Temptation and restraint

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Chapter 9

General discussion

Individuals with obesity and anorexia nervosa exhibit eating behavior that is a threat to their health (Dixon, 2010; Kask et al., 2016; Luppino et al., 2010; Roberts & Hao, 2013). Treatment for both shows only limited effectiveness and high relapse rates (Brockmeyer et al., 2017; Field et al., 2007; Johnson et al., 2012; Khalsa et al., 2017; Mann et al., 2007; Zipfel et al., 2014). Enhancing insight into the factors underlying disordered eating behavior in adolescents seems a crucial starting point for improving existing interventions.

The first aim of this thesis was to examine the role of reward and punishment sensitivity in obesity and anorexia nervosa. Thus far, studies on this topic have shown great methodological variation and mixed findings. Further, previous studies assessed reward and punishment sensitivity by means of self-report questionnaires, thereby omitting the attentional component of reward and punishment sensitivity. The question thus remains whether and how reward and punishment sensitivity are involved in eating behavior.

The second aim of this thesis was to examine the relationship between a more specific operationalization of reward sensitivity – attentional bias to food – and anorexia nervosa. A cross-sectional approach was used to examine differences between patients with AN and adolescents without an eating disorder and a prospective approach was used to examine the role of attention to food in the course of anorexia nervosa. The last study examined the effects of a novel (disengagement) attentional bias modification task on eating behavior in a sample of unsuccessful dieters.

In this chapter the main findings and implications of the studies presented in chapters 2 to 8 will be summarized and limitations, implications, and directions for further research will be discussed.

Summary and integration of findings

Are reward and punishment sensitivity related to adolescent obesity?

It is generally agreed that reward and punishment sensitivity play an important role in obesity. Although researchers have proposed that obese individuals might be less sensitive to punishment (e.g., Danner et al., 2012), empirical findings on the matter have been mixed. Furthermore, theories have proposed different types of relations regarding the role of reward sensitivity in obesity. It has been suggested that increased sensitivity to the rewarding properties of food might be the result of high reward sensitivity, with the consequence that high reward sensitivity would increase the risk for overeating and the development of overweight and obesity (i.e., *hyper-responsiveness theory*; Dawe & Loxton, 2004; Franken & Muris, 2005; Guerrieri et al., 2008). On the other hand, it has been suggested that low sensitivity to reward might result in eating more rewarding foods as a means to compensate for decreased feelings of reward (i.e., *reward deficiency syndrome theory*; Volkow et al., 2002; Wang et al., 2004). Last, it has been suggested that high reward sensitivity and BMI show a more dynamic relationship such that (i) reward sensitivity causes initial overeating, (ii) as a result of overeating, sensitivity to food cues is decreased, and (iii) overeating is maintained by a drive to eat more palatable food to compensate for this lowered feeling of reward (i.e., *dynamic vulnerability model*; Stice et al., 2011). Empirical findings have shown inconsistent results regarding which theory is best supported. These gaps in our knowledge motivated the research in this thesis, which was designed to unravel how reward and punishment sensitivity might be involved obesity.

In chapter 2, the relationship between reward and punishment sensitivity and BMI was examined in a large sample of adolescents (N = 1306). BMI was measured at age 13, 16 and 19. At age 13 self-reported reward responsivity, reward drive and punishment sensitivity was assessed. At age 16, a subgroup (n = 607) performed a measure indexing attention to cues that signal reward and punishment. Self-reported reward responsivity, reward drive and punishment sensitivity were not found to relate to BMI at age 13, or to the change in BMI between the age of 13 and 19. The attentional bias indices were also not related to concurrent BMI or the change in BMI between the age of 13 to 19. These attentional bias null findings were the case for both the more automatic attentional measure as well at the more voluntary attentional measure. Exploratory analyses showed that less effort to avoid punishment on the performance measure was related to a higher concurrent BMI (age 16) and an increase in BMI between the age of 13 and 19 (but not significantly to the change in BMI between age 16 and 19). High effort to obtain reward at age 16 was related to an increase in BMI between age 16 and 19.

In chapter 3, differences in reward and punishment sensitivity were examined for adolescents with obesity and an age and gender matched comparison group with a healthy weight. Reward and punishment sensitivity were measured with the same instruments as in chapter 2. Adolescents with obesity reported less reward responsivity than adolescents with a healthy weight, whereas self-reported reward drive was similar for both groups. No differences in self-reported punishment sensitivity or attention to cues signaling punishment or reward were found between obese and healthy weight adolescents. Exploratory analyses showed that obese adolescents showed less effort to obtain reward, and less effort to avoid punishment than the healthy weight adolescents.

