Temptation and restraint

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Chapter 1

Introduction

Unhealthy foods are abundant and easily accessible. As a consequence, people are often exposed to attractive food cues. This constant temptation can be hard to resist and makes it difficult to stick to a healthy diet and maintain a healthy weight. As such, our food environment, also referred to as an obesogenic environment, is thought to contribute to the high prevalence of overweight and obesity. It should be noted that not everyone in this obesogenic environment has difficulty with restricting food intake. For example, there are many people who are able to maintain a healthy weight. And strikingly, there is also a group of individuals – individuals with anorexia nervosa – who are capable of restricting their food intake even when they are in a state of starvation.

How is it that individuals with anorexia nervosa are so proficient in restricting their food intake? And how can this be reconciled with the other end of the spectrum where individuals have difficulty restricting their food intake and become obese? Although there are no easy answers to these questions, the first part of this thesis aimed to take a step towards an explanation by testing the relevance of two theory-derived trait characteristics – reward and punishment sensitivity – that might be vulnerability factors in harmful food restriction and/or overeating. The second part of the thesis focused on a more specific operationalization of reward sensitivity, namely attention to food, that might be more closely related to disordered eating behavior and might serve as a potential starting point for intervention.

Disordered eating behavior

With a prevalence of 31.1% of adults being overweight, and 12.3% obese, overeating is a major problem in today's society (CBS, 2016). Overweight and obesity have been linked to various chronic diseases (e.g., diabetes and several types of cancer), psychological problems (e.g., anxiety and depression), and a general lower satisfaction with life (Dixon, 2010; Luppino et al., 2010; Roberts & Hao, 2013). The World Health Organization states that overweight and obesity are preventable and recommends that people restrict their caloric intake, increase their fruit and vegetable consumption, and engage in frequent physical activity (WHO, 2018). However, the high prevalence of overweight and obesity shows that this advice is not easy to follow. Another point is that once overweight or obese, people have difficulty losing weight (Johnson, Pratt, & Wardle, 2012; Mann et al., 2007). Specifically, people have a hard time adhering to long-term food restriction efforts (Knäuper, Cheema, Rabiau, & Borten, 2005) or they regain lost weight or gain even more after successfully losing weight (Field et al., 2007).

On the other side of the spectrum, individuals with anorexia nervosa are characterized by such an extreme food restriction that it results in a harmfully low weight and becomes a threat to their health (Kask et al., 2016). Despite this dangerously low weight, individuals with anorexia nervosa have an intense fear of gaining weight or becoming fat. Another important characteristic of individuals with anorexia nervosa is that their body weight and shape have an undue influence on their self-evaluation, and/or their experience of their weight or shape is disturbed (American Psychiatric Association, 2013). The severity of anorexia nervosa is reflected in a mortality rate that is five times higher than that of the general population (Kask et al., 2016). The disorder does not only have a large impact on individuals' own life, but also on their families' functioning. Treatment for individuals with anorexia nervosa are limited in their effectiveness, and relapse after treatment is common (Brockmeyer, Friederich, & Schmidt, 2017).

Taken together, it is clearly of great importance to get a better understanding of the characteristics that are related to extreme food restriction and the development and maintenance of anorexia nervosa on the one hand and overeating and the development and maintenance of overweight and obesity on the other. Adolescence might be an important developmental period to examine these characteristics, as anorexia nervosa typically develops during this period (Schmidt et al., 2016) and adolescent obesity is highly predictive of adult obesity, increased morbidity, and mortality in adulthood (Reilly et al., 2003; Steinbeck, 2010). Moreover, during adolescence food intake is becoming more and more the result of individuals' own characteristics and behavior since food choices are made increasingly independently (Deshpande, Basil, & Basil, 2009).

Part 1: Reward and punishment sensitivity

To understand the impact of reward and punishment sensitivity on behavior it is important to introduce the law of effect (Thorndike, 1932). This principle suggests that our behavior is largely determined by its consequences. When behavior is followed by positive consequences (i.e., reward) it is likely to be repeated and when behavior is followed by negative consequences (i.e., punishment) it is likely to decrease in frequency. For example, if you had a night with a lot of fun while drinking alcohol it is likely that you will drink alcohol again. However, if you have a hangover after a night out drinking alcohol you might be more likely to think twice the next time someone offers you a drink. Although the consequences of behavior might explain a large part of individual behavior, we do not all show the same behavior. For instance, not everyone who gets a hangover stops drinking alcohol. These individual differences might be partly explained by differences in how sensitive individuals are to reward and punishment (Gray, 1970; Gray & McNaughton, 2000). For example, a negative consequence such as a hangover may have greater influence on reducing future drinking behavior for an individual who is sensitive to punishment compared to one who is relatively insensitive to punishment.

