstuk 6**). Een onverwachte bevinding in twee studies was dat impulsiviteit gerelateerd was aan een tragere reacquisitie (**Hoofdstuk 5 en 6**). Impulsiviteit zou dus enkele individuele verschillen in appetitieve conditionering (en onsuccesvol lijnen) kunnen verklaren, maar zijn precieze rol dient verder onderzocht te worden. In een van de studies (**Hoofdstuk 6**) onderzochten we effecten van continue vs. partiële bekrachtiging van stimuli. Zoals verwacht leidde partiële bekrachtiging tot een tragere extinctie van US verwachtingen en trek, en bovendien tot een tragere reacquisitie van US verwachtingen. We concluderen dat de mate van bekrachtiging van de CS–US relatie lijnsucces kan beïnvloeden door te interacteren met de extinctie en reacquisitie van appetitieve responsen.

In de **hoofdstukken 2, 5, 6 en 7** worden data gerapporteerd met betrekking tot twee psychofysiologische maten voor conditionering: speekselproductie en huidgeleiding. Speeksel werd gemeten met behulp van tandartswatjes en deze maat werd afgenomen op baseline en tijdens presentaties van de CS+ en CS– (**Hoofdstukken 2, 5 en 6**). Huidgeleiding werd in één studie gemeten (na blootstelling aan de CS, tijdens de pre-US periode, en na het verdwijnen van de CS; **Hoofdstuk 7**). Daarnaast ontvingen participanten in deze studie ofwel een ambigue instructie over de CS–US relatie, ofwel een niet-ambigue instructie. Wij verwachtten dat de niet-ambigue instructie zou leiden tot grotere differentiële responsen en een snellere extinctie (huidgeleidingsresponsen, US verwachtingen, trek, CS evaluaties). Er werd enig bewijs gevonden voor een geconditioneerde speekselrespons – er was een toename in speekselproductie van baseline naar CS+ (maar niet CS–), maar in geen van de studies was het verschil tussen de CS+ en CS– significant. Bewijs voor een acquisitie van differentiële huidgeleidingsresponsen werd gevonden de periode vóór de US (maar niet gelijk na blootstelling aan de CS), en na het verdwijnen van de CS. Echter, acquisitie van huidgeleidingsresponsen was enkel succesvol in participanten die een meer ambigue instructie over de CS–US relatie hadden ontvangen. Het type instructie had geen invloed op de andere uitkomstmaten, met uitzondering van US verwachtingen: extinctie was langzamer na de ambigue instructies. Wij concluderen dat speekselproductie

(gemeten met watjes) geen bruikbare maat is voor appetitieve conditionering. Huidgeleiding lijkt sensitiever te zijn om verschillen tussen de CS+ en CS- te detecteren, maar een succesvolle acquisitie hangt wellicht af van het type instructies dat is gegeven vóór acquisitie.





# **Valorisation addendum**



## Relevance of the studies

Less than 50 years ago, underweight was one of the main problems society had to face. We have since transitioned to a world that is characterized by dramatic numbers of *overweight* and *obesity*, in some western countries reaching prevalences of up to 70% and 50%, respectively. Although a considerable amount of overweight and obese individuals engage in weight loss attempts, only relatively few are successful in achieving successful long-term weight loss. Further, eating disorders and related disordered behaviours are relatively common as well, the lifetime prevalence of eating disorders being approximately 5%. Since eating disorders and obesity are associated with increased morbidity, mortality, and high economic costs, it is important to study the mechanisms that underlie their aetiology and maintenance and effective ways to tackle them. Both obesity and most eating disorders are characterized by overeating. Overeating presumably often occurs in response to exposure to food-associated cues and contexts that elicit food cue reactivity (e.g., eating desires) – including for example the taste, sight, and smell of food, or certain environments. This dissertation focuses on the role of associative learning in reactivity to food cues. Research into the learning and extinction of appetitive responses can ultimately help design more effective treatments to reduce overeating.

