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RESEARCH ARTICLE

Sensitivity for Cues Predicting Reward and Punishment in Young Women with Eating Disorders

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Abstract

Increasing evidence shows that sensitivity to reward (SR) and punishment (SP) may be involved in eating disorders (EDs). Most studies used self-reported positive/negative effect in rewarding/punishing situations, whereas the implied proneness to detect signals of reward/punishment is largely ignored. This pilot study used a spatial orientation task to examine transdiagnostic and interdiagnostic differences in SR/SP. Participants (14–29 years) were patients with anorexia nervosa of restricting type (AN-R, n = 20), binge/purge ED group [AN of binge/purge type and bulimia nervosa (n = 16)] and non-symptomatic individuals (n = 23). Results revealed stronger difficulties to redirect attention away from signals of rewards in AN-R compared with binge/purge EDs, and binge/purge EDs showed stronger difficulties to direct attention away from signals of punishment compared with AN-R. Findings demonstrate interdiagnostic differences and show that the spatial orientation task is sensitive for individual differences in SP/SR within the context of EDs, thereby sustaining its usefulness as behavioural measure of reinforcement sensitivity.

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Keywords

anorexia nervosa; bulimia nervosa; spatial orientation task; reward and punishment sensitivity

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Introduction

There is accumulating evidence indicating that temperament might be involved in the development and course of eating disorders (EDs) (Atiye, Miettunen, & Raevuori-Helkamaa, 2015; Cassin & Von Ranson, 2005; Harrison, O'Brien, Lopez, & Treasure, 2010). More specifically, individual differences in temperament traits, which determine the tendencies to engage in approach or avoidance behaviour as well as affective reactivity to experiences, can determine vulnerabilities for the development of EDs (Atiye *et al*., 2015; Cassin & Von Ranson, 2005; Harrison *et al*., 2010). However, there are some important unresolved issues and inconsistent findings concerning the specific role of different temperament traits. These may, at least partly, be due to differences between the samples that were studied and to the fact that often self-report measures of temperament traits were used, which may not always tap the core temperamental characteristics.

The multi-causal model with interacting biological, cultural, personality and family factors is generally accepted and figures as the most important etiological model in the ED domain (e.g. Jansen, 2001). Most temperament research focused on anorexia nervosa (AN) and bulimia nervosa (BN) (e.g. Harrison *et al*., 2010). According to Fairburn, Cooper, and Shafran (2003), these disorders share a core symptom of over-evaluation of the self in terms of eating, shape and weight and their control. This transdiagnostic cognitive disturbance is associated with restrictive eating and underweight in the case of AN of the restrictive type (AN-R), with restrictive eating combined with binge/purge behaviour and underweight in the case of AN of the binge/purge type (AN-B/P) and with binge/purge behaviour, sometimes combined with periods of restriction and mostly a normal weight in the case of BN (American Psychiatric Association, 2013; Fairburn *et al*., 2003).

There is increasing evidence that there may be both differences and similarities in the aetiology of these EDs, also in terms of temperamental traits (Hilbert *et al*., 2014). Two prominent traits that have often been linked to EDs are sensitivity to reward (SR) and sensitivity to punishment (SP) (e.g. Harrison *et al*., 2010). These traits are defined as the proneness to detect signals of reward/punishment in the environment and to experience positive/negative effect in rewarding/punishing situations, respectively (Davis & Fox, 2008). SR and SP stem from the reinforcement sensitivity theory (Gray, 1970, 1982, 1987; Gray & McNaughton, 2000), positing that there are three biological systems lying at the basis of human motivational behaviour and emotion. These are the behavioural activation system, activated by signals of reward and leading to approach behaviour; the behavioural inhibition system, activated by goal conflict and leading to inhibition; and the fight flight freeze system, activated by signals of punishment and leading to avoidant or defensive behaviour (Gray, 1970, 1982, 1987; Gray & McNaughton, 2000). The trait SR is determined by the sensitivity of the behavioural activation system, whereas SP is determined by the sensitivity of the behavioural inhibition system and the fight flight freeze system (Gray, 1970, 1982, 1987; Gray & McNaughton, 2000; Harrison *et al*., 2010; Matton, Goossens, Vervaet, & Braet, 2015a).