The studies in this thesis provide inconsistent evidence regarding the relationship between the first self-report component of reward sensitivity, reward responsivity, and obesity. Whereas lower reward responsivity in obese adolescents compared to healthy weight adolescents was found in chapter 3, no negative relationship between reward responsivity and BMI was found in chapter 2. Furthermore, low reward responsivity was not related to increases in BMI between age 13 to age 19. Together, these findings do not seem to be in line with the *reward deficiency syndrome theory*, which suggests that risk for obesity is the result of compensation for a low reward sensitivity by eating more rewarding food. The results were also not in line with the *hyper-responsiveness theory*, which suggests that increased reward responsivity might result in overeating. However, the sample of the study presented in chapter 2 included relatively few adolescents with obesity (age 13, 2.8%; age 16, 3.1%; and age 19, 5.6%) or severe obesity (age 13, 0.3%; age 16, 0.4%; and age 19, 0.8%). The low representation of adolescents with obesity means that they might not have had a large enough impact on the correlational analysis even if they had lowered reward responsivity. It might thus be that lowered reward responsivity is characteristic of individuals with obesity and severe obesity but not of individuals with overweight or related to changes in BMI over time. This would imply that low reward responsivity might be the consequence rather than the cause of obesity. Since adolescent obesity has been related to an increased risk for depression (Luppino et al., 2010) and depression is also characterized by blunted reward responses

(Luking et al., 2017), this decreased reward responsivity is potentially related to, or the consequence of depression.

The studies in chapters 2 and 3 did not show a role for the second self-report component of reward sensitivity, reward drive in obesity. However, our exploration into a behavioral index of motivation to obtain reward based on the attentional bias task provides evidence for a role for differential reward motivation in obesity. Chapter 2 showed that a high motivation to obtain reward is related to an increase in BMI, suggesting that such motivation might be related to the development of obesity. However, this inference should be tempered by the chapter 2 finding that motivation to obtain reward was not related to concurrent BMI. In contrast, chapter 3 showed that adolescents with current obesity and severe obesity are characterized by a lowered motivation to obtain reward. One explanation for these results might be that there is a positive relationship between reward drive and BMI in lower BMI levels (i.e., healthy weight and overweight) and a negative relationship in higher BMI levels (i.e., obese and severely obese). If true, no difference would be found between individuals with a healthy weight and individuals with obesity or severe obesity. In line with this idea, an earlier study showed evidence for such a quadratic relationship between BMI and reward drive, albeit with self-reported reward drive (Verbeken et al., 2012). The only other study reporting on reward drive showed a positive relationship between drive and BMI (De Decker et al., 2016). Since only 0.4% of that sample was obese (Michels et al., 2012), these findings are in line with the proposed quadratic relationship.

To test the quadratic model further, a post-hoc analysis was performed to examine a quadratic relationship between motivation to obtain reward and concurrent BMI in the sample of chapter 2. The result showed that there was indeed evidence for a quadratic relationship between the performance measure of motivation to obtain reward and BMI ($F(2,607.11) = 5.14$, $p < .01$, $R^2 = .02$) but not for the self-report measure ($F(2,1303) = 0.01$, $p = .99$, $R^2 < .01$). The inconsistency with previous findings on self-reported reward drive might be caused by the low internal consistency of the reward drive subscale in chapter 2 (Cronbach's alpha = .63), which was substantially lower than in the study of Verbeken et al. (2012; Cronbach's alpha = .80), and De Decker et al. (2016; Cronbach's alpha = .85).

The studies in this thesis do not provide evidence for a role of attention to cues signaling reward and punishment, or self-reported punishment sensitivity in obesity. However, exploration into motivation to avoid punishment based on the attentional bias task did provide some evidence for differential punishment motivation in adolescents with obesity. Chapter 2 showed that a relatively low effort to avoid punishment was related to higher concurrent BMI and an increase in BMI and chapter 3 showed that obese adolescents had less motivation to avoid punishment. Taken together, the findings seem to indicate that low motivation to avoid punishment might be related to the development and maintenance of obesity. These findings are in line with the idea that obese individuals disregard the negative consequences of their behavior (e.g., Danner et al., 2012). This negative relationship between motivation to avoid punishment and BMI was not paralleled with lower self-reported punishment sensitivity on the BIS/BAS. One potential reason for this is that punishment sensitivity as measured with the BIS/BAS indexes a different aspect of punishment than individuals' motivation to avoid punishment. Punishment sensitivity as indexed by the BIS/BAS seems to be a combination of punishment responsivity and motivation to avoid punishment. Moreover, correlational analyses reported in chapter 5 of this thesis suggest that the punishment sensitivity index of the BIS/BAS might be a stronger reflection of punishment responsivity than of motivation to avoid punishment. Thus, lowered punishment sensitivity in obesity might be limited to a low motivation to avoid punishment.