The concepts of reward and punishment sensitivity stem from the Reinforcement Sensitivity Theory (Gray, 1970; and the revised version, Gray & McNaughton, 2000). According to this theory (Figure 1), individuals who are sensitive to reward will have a more positive response to reward, more attention to reward, and a stronger tendency to approach reward. Individuals who are sensitive to punishment will have a more negative response to punishment, more attention to punishment, and a stronger tendency to avoid punishment. Individual differences in reward sensitivity have been linked to externalizing behavior, such as alcohol use and attention deficit disorder (Jonker, Ostafin, Glashouwer, van Hemel-Ruiter, & de Jong, 2014; Lopez-Vergara & Colder, 2013). Punishment sensitivity on the other hand has been linked to internalizing behavior, such as generalized anxiety and depressive symptoms (Brailean, Koster, Hoorelbeke, & De Raedt, 2014; Sportel, Nauta, de Hullu, de

Jong, & Hartman, 2011). Both reward and punishment sensitivity have also been suggested to play a role in eating related behavior (e.g., Harrison, O'Brien, Lopez, & Treasure, 2010).

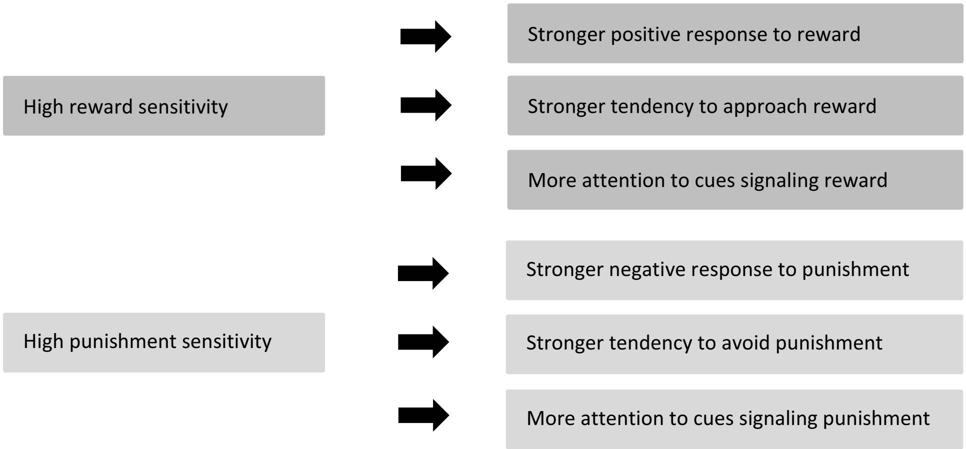

Figure 1. Visualization of the behavior related to reward and punishment sensitivity.

Reward and punishment sensitivity in obesity

As food is considered to have a high intrinsic reward value (Robinson & Berridge, 2001), reward sensitivity has been proposed to play a role in the development and maintenance of overweight and obesity (e.g., Davis et al., 2007). There are currently three theories on the role of reward sensitivity in obesity: (1) The *hyper-responsiveness theory* suggests that obesity might be the result of heightened reward sensitivity. That is, high reward sensitivity is suggested to result in heightened sensitivity to the rewarding properties of food and consequently to an increased risk for overeating and the development of overweight and obesity (Dawe & Loxton, 2004; Franken & Muris, 2005; Guerrieri, Nederkoorn, & Jansen, 2008); (2) The *reward deficiency theory* suggests that obesity might be the result of decreased reward sensitivity. According to this theory, individuals with a low reward sensitivity try to compensate for decreased feelings of reward by eating greater amounts of rewarding foods (e.g., Volkow, Fowler, & Wang, 2002; Wang, Volkow, Thanos, & Fowler, 2004); (3) Last, the *dynamic vulnerability model* suggests that high reward sensitivity is the cause of initial overeating and the development of overweight and that as a consequence of overeating, the reward response to food will decrease, thereby leading to more overeating in an effort to obtain the same objective reward (e.g., Stice, Yokum, Burger, Epstein, & Small, 2011).

Unfortunately, empirical studies on the relationship between reward sensitivity and obesity do not provide a clear picture regarding which theory is most valid. For example, a study comparing children with obesity to children with a healthy weight showed more sensitivity to reward in obese children as reported by their parents (Van den Berg et al., 2011). Conversely, several other studies did not find a difference in reward sensitivity between healthy weight and obese individuals, both in adolescents (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006) and adults (Danner, Ouwehand, van Haastert, Hornsveld, & de Ridder, 2012; Schienle, Schäfer, Hermann, & Vaitl, 2009). Research examining the continuous relationship between reward sensitivity and BMI reports findings ranging from no relationship between BMI and reward sensitivity (Matton, Goossens, Braet, & Vervaet, 2013; Vandeweghe, Verbeken, Vervoort, Moens, & Braet, 2017), to a positive relationship (De Decker et al., 2016; Franken & Muris, 2005), or a quadratic relationship (Davis & Fox, 2008; Dietrich, Federbusch, Grellmann, Villringer, & Horstmann, 2014; Verbeken, Braet, Lammertyn, Goossens, & Moens, 2012). Thus, it remains unclear how reward sensitivity is involved in the development and maintenance of obesity.