Because SP is associated with inhibition and avoidant behaviour as well as with negative affectivity, it has been argued that heightened SP would be characteristic for all ED subtypes. In line with this, empirical research using self-report questionnaires indeed showed that heightened SP is a transdiagnostic feature of EDs (Harrison *et al*., 2010; Matton, Goossens, Vervaet, & Braet, 2015b). In contrast, because high SR is thought to be associated with impulsive approach behaviour and with a higher sensitivity to the rewarding effects of food, it has been argued that SR would be heightened in BN, but lowered in AN-R (Harrison *et al*., 2010; Matton *et al*., 2015a). However, the empirical evidence for the hypothesised role of SR in the various EDs is mixed (Harrison *et al*., 2010). Some studies did indeed find that patients with AN-R scored lower on SR compared with patients with BN (e.g. Harrison *et al*., 2010), yet other studies reported heightened levels of SR in AN-R (e.g. Glashouwer, Bloot, Veenstra, Franken, & De Jong, 2014). Many studies did not discriminate between AN-R and AN-B/P (Harrison *et al*., 2010; Jappe *et al*., 2011), those who did examine both ED types separately reported higher levels of SR in AN-B/P compared with healthy controls (Glashouwer *et al*., 2014) or suggested that the level of SR in AN-B/P was situated in between the level of SR in AN-R and BN (Matton *et al*., 2015a).

Most of these results are based on adult samples or on a mixture of adolescents and young adults (Glashouwer *et al*., 2014; Harrison *et al*., 2010; Jappe *et al*., 2011; Matton *et al*., 2015a). In a non-clinical sample of adolescent girls specifically (mean age 14.13 years), Walther and Hilbert (2016) found high SR, instead of high SP, to be positively associated with restrained eating. In an even younger cohort with participants aged 6 to 13 years, a positive association between SR and overeating was found (Van den Berg *et al*., 2011). Matton, Goossens, Braet, and Vervaet (2013) found in a sample of adolescents aged 14 to 19 years that especially high SP was associated with restrained eating, while especially high SR was associated with external eating. Together, these questionnaire studies among non-clinical adolescent samples provide some additional evidence for the potential role of (subjective) SR and SP in EDs, but similar to the studies in adults, there were various inconsistencies in the findings.

Regarding these inconsistencies, it is important to note that the definition of SR and SP posits that these traits influence both the proneness to detect cues predicting reward/punishment as well as the intensity of the positive/negative effect that is elicited by reward/punishment respectively (Davis & Fox, 2008). While self-reports might be suited to measure this latter component, it seems rather difficult to measure the first component by means of self-reports. One possible answer to this problem is to use performance-based measures.

In the domain of reward-related decision making, several performance-based measures have been used in previous research, such as delay discounting tasks and gambling tasks. By and large these studies showed that adult patients with an ED tend to score poor on reward-related decision making, regardless of the specific ED type (Wu *et al*., 2016). In addition, the meta-analysis of Wu *et al*. (2016) indicated that this pattern was restricted to non-food-related rewards and much weaker in adolescents than in adult samples (Wu *et al*., 2016). Although these findings point to the potential relevance of using behavioural measures of reward-related decision making within the context of EDs, the tasks that were used in these studies provide no straightforward indices of individuals' proneness to detect cues predicting reward or punishment.

Therefore, the current pilot study used a reaction time task that was specifically designed to examine the sensitivity for cues predicting non-food-related reward/punishment. Because measuring this sensitivity could be well captured by using a measurement of attentional bias (prioritising reward/punishment related information), a spatial orientation task (SOT) was used, which was originally developed by Derryberry and Reed (1994). Conceptually, similar research in the context of substance use and addiction has already shown that the SOT can be successfully employed as an index of attentional bias for cues predicting reward/punishment (Colder & O'Connor, 2002; van Hemel-Ruiter, de Jong, Oldehinkel, & Ostafin, 2013; van Hemel-Ruiter, de Jong, Ostafin, & Oldehinkel, 2015). The SOT has two interesting components, which are closely related. First, the SOT allows to differentiate between differences in both attentional engagement (i.e. facilitated attention towards a cue) and attentional disengagement (i.e. difficulty to disengage from a cue) (Posner, Inhoff, Friedrich, & Cohen, 1987; van Hemel-Ruiter *et al*., 2013). This provides the opportunity to examine whether enhanced sensitivity for cues predicting reward/punishment is expressed as an enhanced engagement or as a difficulty to disengage from these signals (or both). Taking both components of attentional bias in consideration might be important based on findings within the context of substance use and anxiety disorders showing that attentional engagement towards and difficulties with attentional disengagement from reward-related cues may independently contribute to the development of problematic behaviour, such as substance misuse (Koster, Crombez, Verschuere, & De Houwer, 2004; van Hemel-Ruiter *et al*., 2013). This might be the case in EDs as well. It has been previously found that patients with a restrictive ED showed attentional avoidance of high-fat food-related cues, but did not show facilitated disengagement from these cues (Veenstra & de Jong, 2012). Although these findings were limited to patients with AN-R and to food-related cues, they imply that the processes of attentional engagement *versus* attentional disengagement may play differential roles in EDs as well. Second, the SOT can discriminate between more automatic attentional biases and attentional processes that are more subject to voluntary control by manipulating the delay between cues and targets (i.e. 250 ms delay *versus* 500 ms delay) (van Hemel-Ruiter *et al*., 2013). This allows examining whether EDs or specific ED subtypes are associated particularly with automatic processes (short trials), with voluntary processes (long trials), or with both, and thus whether or not the level of 'automatic' SR and SP is similar to the level of 'voluntary' SR and SP.