Do patients with anorexia nervosa differ in their reward and punishment sensitivity from adolescents without an eating disorder?

With regard to anorexia nervosa, it has been proposed that an increased sensitivity to punishment might underlie the development and maintenance of characteristics and behaviors such as shape and weight concern, an intense fear of becoming fat, and harm avoidance behavior (Jappe et al., 2011). In line with this, research has consistently found that individuals with anorexia nervosa report higher sensitivity to punishment compared to comparison groups without an eating disorder. Researchers further suggested that individuals with anorexia nervosa are characterized by low reward sensitivity, as this might lower the reward value of food and facilitate food restriction (Glashouwer et al., 2014; Harrison et al., 2016; Harrison et al., 2010). However, findings on the relationship between reward sensitivity and anorexia nervosa have been mixed. Studies assessing reward and punishment sensitivity in the context of anorexia nervosa have also failed to include the attentional component, thereby providing a limited view of the role of these concepts in anorexia nervosa. In light of these gaps in our knowledge, this thesis was designed to provide insight into the role of reward and punishment sensitivity in anorexia nervosa. Similar to the studies on obesity in this thesis, self-reported reward and punishment sensitivity were complemented with performance measures of attention to cues signaling reward and punishment.

In chapter 4, no differences were found on self-reported reward responsivity, reward drive, and attention to cues signaling reward between patients with anorexia nervosa and adolescents without an eating disorder. The null findings occurred for the more automatic as well as the more voluntary attentional processes. Exploration of potential differences between patients who primarily use dieting and exercise to accomplish weight loss (i.e., restrictive subtype) and patients who also engage in binge eating and purging behaviors (i.e., binge purge subtype) showed no differences between these subgroups. These findings seem in line with other studies that have used the BIS/BAS to index reward sensitivity (Jappe et al., 2011; Matton et al., 2015; Monteleone et al., 2014). However, the absence of a difference in self-reported reward sensitivity on the SPSRQ is not consistent with previous research showing heightened reward sensitivity in patients with anorexia nervosa (Glashouwer et al., 2014; Jappe et al., 2011). Across studies the reported reward sensitivity by patients was comparable, but the reward sensitivity reported by the comparison groups differed. This implies that these inconsistent findings might be due to differences in the comparison groups that were selected. Most importantly however, findings with regard to reward sensitivity as measured with the SPSRQ should be interpreted with caution, given that previous research has shown that heightened reward sensitivity in patients with anorexia nervosa might be due to higher scores on items about appearance and interpersonal reward (e.g., “do you often meet people that you find physically attractive” Glashouwer et al., 2014), which in the context of anorexia nervosa might be considered punishing rather than rewarding. That patients with anorexia nervosa did not show less attention to cues signaling reward than adolescents without an eating disorder is also in line with previous research (Matton et al., 2017). Moreover, prior research showed that patients with anorexia nervosa do not differ from healthy women in their brain activation during reward anticipation (Murao et al., 2017). Taken together, the findings point to the conclusion that patients with anorexia nervosa are equally sensitive to reward as adolescents without an eating disorder.

Compared to adolescents without an eating disorder, patients with anorexia nervosa reported higher sensitivity to punishment. This was found when punishment sensitivity was assessed with the SPSRQ as well as with the BIS/BAS. These findings are in line with previous research (Claes et al., 2006; Glashouwer et al., 2014; Jappe et al., 2011; Matton et al., 2015; Monteleone et al., 2014). Heightened self-reported punishment sensitivity was not paralleled by increased attention to cues signaling punishment. This might imply that heightened punishment sensitivity is limited to patients' own experience and is not reflected in their actual behavior. However, the questionnaires that were used to index sensitivity to punishment, assessed punishment sensitivity as a combination of punishment responsivity, and motivation to avoid punishment. It might thus be that it is not so much limited to their own experience, but limited to responsivity and/or motivation to avoid punishment.

Intermezzo: The development of a new self-report measure of reward and punishment sensitivity

In chapters 2-4, commonly used measures were used to index reward and punishment sensitivity. Using these measures has the important advantage that the current results can be directly compared to results of earlier studies. Nevertheless, these measures have several important limitations. First, the type of reward and punishment that is referred to in the questions is sometimes very specific (e.g., drugs or physical appearance) which in the context of anorexia nervosa might lead to measurement bias (cf., Glashouwer et al., 2014). The conceptual overlap between items of the reward and punishment sensitivity questionnaires and measures of clinical symptoms might pose a more general problem in psychopathology research. Second, although the BIS/BAS differentiates between reward responsivity and reward drive, neither the BIS/BAS nor the SPSRQ differentiates between punishment responsivity and punishment drive.