Although reward sensitivity has received great interest in the context of obesity, less focus has been placed on the potential role of punishment sensitivity in the development and maintenance of obesity. Even so, it has been suggested that overeating might be related to individuals' tendency to respond to reward and to disregard the negative consequences of their behavior (e.g., Danner et al., 2012). In other words, individuals who tend to overeat and develop overweight or obesity might do so because they are relatively insensitive to the negative outcomes of overeating. As such, a relatively low sensitivity to punishment might be related to the development and maintenance of obesity.

However, empirical studies do not show consistent evidence for reduced punishment sensitivity in obesity. Although one study showed lower punishment sensitivity in obese versus healthy weight adults (Danner et al., 2012), others showed no difference between obese and healthy weight individuals in both adults (Schienle et al., 2009) and children (Nederkoorn et al., 2006). Research examining the continuous relationship between punishment sensitivity and BMI reported no significant relationship in adolescents or adults (Dietrich et al., 2014; Matton et al., 2013). In sum, empirical evidence shows inconsistency and much uncertainty still exists about the role of reward and punishment sensitivity in obesity.

Starting points for this thesis

Most studies have assessed sensitivity to reward and punishment with self-report questionnaires such as the Behavioral Inhibition Scale/ Behavioral Activation Scale (BIS/BAS; Carver & White, 1994) or the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Ávila, Moltó, & Caseras, 2001). Although these questionnaires have been used interchangeably as measures of reward sensitivity, they seem to index different aspects of the construct (see Table 1 for an overview and examples of items). Specifically, the SPSRQ has one reward subscale (SR) that consists of a mixture of questions about reward responsivity and motivation to approach reward whereas the BIS/BAS consists of three subscales: reward responsivity (BAS-RR), reward drive (BAS-Drive; i.e., reward motivation), and fun seeking (BAS-FS).

Studies on the relationship between reward sensitivity and obesity have mostly used measures that combine reward responsiveness and reward drive (Danner et al., 2012; Davis & Fox, 2008; Dietrich et al., 2014; Franken & Muris, 2005; Matton et al., 2013; Schienle et al., 2009; Van den Berg et al., 2011; Vandeweghe et al., 2017). That is, they used a combined score of the three reward subscales of the BIS/BAS (BAS-Total) or the SPSRQ to index reward sensitivity. However, when examining the theories on the role of reward sensitivity in obesity it seems that reward responsivity and drive could be differentially related to BMI. For example, the *dynamic vulnerability model* seems to suggests that reward responsivity might decrease by overeating (i.e., lowered reward response as consequence of overeating) and reward drive might increase to compensate for this decrease in responsivity (i.e., overeating in an effort to obtain the same reward feeling). Thus, the relationship between reward responsiveness and BMI, and the relationship between reward drive and BMI might follow different patterns. These relationships might be opposite to each other in the higher BMI ranges, where drive is suggested to have increased as a compensation for decreased responsivity. Consequently, reporting on a measure that combines these two components, or reporting only one of these components (e.g., only the drive subscale) might provide an incomplete picture. For this reason, the studies in this dissertation examined both reward responsiveness and reward drive.

Table 1. *Subscales and items of the BIS/BAS and SPSRQ*

Reward sensitivity		
Questionnaire	**Subscale**	**Item from questionnaire**
BIS/BAS	**Reward responsiveness**	It would excite me to win a contest
		When I get something I want, I feel excited and energized
	Reward Drive	If I see a chance to get something I want, I move on it right away
		I go out of my way to get things I want
	Fun Seeking	I crave excitement and new sensations
		I often act on the spur of the moment
SPSRQ	**Sensitivity to Reward**	Do you like to take some drugs because of the pleasure you get from them?
		Does the good prospect of obtaining money motivate you strongly to do some things?
Punishment sensitivity		
Questionnaire	**Subscale**	**Item from questionnaire**
BIS/BAS	**Punishment Sensitivity**	Criticism or scolding hurts me quite a bit
		I worry about making mistakes
SPSRQ	**Sensitivity to Punishment**	Do you often refrain from doing something because you are afraid of it being illegal?
		Are you often worried by things that you said or did?

Note. BIS/BAS = Behavioral Inhibition Scale/Behavioral Activation Scale, SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire.