Although there have been numerous studies on attention deployment with regard to food cues in ED samples (e.g. Werthmann, Jansen, & Roefs, 2015) as well as with non-food cues who were also rewarding (e.g. Simon *et al.*, 2015), to the best of our knowledge, the current study is the first to specifically operationalise SR and SP with the use of the SOT as a behavioural measurement in a sample of patients with an ED. As such, the major aim of the current pilot study was to examine transdiagnostic and interdiagnostic differences in attentional biases towards signals of reward/punishment in patients with AN-R, with a binge/purge ED, being AN-B/P and BN, and a non-ED control group. It was not chosen to create a general AN group including both AN-R and AN-B/P patients because this could bias the results because differences in the level of SR are expected between purely restrictive *versus* binge/purge EDs (Matton, *et al.*, 2015a; Schag, Schonleber, Teufel, Zipfel, & Giel, 2013). The diagnoses AN-B/P and BN were however merged in one category (binge/purge ED), because both ED subtypes are characterised by binge/purge behaviour and are thought to be more similar to each other in terms of temperament compared with patients with AN-R (Claes, Robinson, Muehlenkamp, Vandereycken, & Bijttebier, 2010). It was anticipated that attentional bias towards signals of reward would be heightened in patients with a binge/purge ED and lowered in patients with AN-R. In addition, it was anticipated that attentional bias towards punishment would be generally heigthened in patients with an ED compared with the non-symptomatic control group (Harrison *et al.*, 2010; Matton *et al.*, 2015a). Because little research has been conducted in this area before, no *a priori* predictions were made about the possible direction of differences between engagement and disengagement trials nor between short delay *versus* long delay trials. However, based on the findings of Veenstra and de Jong (2012), it was assumed that interdiagnostic differences would be more pronounced on engagement trials compared with disengagement trials.

It was chosen to focus on adolescents and young adults (14–29 years), as it has been found that the prevalence and incidence of EDs is highest in this age group (Hoek & van Hoeken, 2003). Because previous research also showed that SR might be temporarily enhanced in adolescents (Galvan, 2013), and studies on reward-related decision making suggest differences in reward processing between adolescents and adults with an ED (Wu *et al.*, 2016), the association between age and the outcomes on the SOT were taken into account as well.

Materials and methods

Participants and procedure.

A clinical sample of 36 female inpatients diagnosed with AN-R (n = 20), AN-B/P (n = 7) or BN (n = 9) was recruited *via* a centre for EDs at a university hospital. Since data collection started in the beginning of 2013, the diagnoses were based on a structured interviewing method using DSM-IV-TR criteria (American Psychiatric Association, 2000) and were assigned by trained psychiatrists and psychologists. The age of the participants varied between 14 and 29 years (M = 18.78, SD = 4.05), and the average self-reported duration of the ED varied between 1 and 14 years (M = 3.21; SD = 3.73). The body mass index (BMI) of participants with AN-R or AN-B/P varied between 12.93 and 17.50 (M = 15.05, SD = 1.38). In participants with BN, the BMI varied between 17.54 and 21.57 (M = 19.72, SD = 1.17). A more detailed description of the psychometric characteristics for each diagnostic subgroup can be found in Table 1. The SOT was completed by the participants in a separate room at the hospital during a therapy-free moment and in the presence of a researcher. Informed consent was obtained from the participants as well as from their parents in the case of underaged participants. The participants were informed that their participation was voluntary and that they were free to quit the study at any time. They were also assured that their participation in the study was independent from their treatment at the ED centre.