These limitations motivated the development of a questionnaire that differentiates between responsivity and motivation and measures these concepts without specifying specific types of reward and punishment. Chapter 5 reported the studies related to the development of this questionnaire. The final version of the questionnaires consists of 18 items and the confirmatory factor analyses showed support for the proposed 4 factor structure of reward responsivity, motivation to approach reward, punishment responsivity, and motivation to avoid punishment. Furthermore, the subscales showed acceptable to good internal consistency. The findings indicate that the Reward and Punishment Responsivity and Motivation Questionnaire (RPRM-Q) might be a helpful instrument to examine the potential differential contribution of reward and punishment responsivity and motivation to approach reward and avoid punishment. For example, it might provide further insight into whether patients with anorexia nervosa are more responsive to punishment, have more motivation to avoid punishment, or whether their reported heightened punishment sensitivity is a reflection of the combination of these two aspects.

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?

The second part of this thesis aimed to examine the relationship between a more specific operationalization of reward sensitivity, attention to food, and anorexia nervosa. Individuals' attention has been proposed to be biased to positive and negative cues in the environment, and this bias has been suggested to be stronger when the cue is relevant to specific concerns of the individual (Field et al., 2016; Pool et al., 2016). Consequently, an attentional bias to food might play a more direct role in disordered eating behavior than the bias to general cues of reward and punishment. Nevertheless, previous research has failed to find convincing evidence for a differential pattern of attention to food in patients with anorexia nervosa. However, a limitation of these studies is that they used measures of attention to food cues that are unable to distinguish between engagement and disengagement. If these two processes play a differential role in eating behavior, using measures that do not differentiate between these two components of attention can result in divergent results. To address this issue, the research in chapter 6 examined whether patients with anorexia nervosa showed less attention to food as measured with the Attentional Response to Distal vs. Proximal Emotional Information (ARDPEI) (Grafton & MacLeod, 2014), a task designed to provide separate measures of attentional engagement and attentional disengagement.

Chapter 6 examined whether patients with anorexia nervosa showed less attention to food cues than adolescents without an eating disorder who were matched on age, educational level, and gender. The two groups did not differ in difficulty in disengaging attention from food cues compared to neutral cues, but they differed in attentional engagement with food cues. Specifically, when the cues were shown briefly (100 ms), adolescents without an eating disorder showed significantly more attentional engagement with food cues than with neutral cues. Patients with anorexia nervosa did not show such difference, and showed less attentional engagement with food cues than adolescents without an eating disorder. Together, the results suggest that patients with anorexia nervosa might lack the bias for food involved in healthy eating behavior.

Chapter 7 extended the cross-sectional study of chapter 6 by examining whether this differential attentional engagement with food cues was prospectively related to the course of anorexia nervosa. One year after baseline assessment, patients' eating disorder symptoms and attention to food cues were re-assessed. Overall, patients with anorexia nervosa showed an improvement over this year as their eating disorder symptoms decreased and their BMI increased. However, their attentional engagement to food cues did not change during this period. Further, there was no evidence that change in eating disorder symptoms or BMI was related to a change in attentional engagement for food cues. There was also no evidence that the strength of patients' attention to food at baseline was related to the change in eating disorder symptoms between baseline and follow-up.

Interestingly, on a group level no change in attentional bias to food cues in patients with anorexia nervosa was found between baseline and follow-up. This seems to be in line with the suggestion that automatic processes, of which attention is one, might be difficult to change (Vartanian et al., 2004) and that current treatment for eating disorders might have a limited effect on automatic processes (Neimeijer et al., 2015). It has been suggested that weight restoration in patients with anorexia nervosa does not have to coincide with the normalization of eating behavior, and persisting aberrant eating behavior may increase the risk for relapse (Hansson et al., 2011; Lloyd & Steinglass, 2018). Consequently, it might be that decreased attentional engagement with food cues is a risk factor for relapse in patients with anorexia nervosa.

Can we manipulate specifically difficulty to disengage attention from food cues and does this influence eating behavior?

The last topic of the thesis was to examine whether it is possible to modify attention to food cues. Thus far, research addressing the possibility of attentional bias modification to food cues have focused on individuals with obesity. These studies showed that it might be possible to change individuals' attention, and provided some initial evidence that changing this bias might influence eating behavior (Kemps et al., 2014, 2016; Smith et al., 2018). However, this effect on food intake was only found when comparing individuals who were trained to direct their attention towards food with individuals who were trained to direct their attention away from food, and not when compared to a control group. 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 since not all studies showed decreased attention to food cues after an attentional bias modification training (Boutelle et al., 2014, 2016; Verbeken et al., 2018), it might be more likely that the training was limited in its strength.. Importantly, these studies all used adapted versions of the visual probe task as training paradigm (MacLeod et al., 1986). This paradigm may be ill-suited to specifically target disengagement biases (cf., Grafton & MacLeod, 2014), which may be more important than engagement biases for predicting dieting success (cf., Franken, 2003). This thesis examined the efficacy of a new training task (the bouncing image training task, BITT) to target disengagement biases toward food cues. As a first step, the BITT was examined in women who were unsuccessful dieters.