Finally, to fully unravel the relationship between obesity and both reward and punishment sensitivity, the last of the three components – attention – should be examined. It has been suggested that individuals who are sensitive to reward and punishment are more prone to detect signals of reward and punishment in the environment, respectively (Davis & Fox, 2008). Thus far, attention to cues signaling reward and punishment has not been examined in the context of obesity. Moreover, neither the BIS/BAS nor the SPSRQ provides the option to index this aspect of reward and punishment sensitivity. Importantly, proneness to detect signals of reward and punishment in the environment might be difficult to measure using self-report, because visual attention is suggested to be an automatic (i.e., involuntary) process that does not require (or imply) awareness (Pool, Brosch, Delplanque, & Sander, 2016). Because individuals, and particularly adolescents, might lack insight into their behavior, they might be unable to report about these tendencies (e.g., Gregg, Klymowsky, Owens, & Perryman, 2013). Therefore, a performance measure that assesses attention to cues that signal reward and punishment sensitivity seems an important addition to self-report measures in research examining the role of reward and punishment sensitivity in obesity.

The Spatial Orientation Task (SOT; Derryberry & Reed, 2002) has been used to index attention to cues signaling reward and punishment sensitivity. Research showed that the SOT had predictive validity with regard to anxiety, substance use and depression (Derryberry & Reed, 2002; Van Hemel-Ruiter, de Jong, Oldehinkel, & Ostafin, 2013; Vrijen, Hartman, & Oldehinkel, 2018). The SOT assesses two important aspects of attention: the extent to which attention is drawn by a cue (i.e., attentional engagement), and how long attention is maintained on the cue possible due to a difficulty to disengage (i.e., attentional disengagement; Grafton & MacLeod, 2014; Posner, 1980; Posner & Petersen, 1990). It has been suggested that attentional engagement is an early attentional process mainly directed by bottom-up processes and that attentional disengagement is a later attentional process directed more by top-down processes (Mogg & Bradley, 2016; Pool et al., 2016). The SOT provides the option to take this into account since it differentiates between more automatic process that occurs in a short time period (250 ms) and more voluntary processes that occur over a longer time period (500 ms). For this reason, the SOT was used in this thesis to complement the self-report assessment of reward and punishment sensitivity.

The cross-sectional approach that was taken in previous research examines whether differential reward and punishment sensitivity and obesity co-occur. However, this method does not examine whether reward and punishment sensitivity are related to the development and maintenance of obesity over time. A last important aim of the current research was therefore to examine the longitudinal relationship between reward and punishment sensitivity and BMI. This provides the opportunity to examine whether reward and punishment sensitivity are related to changes in BMI.

Reward and punishment sensitivity in anorexia nervosa

It has been suggested that individuals with anorexia nervosa might be relatively insensitive to reward (Harrison, et al., 2010; Harrison, Sternheim, O'Hara, Oldershaw, & Schmidt, 2016). As a consequence they might be less sensitive to the rewarding properties of food (Glashouwer, Bloot, Veenstra, Franken, & de Jong, 2014), which would make it easier to restrict food intake even in a state of starvation, when food cues have a higher reward value (Charbonnier et al., 2018; Pool et al., 2016). However, studies do not consistently find lowered reward sensitivity in individuals with anorexia nervosa. Although one study showed that individuals with anorexia nervosa reported less reward sensitivity than a healthy comparison group (Claes, Nederkoorn, Vandereycken, Guerrieri, & Vertommen, 2006), several other studies did not find differences between patients with anorexia nervosa and healthy comparisons in their reported reward sensitivity (Jappe et al., 2011; Matton, Goossens, Vervaet, & Braet, 2015; Monteleone, Scognamiglio, Monteleone, Perillo, & Maj, 2014). Lastly, there are two studies that found that patients with anorexia nervosa reported higher reward sensitivity than a comparison group without an eating disorder (Glashouwer et al., 2014; Jappe et al., 2011).

Patients with anorexia nervosa have been suggested to be characterized by an increased sensitivity to punishment (e.g., Harrison et al., 2010). High punishment sensitivity has been related to more intense shape and weight concerns (Matton et al., 2013; Mussap, 2007), and a stronger fear of becoming fat (Dalley, 2016). Additionally, patients with anorexia nervosa often show harm avoidant behaviors (e.g., fearfulness, shyness and worrying), and comorbid anxiety disorders (Kaye, Bulik, Thornton, Barbarich, & Masters, 2004; Klump et al., 2004). It has been suggested that an increased sensitivity to punishment might underlie the development and maintenance of these characteristics and behaviors (Jappe et al., 2011). Patients' food restriction and purging behaviors might thus be seen as avoidance behaviors, expressions of their sensitivity to punishment. Indeed empirical studies consistently showed that adolescent and adult patients with anorexia nervosa reported higher sensitivity to punishment than individuals without an eating disorder (Claes et al., 2006; Glashouwer et al., 2014; Jappe et al., 2011; Matton et al., 2015; Monteleone et al., 2014).