## Target groups

The studies reported here are of relevance to clinical psychologists and other specialists who treat overeating and obesity, and individuals who wish to reduce overeating and lose weight. Further, the studies have broader societal relevance, as effective treatments for overeating and obesity will reduce the very high economic costs associated with obesity. The studies highlight that responses to food cues can be *learned* – and, at least to some extent, extinguished. The studies also suggest that different types of stimuli can become associated with eating and consequently elicit eating desires: geometrical shapes, boxes, virtual environments, and (possibly) times of day. Adequately trained therapists may in the future incorporate cue exposure sessions (the clinical analogue of experimental extinction) in their treatment that include exposure to various (personalized) cues that have become associated with food intake, and techniques that may promote successful long-term weight loss (e.g., occasional reinforcements).

## Activities and products

The main aim of the studies described in this dissertation is relatively fundamental – to improve our understanding of the role of Pavlovian learning in responses to food cues. Their ultimate aim, however, is to improve the successfulness of treatments aimed at reducing overeating and facilitating weight loss, and understand the mechanisms that underlie them.

Cue exposure therapy is the most straightforward intervention that may be derived from our findings: we have consistently demonstrated that a (partial) reduction in eating desires occurs over the course of extinction. This suggests that repeatedly exposing an individual to food cues (e.g., the sight and smell of food) in therapy may result in similar reductions in eating desires and other appetitive responses. Indeed, the very few cue exposure studies that have been conducted suggest cue exposure to be effective in reducing US expectancies, cue-elicited cravings, overeating, and binge eating. However, there is also evidence that it may not yet be very effective at preventing relapse. This seems in line with the current finding that conditioned appetitive responses can spontaneously return, and is consistent with the idea that extinction is not “unlearning”. In this dissertation, techniques have been studied that may help improve the long-term successful of cue exposure therapy (and dieting attempts in general): occasional reinforced extinction and eating expectancy violation. Whereas our findings suggest that it is not necessary to attempt to heighten the violation of eating expectancies during cue exposure sessions, we found evidence for the potential effectiveness of occasional reinforced extinction. This technique could be implemented by letting patients occasionally consume foods that they usually overconsume (e.g., taking small bites of foods). Finally, our studies suggest that contexts like environments can also become associated with intake, and we found preliminary evidence that eating desires can become associated with times of day in real-life. This suggests that cue exposure therapy should include not only exposure to the sight and smell of food but also to other stimuli that have become associated with intake in an individual, such as certain environments. In fact, we have recently investigated the effectiveness of an eight-session cue exposure intervention including exposure to individualized cues (e.g., certain environments and situations) and techniques to reduce relapse (e.g., occasional reinforced extinction). We found that participants (overweight and obese women) consumed less of their favourite food that they were exposed to during the intervention, compared with participants who received an active control intervention. Further, women who received cue exposure therapy lost weight during the intervention, whereas those who received the control intervention did not. These effects were maintained at a three-month follow-up. Thus,

(optimized) cue exposure therapy may be a useful addition to existing treatments, though additional research is needed into its mechanisms and manners in which it can be optimized.

## **Innovation**

Although obesity is a medical condition, it is characterized by a behavioural problem. Yet, obesity research and treatment have mainly been approached from a biomedical perspective, largely ignoring psychological mechanisms. The current dissertation focuses on the role of one psychological mechanism that may underlie cue-elicited food desires and eating behaviour in humans: associative learning processes. As described in the previous section, a novel clinical implication of the findings presented in this dissertation is that the long-term effectiveness of cue exposure therapy (and weight loss attempts in general) may be facilitated by incorporating occasional reinforced extinction, and by exposing individuals to (personalized) cues and contexts that have previously become associated with (over) eating. Further, the current findings suggest that learning histories (schedules of reinforcement) and certain personality aspects (impulsivity) may explain individual differences in (short and long-term) dieting success in humans by influencing the acquisition, extinction, and return of appetitive responses to food cues. Although more research is necessary, cue exposure therapy might benefit from taking into account individual differences in such learning histories and personality aspects. Thus, the current findings shed more light on the role of learning processes in food desires, dieting success, and obesity, and they provide new recommendations for treatment.

## **Dissemination**

Knowledge dissemination has taken place in several forms. The findings have been presented at conferences that were attended by health care professionals (e.g., VGCT, NAE), and articles have been published in Dutch journals (e.g., in *de Psycholoog*). In addition, several talks were given at local events for the community (e.g., The Parcours of Arts and Science), and for primary and secondary school children (KidzCollege). Findings were also regularly disseminated to the media through (filmed) interviews and demonstrations (e.g., UM Webmagazine; L1). Finally, the findings were incorporated in teaching materials in newly devel-

oped bachelor courses taught at Maastricht University (Eating Behaviours) and University College Venlo (Psychology of Eating).