Participants in the study presented in chapter 8 were randomly assigned to a waitlist control group performing a pre and post-assessment of attentional bias and eating behavior or to a training group that additionally completed the BITT training every day for a week. Participants following the training showed reduced attention to food cues compared to the wait-list control group. Moreover, the reduction in attentional bias reflected a reduction in difficulty to disengage attention from food cues and not a reduction in attentional engagement with food cues. No difference in food craving and food intake was found between the groups after the training period. In sum, the BITT appears to be a promising procedure for addressing problems in attentional disengagement from food cues. However, the findings question the causal role of attentional disengagement to food cues since no influence on eating behavior was found.

Strength and limitations

The studies in this thesis have a number of strengths. First, the use of cross-sectional and longitudinal designs provided the opportunity to test the prognostic value of (i) reward and punishment sensitivity on change in BMI and (ii) attentional bias to food on change in symptoms and BMI in patients with AN. Second, the sample sizes were large enough (and the drop-out in chapter 7 was low enough) to provide sufficient power for examining the hypotheses. Third, the inclusion of individually matched comparison groups to adolescents with anorexia nervosa and obesity reduced the possible influence of third variables such as gender and age. Finally, complementing self-report measures of reward and punishment sensitivity with a performance measure of attention provided a comprehensive view of the relationship between reward and punishment sensitivity and disordered eating behavior.

There are also aspects of the reported studies that need some further consideration. First, it has been suggested that reaction time measures such as the SOT and the ARDPEI might have low internal consistency, negatively influencing the interpretability of results (Parsons, Kruijt, & Fox, 2018). Indeed split-half internal consistency of the SOT in chapter 4 showed low internal consistency. However, these estimates should be taken with some caution since the indices used in the split-half reliability analyses were calculated from fewer trials than were expected to be necessary for an acceptable signal to noise ratio. That is also why a split-half reliability index of the ARDPEI was not calculated in chapters 6 and 7. For this task, a split-half results in too few trials per type and would thus result in a comparison of two a priori unreliable indices (cf., Elgersma et al., 2019).

Nevertheless, reliability of performance measures might require more in-depth examination. A potential issue with the reliability of the attentional bias measures is that these are based on difference scores. The reliability of a difference score will be low when the components of these difference scores are (highly) correlated (Thomas & Zumbo, 2011). Attentional bias scores are calculated by subtracting two or more reaction times of different types of trials, for example the average reaction time on cued trials from the average reaction time on uncued trials. These reaction times within a task are often correlated, which would result in low reliability of such a difference score. Recent research examined whether this problem could be countered by decreasing the correlation between the components of difference scores in the SOT (Kreuze, Jonker, Hartman, Nauta, & De Jong, in prep). It was hypothesized that an important reason for this correlation between the subcomponents of the difference score is individuals' average speed of responding. Indeed, in this study controlling for individuals' average response time on cued and uncued trials resulted in a substantial improvement of the reliability as estimated with Spearman Brown correlations (Spearman Brown coefficient of .7-.8).

A second limitation is that, with the exception of chapter 8, the studies in this thesis used a correlational design. Although the longitudinal designs in chapters 2 and 7 provide more information than cross-sectional designs regarding the potential direction of the relationships, causality still cannot be inferred from this type of research. To be able to infer causality, it is necessary to establish that there are no third variables that can explain the association between the variables. That is, an experimental design such as reported in chapter 8 on the role of attention to food in unsuccessful dieters, is necessary to establish causality. For studies on the role of reward and punishment sensitivity is would thus be necessary to either increase or decrease sensitivity to reward or punishment and examine the effect on eating behavior. Alternatively, eating disorder symptoms could be increased or decreased, and the effect on reward and punishment sensitivity examined. Similarly, to examine the causal role of low attentional engagement with food cues in anorexia nervosa, the effect of a training to decrease this bias on eating behavior should be examined. Chapter 7 already provided relevant information about the potential influence of decreasing eating disorder symptoms on attentional engagement with food cues. However, since patients received treatment as usual there might have been substantial diversity in treatment. It should therefore be examined in more detail whether specific types of treatment aimed at changing eating behavior, for example food exposure, have an impact on attention to food cues.