Starting points for this thesis

Similarly to the studies in obesity, most studies on the relationship between reward and punishment sensitivity and anorexia nervosa have focused on self-reported reward and punishment sensitivity using the BIS/BAS and the SPSRQ interchangeably. In the context of anorexia nervosa the differences in type of behavior that is indexed by these questionnaires might also be important. Further, it was pointed out that the BIS/BAS and the SPSRQ have another difference that might be important in the context of anorexia nervosa. That is, the BIS/BAS has been designed as a general (i.e., stimulus independent) measure of reward and punishment sensitivity (Carver & White, 1994), and the SPSRQ is designed to measure responses to specific situations reflecting reward and punishment sensitivity (e.g., drug use, or social rejection; Torrubia et al., 2001). Interestingly, both studies that showed higher reward sensitivity in patients with anorexia nervosa compared to individuals without an eating disorder used the SPSRQ to index this sensitivity (Glashouwer et al., 2014; Jappe et al., 2011). Moreover, it was shown that this increased reward sensitivity disappeared after excluding the items on appearance and social rejection (Glashouwer et al., 2014). Consequently, using these two questionnaires interchangeably might result in mixed findings. That is why in this thesis reward and punishment sensitivity in anorexia nervosa were examined by using both the BIS/BAS and SPSRQ.

Using these two questionnaires simultaneously provides insight into whether differences in the questionnaires indeed added to the inconsistencies in findings. Nevertheless, since these questionnaires do not incorporate the attention aspect of reward and punishment sensitivity, this approach will not provide a comprehensive overview of reward and punishment sensitivity in anorexia nervosa. Therefore, a performance measure that assesses attention to cues that signal reward and punishment sensitivity also seems an important addition in the context of anorexia nervosa. Recently a pilot study examined differences between patients with an eating disorder and a non-eating disordered comparison group in performance on the spatial orientation task (Matton, et al., 2017). In this study there was a non-significant trend that patients with an eating disorder (i.e., anorexia nervosa and bulimia nervosa) showed stronger attentional engagement towards cues that signal punishment than the non-eating disordered comparison group. No differences were found between the eating disorder group regarding attention to cues signaling reward, although there was some evidence that patients with a binge eating and/or purging type of eating disorder (i.e., anorexia nervosa binge purge type and bulimia nervosa) had less difficulty to disengage their attention from cues signaling reward than patients with a restrictive type of eating disorder (i.e., anorexia nervosa restrictive type). However, by combining patients with anorexia nervosa and patients with bulimia nervosa into one eating disorder group, and patients with anorexia nervosa binge purge type with bulimia nervosa into a binge-purge type eating disorder group, it is possible that the difference was carried by the patients with bulimia nervosa. Further, the study had a low statistical power due to small sample sizes. Therefore, in this thesis, reward and punishment sensitivity in anorexia nervosa was measured with the SOT in a large group of patients with anorexia nervosa.

Interlude: the development of a new self-report measure of reward and punishment sensitivity

The aim of the first part of this thesis was to increase our understanding of the role of reward and punishment sensitivity in obesity in anorexia nervosa. In the studies that were set out reward and punishment sensitivity were operationalized using currently available measures. An important advantage of this approach is that results can be directly integrated into the literature. Nevertheless, the currently available self-report measures of reward and punishment sensitivity seem to have some important limitations. Consequently, to overcome these limitations it might be beneficial to develop a new measure of reward and punishment sensitivity.

<u>Starting points for this thesis</u>

There seem to be two important limitations to the currently available questionnaires of reward and punishment sensitivity. First, the specificity of the rewards and punishments in the SPSRQ seem to have an unwanted influence on findings. More specifically, it seems that the use of specific types of rewards (e.g., physical appearance) might cause measurement bias. This might be a more general problem in psychopathology research due to the conceptual overlap between the items of the SPSRQ (e.g., drugs) and the items of measures of clinical symptoms (e.g., substance use). Second, only the BIS/BAS has separate subscales for responsivity and drive, and only with regard to reward sensitivity. Differentiating between responsivity and drive with regard to punishment sensitivity might also be important to further our understanding of the role of sensitivity to punishment in behavior. For example, understanding whether heightened punishment sensitivity as reported by patients with anorexia nervosa is due to a stronger negative response to punishment or a stronger motivation to avoid punishment might influence how we would try to take punishment sensitivity into account in the treatment of patients with anorexia nervosa. That is why in this thesis a new questionnaire was developed aimed to measure sensitivity to reward and punishment independent of specific stimuli, and to differentiate between responsivity and motivation in reward and punishment sensitivity.