We plan to continue knowledge dissemination in the future using the channels described above. Before cue exposure therapy can be applied in clinical contexts, more research is needed on its mechanisms, effects, and manners in which it may be optimized. If these additional studies confirm its long-term effectiveness, cue exposure therapy can be incorporated in existing treatments such as CBT. This can be achieved by giving lectures to health care professionals (e.g., clinical psychologists), and providing the necessary workshops and trainings to optimally perform cue exposure therapy.





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# **Curriculum Vitae**



Karolien van den Akker was born on September 20th 1988 in Aachen, Germany. After graduating from secondary school (2006, Atheneum, Grotius College, Heerlen) she completed a bachelor in Cognitive Psychology (2009) and a master in Health and Social Psychology (2010) at Maastricht University. During her time in Maastricht she also worked as a student assistant for research projects in the Eating Disorders and Obesity group. In 2009, she participated in an international exchange program (Erasmus) at Loughborough University, United Kingdom. After her master, she completed another 2-year master in Nutrition and Health (2012, Nutritional Physiology and Health Status) at Wageningen University. In 2012, she also started working as a PhD candidate at the Eating Disorders and Obesity section at Maastricht University under supervision of prof. dr. A. Jansen and dr. R. Havermans. She currently works as a postdoctoral researcher in the same group.



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- 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.
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**van den Akker, K.**, Havermans, R.C., & Jansen, A. Appetitive conditioning to specific times of day. *In revision (Appetite)*.

**van den Akker, K.** Nederkoorn, C., & Jansen, A. Electrodermal responses in appetitive conditioning are sensitive to contingency instruction ambiguity. *Under review*.

**van den Akker, K.**, Bongers, P., & Jansen, Validation of prospective portion size and latency to eat as behavioural measures of reactivity to snack foods. *Submitted for publication*.

**van den Akker, K.** Nederkoorn, C., & Jansen, A. Appetitive learning deficits in overweight and obese individuals. *In preparation*.

**van den Akker, K.**, Schyns, G.L.T., Werthmann, J., Roefs, A., Houben, K., & Jansen, A. Effects of cue exposure therapy on response inhibition and attentional bias for food. *In preparation*.

Schyns, G.L.T., **van den Akker, K.**, Roefs, A., Houben, K., & Jansen, A. Successful weight loss after food cue exposure therapy aimed at inhibitory learning. *In preparation*.

#### Conference and symposium presentations

**van den Akker, K.**, Jansen, A., & Havermans, R.C. (2016, June). *The learning and extinction of conditioned responses to food cues*. Oral presentation at the World Congress for Behaviour and Cognitive Therapy (WCBCT), Melbourne, Australia.

**van den Akker, K.**, Schyns, G.L.T., & Jansen, A. (2016, June). *Acquisition and extinction of appetitive responses to food cues in overweight and normal-weight individuals*. Oral presentation at the World Congress for Behaviour and Cognitive Therapy (WCBCT), Melbourne, Australia.