Third, the behavioral measure of motivation to obtain reward and avoid punishment in chapters 2 and 3 was indexed based on face validity rather than construct validity. Future research should examine whether this finding can be replicated with a validated measure of reward and punishment motivation. One potential option for this might be the point-scoring reaction time task (Colder et al., 2011), which is designed to assess motivation to obtain reward and punishment.

Fourth, the results of the studies reported in chapters 4, 6, and 7 might have been influenced by the decision to recruit patients with full-threshold anorexia nervosa as well as patients with atypical anorexia nervosa. This decision was based on the premise that atypical and full-threshold anorexia nervosa do not seem to differ in psychological and physical severity (Sawyer et al., 2016) and that the difference in diagnosis seems to be minor. That is, patients with full-threshold anorexia nervosa demonstrate considerable weight loss and are underweight whereas patients with atypical anorexia nervosa also demonstrate considerable weight loss but are not underweight. However, in chapter 4 we found some indications that there might be differences between full-threshold and atypical anorexia nervosa patients. After excluding patients with atypical anorexia nervosa from analyses, it was found that patients with full-threshold anorexia nervosa showed more attentional engagement with cues signaling punishment than the comparison group. This suggests that attentional engagement with cues signaling punishment might play a role in the development of full-threshold and not atypical anorexia nervosa. Future research is necessary since splitting the group of patients into full-threshold (n = 49) and atypical (n = 20) resulted in small sample sizes, which limits the power of statistical tests.

Clinical implications and future directions

The aim of this thesis was to improve our understanding of the factors underlying problematic eating behavior in adolescents. Understanding the factors that are related to the development and maintenance of disordered eating behavior might provide important starting points for improving existing interventions. In this last part the implications of the findings reported in this thesis will be discussed.

Obesity

In general the findings of this thesis show that the involvement of reward and punishment sensitivity in obesity is not straightforward. An important conclusion to take from this is that it seems pivotal to differentiate between the subcomponents of reward and punishment sensitivity. With regard to punishment sensitivity it was only partly possible to make this distinction with the available measures. Self-reported punishment sensitivity and attention to cues signaling punishment did not seem to be related to obesity. However, it was shown in chapters 2 and 3 that low motivation to avoid punishment was related to obesity, and an increase in BMI. The new questionnaire reported in chapter 5 might be helpful for future research to improve insight into whether it is indeed only low motivation to avoid punishment that plays a role, or whether punishment responsivity might also play a role in obesity.

With regard to reward sensitivity, it was specifically found that a high motivation to obtain reward as measured with a performance measure was related to obesity and increases in BMI (chapter 2). Since reward (and punishment) sensitivity might be relatively stable personality characteristics and thus difficult to change (Harrison et al., 2016; Kasch, Rottenberg, Arnow, & Gotlib, 2002), other approaches than directly trying to change these characteristics might be required to address this in treatment. One way might be to find alternative sources (e.g., hobbies rather than food) as a target for motivation to obtain reward. Another option might be to devaluate the reward value of food. If the food cue is associated less with reward it might also be less of a motivated cue to approach. It was found that obese individuals have a high reward response to the anticipation of food intake (Stice et al., 2008). Further, food specific inhibitory training was found to reduce food cue reactivity (Chen et al., 2018). Also exposure to food cues without eating might reduce the anticipatory psychological and physical response to food (Schyns, Roefs, Smulders, & Jansen, 2018). Thus, habituation to food in the absence of the expected reward (i.e., without eating) might result in a decreased association between food and reward.

Last, executive control might be considered as third variable in the relationship between reward and punishment sensitivity and behavior and thus as a potential target for training. According to dual-process models, behavior results from the interplay of bottom-up motivational processes such as automatically triggered approach responses towards food and top-down control processes (i.e., deliberate decision making processes) (Strack & Deutsch, 2004). In order to make deliberate decisions, such as redirecting thoughts and actions towards healthy eating behavior when tempted by unhealthy food, adequate executive control is required (e.g., Hofmann, Baumeister, Förster, & Vohs, 2012; Tahaney, Kantner, & Palfai, 2014). Individuals low in self-control are expected to be unwilling or unable to restrain themselves from such bottom-up motivational processes (Hofmann et al., 2012). Although this interplay has yet to be examined in obesity, there is some evidence of reduced executive control in obese versus healthy weight children (Nederkoorn, Coelho, Guerrieri, Houben, & Jansen, 2012; Verbeken, Braet, Claus, Nederkoorn, & Oosterlaan, 2009). Further, studies in the context of alcohol use and unsuccessful dieting in individuals with a healthy weight have shown that there might indeed be an interplay between executive control and reward and punishment sensitivity (Jonker, Bennik, & de Jong, 2016; Jonker et al., 2014). Specifically, low punishment sensitivity was related to high amounts of alcohol use only in individuals with a relatively low executive control, suggesting that high executive control might protect against the influence of low punishment sensitivity on alcohol use (Jonker et al., 2014). Further, in individuals with a relatively weak executive control, high reward sensitivity was related to more unsuccessful dieting, suggesting that high executive control could reduce the influence of high reward sensitivity (Jonker et al., 2016). If executive control indeed moderates the relationship between reward and punishment sensitivity and obesity, this might be a potential explanation of why research has shown such inconsistent findings. Furthermore, a review showed that in healthy weight individuals an executive control training can reduce ad-libitum food intake (Jones et al., 2016), and a recent study showed that providing an executive control training to obese children might temper their food consumption (Rhee, Kessl, Manzano, Strong, & Boutelle, 2019). Thus, executive control training might be helpful in reducing the influence of reward and punishment motivation on behavior.