Part 2: Attention to food

Part 2 of this dissertation aimed to examine the relationship between a more specific operationalization of reward sensitivity, attention to food, and eating behavior. The incentive sensitization theory proposes that incentive salience is attributed to a cue after repeated associations between this specific cue (e.g., food) and the experience of reward (Berridge, 2009; Robinson & Berridge, 2001). As a result of this attribution of incentive salience, the cue becomes attention grabbing and an enhanced motivational target. Consequently, not only attention to general cues signaling reward and punishment, but also attention to food cues is likely differentially related to eating behavior. Moreover, individuals' attention has been proposed to be biased towards negative and positive cues in the environment, and this bias seems to be stronger when the cue is relevant to specific concerns of the individual (Field, Werthmann, & Franken, 2016; Pool et al., 2016). Thus, individuals' attentional bias to food cues might be stronger than the attentional bias to general rewards. Furthermore, attention to food has been suggested as a potential intervention for eating behavior (e.g., Kakoschke, Kemps, & Tiggemann, 2014; Kemps, Tiggemann, & Hollitt, 2014, 2016). Since domain specific interventions might be more effective than general interventions (Chen, Kelley, Lopez, & Heatherton, 2018), understanding how attention to food cues is related to eating behavior might serve as an important starting point for treatment.

Attention to food in anorexia nervosa

In line with the suggestion that the reward value of food increases with hunger and decreases with satiation (Charbonnier et al., 2018), several studies with healthy weight individuals have found that hunger (i.e., food deprivation) heightened attention to food cues (Castellanos et al., 2009; Giel et al., 2011; Nijs, Muris, Euser, & Franken, 2010; Stockburger, Weike, Hamm, & Schupp, 2008; Tapper, Pothos, & Lawrence, 2010; but see, Leland & Pineda, 2006). In addition, there is evidence indicating that healthy weight individuals no longer show an attentional bias to food when they are satiated (e.g., Castellanos et al., 2009; Stockburger et al., 2008). In contrast to such adaptive processes, individuals with anorexia nervosa are able to restrict their food intake even when they are deprived of food. In line with the idea that individuals with anorexia nervosa are relatively insensitive to reward, it might be that this food restriction is facilitated by decreased attention to food cues (Lloyd & Steinglass, 2018).

Thus far, a couple of studies have examined differences between patients with anorexia nervosa and comparison groups without an eating disorder in their attentional bias to food cues (Giel, et al., 2011; Kim et al., 2014; Veenstra & de Jong, 2012). In a study using a dot-probe task (MacLeod, Mathews, & Tata, 1986), in which a food and an animal image were shown simultaneously for 1000 ms, no difference was found in attention to food cues between patients with anorexia nervosa and a comparison group without an eating disorder (Kim et al., 2014). In a study using the exogenous cueing task (Koster, De Raedt, Goeleven, Franck, & Crombez, 2005), in which low or high caloric food or non-food control images were shown for 300, 500, or 1000ms, patients with anorexia nervosa were also not found to differ in attention to food from a comparison group without eating disorder symptoms (Veenstra & de Jong, 2012). Using an free-viewing eye-tracking paradigm in which participants were presented with a food and a household image simultaneously for 3000 ms, patients with AN again did not differ from healthy individuals (who were either food deprived for 8 hours or non-food deprived) in the number of initial fixations on food images, but total gaze duration to the food pictures was lower in patients with anorexia nervosa than in both healthy comparison groups (Giel et al., 2011). Thus, findings do not show consistent evidence for a role of attentional bias to food in patients with anorexia nervosa.

Starting point for this thesis

Because of the methodological variations and the small samples of two of these studies (i.e., Giel et al., 2011 included 19 patients with anorexia nervosa; Kim et al., 2014 included 32 patients with anorexia nervosa), it seems premature to conclude that patients with anorexia nervosa are not characterized by a decreased attentional bias for food cues. Importantly, thus far attentional bias to food was measured with tasks that are not able to distinguish between the two distinct attentional processes of automatic orientation towards food cues (i.e., attentional engagement) and maintaining attention on food cues possibly due to a difficulty to disengage from food cues (i.e., attentional disengagement) (Grafton & MacLeod, 2014; Posner, Inhoff, & Friedrich, 1987). If indeed these two processes are differentially involved in dysfunctional eating behavior, measures that do not differentiate between attentional engagement and attentional disengagement might provide apparently contrasting and divergent results.