- van den Akker, K.** (2016). *De rol van klassieke conditionering bij het ervaren van trek*. Oral presentation at the 5th meeting of the Nederlandse academie voor Voedingwetenschappen (NAV), Maastricht, The Netherlands.
- van den Akker, K.,** Schyns, G.L.T., & Jansen, A. (2016, January). *Acquisition and extinction of appetitive responses to food cues in overweight vs. normal-weight individuals*. Poster presentation at the Research Day of the Faculty of Psychology and Neuroscience, Maastricht, The Netherlands.
- van den Akker, K.,** Jansen, A., & Havermans, R.C. (2015, November). *Het ontcrachten van eet-verwachtingen bij aangeleerde trek*. Oral presentation at the annual meeting of the Society for Behaviour and Cognitive Therapy (VGCT), Veldhoven, The Netherlands.
- van den Akker, K.,** Schyns, G.L.T., & Jansen, A. (2015, September). *Acquisition and extinction of appetitive responses to food cues in overweight and normal-weight individuals*. Poster presentation at the Summer School on Emotional Learning and Memory in Health and Psychopathology, KU Leuven, Belgium.
- van den Akker, K.** Jansen A., & Havermans, R.C. (2015, June). *The learning and extinction of the desire to eat*. Oral presentation at a symposium of the Dutch-Flemish Postgraduate School for Research and Education, Heeze, The Netherlands.
- van den Akker, K.,** Van den Broek, M., Havermans, R., Jansen, A. (2015, April). *Effects of extinction instructions on the extinction and spontaneous recovery of conditioned responses to chocolate-associated cues*. Poster presentation at the British Feeding and Drinking Group Meeting, Wageningen, The Netherlands.
- van den Akker, K.** van den Broek, M., Havermans, R.C., & Jansen, A. (2015, January). *Effects of extinction instructions on the extinction and spontaneous recovery of conditioned responses to chocolate-associated cues*. Poster presentation at the Research Day of the Faculty of Psychology and Neuroscience, Maastricht, The Netherlands.
- van den Akker, K.** (2015, January). *Conditioned desires to eat in Virtual Reality*. Oral presentation at the Virtual Reality Symposium, Eindhoven, The Netherlands.
- van den Akker, K.** (2014, September) *Pavlov, obesitas, en lijnen*. Invited oral presentation during the Parcours of Arts and Science, Maastricht, The Netherlands.
- van den Akker, K.,** Jansen, A. (2014, September). *Conditioned desires to eat in the laboratory*. Oral presentation at the annual meeting of the European Association for Cognitive and Behavioural Therapies (EABCT), The Hague, The Netherlands.

- van den Akker, K.,** Havermans, R.C., Bouton, M.E., & Jansen, A. (2014, July). *How partial reinforcement affect the extinction and reacquisition of appetitive responses. A new model for dieting success?* Poster presentation at the annual meeting of the Society for the Study of Ingestive Behavior, Seattle, United States of America.
- van den Akker, K.,** Jansen, A., Bouton, M.E., & Havermans, R.C. (2014, May). *Partial reinforcement of food cues, impulsivity, and the extinction and reacquisition of appetitive responses. Possible implications for (un)successful dieting.* Oral presentation at the 12th Endo-Neuro-Psycho Meeting, Lunteren, The Netherlands.
- van den Akker, K.,** Jansen, A., Havermans, R., Bouton, M.E. (2014, April). *A Classical conditioning approach to unsuccessful dieting.* Oral presentation at the British Feeding and Drinking Group Meeting, Portsmouth, United Kingdom.
- van den Akker, K.** & Schyns, G.L.T. *De psychologie van eten en het doen van onderzoek.* (2014, March). Invited oral presentation for a career event for psychology students: "Experience your Future", Nijmegen, The Netherlands.
- van den Akker, K.,** Jansen, A., Frentz, F., & Havermans, R. (2014, March). *Klassische appetitive Konditionierung als Mechanismus für Essen aus Gewohnheit.* Oral presentation at the 4. Wissenschaftlichen Kongress der Deutschen Gesellschaft für Essstörungen, Leipzig, Germany.
- van den Akker, K.,** Havermans, R.C., Bouton, M.E., & Jansen, A. (2013, January). *Diet today, indulge tomorrow: partial reinforcement of food cues and impulsivity slow down extinction. A new model of unsuccessful dieting.* Oral presentation at the Research Day of the Faculty of Psychology and Neuroscience, Maastricht, The Netherlands.
- van den Akker, K.,** Jansen, A., Frentz, F., Havermans, R. (2013, November). *Klassieke conditionering van "eten uit gewoonte".* Oral presentation at the annual meeting of the Society for Behaviour and Cognitive Therapy (VGCT), Veldhoven, The Netherlands.
- van den Akker, K.,** Jansen, A., Frentz, F., Havermans, R. (2013, May). *Contextual appetitive conditioning and the role of impulsivity.* Oral presentation at the 11th Endo-Neuro-Psycho Meeting, Lunteren, The Netherlands.
- van den Akker, K.,** Jansen, A., Frentz, F., & Havermans, R. (2013, April). *Impulsivity makes one more susceptible to overeating after contextual appetitive conditioning.* Oral presentation at the British Feeding and Drinking Group Annual Meeting, Loughborough, United Kingdom.