Attention to general signals of reward and punishment was not found to be related to obesity. However, this does not rule out that attention to specific cues such as food might play a role, and that attentional bias modification might be effective in the treatment of obesity. Nevertheless, the results from the attentional bias modification training reported in chapter 8 do not show convincing evidence for the use of attentional bias modification in its current form. Two important steps still need to be taken before attentional bias modification can be recommended or advised against in the treatment of obesity. First, it should be examined whether indeed specifically difficulty to disengage from food cues is implicated in overeating. Although studies have shown that obesity is characterized by more attention to food cues (Kemps et al., 2014; Nijs, et al., 2010), several others did not find differences between obese and healthy weight individuals (Castellanos et al., 2009; Loeber et al., 2012; Werthmann et al., 2011). Importantly, these studies have assessed attention to food with the visual probe task (MacLeod, Mathews, & Tata, 1986). As the visual probe task is not able to distinguish between attentional engagement and attentional disengagement (Grafton & MacLeod, 2014), it remains unclear what specific attentional process might play a role in obesity. Second, the procedure of the attentional bias modification training should be adapted such that its intended effect becomes stronger. Although the BITT tested in this thesis proved successful in reducing individuals´ difficulty to disengage attention from food cues, it did not result in less food intake. However, since the reduction in difficulty to disengage attention from food cues was fairly small ($\eta^2_p = 0.04$), it is possible that a daily 10-minute session for one week might not be sufficient to reach a meaningful change in attention to food. Future research should examine whether following a more intensive BITT training for a longer period of time might result in larger and more systematic changes in attentional bias and whether such larger changes in attentional bias for food might also impact participants' eating behavior. Further, it might be too optimistic to expect that this type of intervention, which only targets automatic processes, can be used as stand-alone treatment. It might be necessary to additionally intervene on the more explicit level, for example by teaching about healthy eating behavior. Consequently, it should be examined whether the BITT training would impact eating behavior when it is added to interventions such as consultation with a dietician.

Anorexia nervosa

Based on previous research and chapter 4 of this thesis, it can be concluded that patients with anorexia nervosa show heightened sensitivity to punishment. Future studies should further examine whether this relatively high punishment sensitivity plays a role in the development and/or maintenance of the disorder, whether it is a personality characteristic that fluctuates together with the symptoms of AN, or whether high reports of punishment sensitivity are a consequence of the disorder. Previously, it was found that punishment sensitivity was not related to eating disorder symptoms and BMI one year later (Glashouwer et al., 2014). However, since baseline eating disorder symptoms were not controlled for in that study, the possibility that high punishment sensitivity is related to persistence of eating disorder symptoms cannot be ruled out. A study examining the change of punishment sensitivity in patients with anorexia nervosa did not find a significant reduction in sensitivity to punishment after treatment (Harrison et al., 2016). However, the sample reported in this study was described as severely ill, with a mean illness duration of more than 6.5 years, and change in symptoms was reported to be small. Further, change in punishment sensitivity was not examined in relation to change in eating disorder symptoms. Taken together, it might still be that punishment sensitivity does change when eating disorder symptoms change.

Regardless of whether changes in eating disorder symptoms depend on changes in punishment sensitivity, the robust finding that patients with anorexia nervosa show heightened punishment sensitivity warrants attention during treatment. It should be acknowledged that as a consequence of high sensitivity to punishment, patients likely have a tendency to perceive their actions as incorrect or flawed (Wierenga et al., 2014). Combined with sensitivity to interpersonal punishments such as criticism and a tendency to avoid situations associated with potential punishment, punishment sensitivity is expected to interfere with patients' motivation for treatment (Monteleone et al., 2018). Further, this general tendency to avoid might interfere with learning that the punishing consequences might not be as punishing as they believe. Moreover, even when they do not avoid a situation, they might mainly focus on the negative consequences, preventing them from forming new positive associations. It might be helpful to discuss these issues and to help patients' focus on the rewarding consequences.