Recently, a new task – the Attentional Response to Distal vs. Proximal Emotional Information (ARDPEI) task – was developed specifically to differentiate between attentional engagement and disengagement (Grafton & MacLeod, 2014). The ARDPEI provides measures of an attentional process that occurs in a short time period (i.e., more automatic; 100 ms) and an attentional process that happens over a longer time period (i.e., allowing some voluntary control; 500 ms). The ARDPEI thus provides the opportunity to take into account that attentional engagement is an early attentional process mainly directed by bottom-up processes, and attentional disengagement is a later attentional process directed more by top-down processes (Mogg & Bradley, 2016; Pool et al., 2016). In this thesis it was therefore examined whether patients with anorexia nervosa have less attention to food as indexed by the ARDPEI, than adolescents without an eating disorder.

Further, it was tested whether low attentional engagement with food cues is involved in the persistence of anorexia by taking a longitudinal approach. Specifically, it was examined whether an improvement in eating disorder symptoms would be related to an increase in attention to food, and whether relatively little attention to food cues at baseline is related to less improvement in eating disorder symptoms.

Manipulating attention to food

The idea that an attentional bias can be manipulated (i.e., attentional bias modification) and as such might be used as an intervention was first suggested by anxiety disorders researchers (e.g., MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). It was suggested that by inducing this bias the causal role of the attentional bias to anxiety symptoms could be explored, and that decreasing this bias might lead to a reduction in anxiety symptoms (e.g., Mathews & MacLeod, 2002). Eating behavior researchers analogously suggested that modification of attention to food cues might serve as treatment for unhealthy or disordered eating behavior (e.g., Kakoschke et al., 2014).

Studies examining the effect of attentional bias modification on attention to food have mainly focused on individuals with obesity. Previous research has found that training obese individuals to direct their attention away from food resulted in a decrease in attention to food and that training them to direct their attention towards food resulted in an increase in attention to food (Kemps et al., 2014). It was additionally shown that these training effects were maintained after 24 hours and at one-week follow-up (Kemps et al., 2016). Last, attesting to the potential causal role of attentional bias to food cues in eating behavior, this line of research has shown that women following a training to direct their attention away from food cues consumed fewer calories on a taste-test than women following a training to direct their attention towards food cues (Smith, Treffiletti, Bailey, & Moustafa, 2018). However, studies in which obese individuals were trained to direct their attention away from food cues found no beneficial effects of attentional bias modification on food intake compared to a wait-list control group (Boutelle, Kuckertz, Carlson, & Amir, 2014; Boutelle, Monreal, Strong, & Amir, 2016; Verbeken et al., 2018). However, the small sample sizes (between 8 and 18 participants per group) in these studies led to low statistical power to find true effects.

Starting points for this thesis

Taken together, there seems to be some initial evidence that attention to food cues can be modified and that such modification might influence eating behavior. However, a difference in food intake was found when comparing an avoid-training group with an attend-training group (Smith et al., 2018), but not when compared to a control group (Boutelle et al., 2014, 2016; Verbeken et al., 2018). This might mean that the difference in eating behavior in Smith et al. was due to an increase in food intake in the attend-training group rather than a decrease in food intake in the avoid-training group. However, also no change in attention to food was found after the avoid-training compared to a control group (Boutelle et al., 2014, 2016; Verbeken et al., 2018). Further, sample sizes of these were small providing not enough power to find small effects. It might therefore be likely that the training is limited in its strength. One reason for this might be that the training tasks that have been used do not effectively target attentional disengagement, suggested to play a role in overeating.

These training tasks are typically adapted from the visual probe assessment paradigm (MacLeod, Mathews, & Tata, 1986). In the visual probe task, two images (or words) are shown simultaneously next to each other on the screen. After a short interval, a probe stimulus (e.g., a dot) appears in the location where one of the images was just shown and the participant must quickly identify the location of this probe (e.g., Kemps et al., 2016). In visual probe tasks configured to reduce attention to food cues, each stimulus pair contains a food-related item and a non-food item and the probe consistently appears in the location of the non-food item. Because participants start each trial by focusing on a fixation cross in the middle of the screen, the images always appear distal to attended location. The location of the probe is likely identified either after attentional engagement with the non-food item, or after attentional engagement with the food item followed by disengagement to move attention towards the location of the probe. As a result, dot-probe modification tasks might reduce attentional engagement with food cues, difficulty to disengage attention from food cues, or a combination of both (cf., Grafton & MacLeod, 2014). Since especially the difficulty to draw attention away from food cues is (theoretically) implicated in overeating and unsuccessful dieting (cf., Franken, 2003), a training paradigm that specifically targets difficulty to disengage attention from food cues might be more effective in reducing attention to food cues of individuals who tend to overeat. Thus, this thesis used a new attentional bias modification paradigm designed to specifically increase attentional disengagement from food cues.

This new paradigm was adapted from the Emotion-in-Motion task by using food images rather than emotion-related images (Notebaert et al., 2018). This adapted version was termed the Bouncing Image Training Task (BITT). In the BITT, eight square boxes simultaneously move around the computer screen, bouncing off each other and the screen edges. Seven boxes contain images of food items (distractor boxes) and one box contains an image of a non-food item (target box). Participants are instructed to attend to this target box. At frequent intervals, the images in the eight boxes change. When the image of the tracked box changes into another non-food item, it remains the target box. However, when the image of the tracked box changes into a food image, participants are required to disengage attention from this box immediately and locate the new target box as soon as possible. Thus, participants have to execute an attentional disengagement response if the box displays a food image and inhibit a disengagement response if the box continues to display a non-food item.

In this thesis, a first step was taken to examine the effectiveness of this new paradigm to facilitate disengagement from food cues. As it has been suggested that individuals need motivation to change their behavior to benefit from an attentional bias modification training (Heitmann et al., 2017), the effectiveness of the BITT was examined in women who were motivated to follow a diet but indicated poor success (i.e., unsuccessful dieters). To examine whether the BITT training would serve to train an attentional disengagement bias from food cues, women following the training were compared to women in a wait-list control group. Change in performance on the BITT between pre- to post-training was assessed. Since such improvement need not reflect the acquisition of the intended change in attentional bias (Heitmann et al., 2017), but might reflect task improvement due to other learning processes, change in attention to food cues was additionally assessed with two attentional bias assessment tasks. As a secondary issue, the impact of the BITT on food craving and food intake was examined.

Outline and scope of this thesis

The first part of this thesis aimed to examine reward and punishment sensitivity in obesity and anorexia nervosa. By complementing self-report measures of reward and punishment sensitivity with a performance measure of attention to cues signaling reward and punishment, this thesis aimed to provide a comprehensive overview of the relationship between reward and punishment sensitivity and adolescent obesity and anorexia nervosa.

The studies presented in chapters 2 and 3 aimed to examine the relevance of reward and punishment sensitivity in obesity. In **chapter 2,** a cross-sectional as well as longitudinal approach was taken to examine the relationship of reward and punishment sensitivity in the development and maintenance of obesity in adolescence. This study examined whether self-reported reward and punishment sensitivity and attention to cues signaling reward and punishment were related both to BMI and to the change in BMI between the age of 13 and 19. In **chapter 3,** treatment seeking obese adolescents were compared to adolescents with a healthy weight matched on age and gender to examine differences in reward and punishment sensitivity.

Chapter 4 aimed to examine differences in reward and punishment sensitivity between patients with anorexia nervosa and adolescents without an eating disorder. These groups were compared on self-reported reward and punishment sensitivity and a performance measure of attention to cues signaling reward and punishment. It was examined whether patients with anorexia nervosa show lower sensitivity to reward and higher sensitivity to punishment.

The last aim in the first part was to develop a new self-report measure of reward and punishment sensitivity that is able to differentiate between (i) reward responsivity and motivation to approach reward to reward and (ii) punishment responsivity and motivation to avoid reward/punishment. Importantly, the aim was to measure these constructs independent of specific rewarding or punishing stimuli. In **chapter 5,** the development of this new questionnaire, the Reward and Punishment Responsivity and Motivation Questionnaire (RPRM-Q), and its psychometric qualities are reported.

The second part of this thesis examined the relationship between attentional bias to food and eating behavior. In **chapter 6,** differences between patients with anorexia nervosa and a matched comparison group on attentional engagement with and difficulty to disengage from food cues were examined. It was expected that patients with anorexia nervosa would show less attentional engagement to food cues, and less difficulty to disengage from food cues than adolescents without an eating disorder. In **chapter 7,** this research was extended by examining whether differential attention to food cues was predictive for the course of anorexia nervosa. It was tested whether improvement of eating disorder symptoms and BMI depends on the normalization of this decreased attention to food cues, and whether decreased attention to food cues contributes to the persistence of eating disorder symptoms.

In **chapter 8,** research on the efficacy of the modification of attentional bias to food was extended by testing the capacity of a new training paradigm to decrease food-related attentional disengagement biases in unsuccessful dieters. Further, it was examined whether this potential decrease in attention also reduced food intake and food craving.

Finally, **chapter 9** provides an integration and discussion of the results presented in the chapters 2 – 8. The main points of this discussion are: (1) are reward and punishment sensitivity related to adolescent obesity? (2) do patients with anorexia nervosa differ in their reward and punishment sensitivity from adolescents without an eating disorder? (3) do patients with anorexia nervosa differ in their attention to food from adolescents without an eating disorder, and is this differential attentional pattern related to the course of anorexia nervosa? and (4) can we manipulate specifically difficulty to disengage attention from food cues and does this influence eating behavior?