In the second part of this dissertation (chapters 6 and 7), attention to food was examined in the context of anorexia nervosa. The results demonstrated that patients with AN did not show the attentional engagement bias to food cues that was found in adolescents without an eating disorder. These findings seem to indicate that in patients with anorexia nervosa, food cues fail to grab attention. It has been suggested that bottom-up attentional engagement is focused on salient or threatening cues (Mogg & Bradley, 2016), and that cues become salient or threatening when they have rewarding or punishing properties (Franken, 2003). Since food is considered to have an intrinsically high reward value (Robinson & Berridge, 2001) current findings imply that food is a salient cue with rewarding properties for adolescents without an eating disorder. The absence of this bias in patients with anorexia nervosa suggests that food cues are neither appetitive (i.e., rewarding) nor threatening (i.e., punishing) to them. This contradicts an earlier suggestion that food might have a threat value for patients with anorexia nervosa (Neimeijer, Roefs, & de Jong, 2017), based on the finding that food cues resulted in task interference in patients with anorexia nervosa. This interference effect, found during a single target Rapid Serial Visual Presentation (RSVP) paradigm, is thought to reflect a temporal attentional bias to food in patients with anorexia nervosa (Neimeijer et al., 2017). Although this interference effect might indeed be explained by an attentional bias for food cues, it may also be due to cognitive avoidance of the food cue (De Ruiter & Brosschot, 1994). Furthermore, the comparison group in this study did not show such an interference effect caused by food images during the RSVP, adding to the idea that the behavior indexed by the RSVP differs from the attentional bias as indexed by the ARDPEI. Nevertheless, these results do seem to contrast the findings of chapter 6. As a first step to understand these apparently contradicting findings, both studies might require replication. Further, by combining the ARDPEI and the RSVP with EEG measures the validity of these tasks as measures of attentional bias can be assessed.

Change in symptoms and BMI did not depend on the change in attentional engagement with food in the full sample of patients with anorexia nervosa, nor was this attenuated attentional engagement related to the change in symptoms and BMI. Importantly, attentional engagement to food cues did not seem to change whereas patients did show an improvement in eating disorder symptoms and BMI between baseline and follow-up. Since it has been suggested that patients might persist in aberrant eating even after weight restoration and that persistent aberrant eating might increase the risk for relapse (Hansson et al., 2011; Lloyd & Steinglass, 2018), future studies should examine whether low attentional engagement might be a risk factor for relapse. Additionally, it could be fruitful to explore whether attentional engagement to food cues is predictive of the effectiveness of interventions directly aimed at changing food intake such as food exposure and whether such interventions change attentional engagement to food cues.

Last, since patients with anorexia nervosa showed heightened punishment sensitivity, it might be important to examine attention to specific cues of punishment in the context of anorexia nervosa. For example, there is some evidence that patients with anorexia nervosa have increased attention to thin and fat bodies (Pinhas et al., 2014), increased attention to their own unattractive body parts (Bauer, Schneider, Waldorf, Cordes, et al., 2017), and decreased attention to their own attractive body parts (Bauer, Schneider, Waldorf, Braks, et al., 2017). Future studies should examine the role of attentional bias to specific cues of punishment in the development and maintenance of anorexia nervosa.

Conclusion

In sum, the findings of this thesis do not allow for a simple answer to the question whether reward and punishment sensitivity play a role in obesity. Importantly the mixed findings seem to indicate that differentiating between responsivity, drive and attention with regard to reward and punishment sensitivity might be important in the context of obesity. The results indicate that it is mainly motivation to obtain reward and motivation to avoid punishment that are related to obesity. Findings suggest that increased motivation to obtain reward might be related to increases in BMI in individuals with a healthy weight or overweight, whereas decreased motivation to reward might be related to increases in BMI in individuals with obesity or severe obesity. Further, lowered reward responsivity was found in obese and severely obese adolescents. It would be critical to test whether this lowered reward responsivity might be a consequence rather than a cause of obesity. Heightened attention to cues signaling reward and lowered attention to punishment do not seem to be related to obesity.

With regard to anorexia nervosa there was no indication for a difference between patients with anorexia nervosa and adolescents without an eating disorder on any reward sensitivity measure. Taken together with findings from previous studies it seems only fair to conclude that patients with AN are equally sensitive to reward as adolescents without an eating disorder. There was clear evidence that patients with anorexia nervosa show heightened punishment sensitivity. Furthermore, it was found that patients with anorexia nervosa lack the attentional engagement bias to food that seems to be involved in healthy eating behavior. The relevance of this finding should be further examined since a change in this bias was not crucial for patients' initial improvement in eating disorder symptoms and BMI.