A non-eating disordered control sample consisting of 23 female participants was recruited *via* secondary schools and among university students. Participants were excluded from the control sample if they had an average score of four points or more on one or more of the subscales of the Child Eating Disorder Examination Questionnaire (ChEDE-Q; Bryant-Waugh, Cooper, Taylor, & Lask, 1996; Decaluwé & Braet, 1999 adapted from Fairburn & Beglin, 1994). Participants with a BMI of 17.5 or less or with a BMI of more than 25 were excluded as well to rule out the

Table 1 Sample table for describing participants and significant group differences (univariate regression analyses and chi-square test)

	Participants					
	AN-R	AN-B/P	BN	HC	Total	$F/^2$
Gender						
Female	N = 20	N = 7	N = 9	N = 23	N = 59	
Age (years)						
Mean	17	22	20	17	18	$F = 4.14$**
Range	14–27	17–29	16–24	14–28	14–29	
Body mass index						
Mean	14.89	15.49	19.79	20.94	18.10	
Range	12.93–17.50	13.79–17.10	17.54–21.57	18.29–24.46	12.93–24.46	$F = 65.68$***
Mean illness duration (years)						
Mean	2.6	6	2.5			
Range	1–13	1–14	1–5.5			
Mean treatment duration (months)						$F = 9.48$***
Mean	3.9	10.2	13.7			
Range	1–12	1–18	1–30			
Educational level						
ASO	12	2	0	9	23	$F = 6.43$**
BSO	0	0	1	0	1	
TSO	4	0	2	2	8	
Higher education	2	1	4	12	19	
Working	2	4	3	0	9	$^2 = 34.24$***

*$p < .05$,
**$p < .01$,
***$p < .001$.

possible association between underweight or overweight and SR and SP (Davis & Fox, 2008). These criteria resulted in the exclusion of nine participants of the original 32 participants, leading to the final sample of 23 participants. The age of the participants varied between 14 and 28 years (M = 17.43; SD = 2.71). The mean age in the control sample was similar to the mean age in the clinical sample ($t(58) = -1.37$, $p > .05$). The BMI of the participants in the control sample varied between 18.29 and 24.46 (M = 20.94; SD = 1.83). Again, a more detailed description of the psychometric characteristics of this control group can be found in Table 1. Of the total sample, 11 participants were recruited *via* secondary schools by psychology students. The remaining 12 participants were university students who received credits for participating in the study. All participants of the control sample completed the SOT in a separate room at the university in the presence of a researcher. Informed consent was obtained from the participants as well as from their parents in the case of underage participants. The participants were informed that their participation was voluntary and that they were free to leave the study at any time. After the completion of the computer task, the participants were asked to complete the ChEDE-Q, and they were weighed and measured by the researcher. The study procedure was approved by the ethics committees of both the participating university hospital and the university.

Spatial orientation task

General task outline

The SOT (Derryberry & Reed, 1994, 2002) was developed to measure the level of attentional engagement towards and the difficulty to disengage attention from places where reward or punishment is expected (i.e. attentional bias towards signals of reward or punishment). In this task, participants are asked to respond as quickly as possible to a neutral target that is preceded by a cue in order to gain points or to avoid losing points. Participants have to respond on the target by pressing the 'b' key of the computer, and their score is presented in the middle of the screen. There are two types of games: in positive games, the participants win 10 points if they respond sufficiently fast, and their score remains unchanged if they respond too slowly, whereas in negative games, the participants lose 10 points if they respond too slowly, and their score remains unchanged if they respond sufficiently fast. When participants respond before the target has appeared, or respond when no target appears at all (catch trials), they lose 10 points regardless of the game type. The complete task consists of eight games, four positive and four negative, which are alternated every two games. Each game consists of 32 cued, 16 uncued and 8 catch trials that are presented in random order. The eight games are preceded by four training games (two positive and two negative).

In the present study, the task was performed on a Dell Inspiron 6000 using E-prime software version 2.2 with the participants 50 cm removed from the screen. Before the beginning of the task, participants were verbally encouraged to try to win as much points as possible in positive games and to try to lose as few points as possible in negative games.

Previous research has shown that the SOT is a valid task for assessing attentional bias towards signals of punishment and reward (Colder & O'Connor, 2002; Derryberry & Reed, 2002; van Hemel-Ruiter *et al.*, 2013; van Hemel-Ruiter *et al.*, 2015). Supporting the validity of the SOT as a measure of individual differences, earlier research in the context of substance abuse showed that the strength of participants' attentional engagement towards signals of reward was positively associated with alcohol use in undergraduates (Colder & O'Connor, 2002) as well as adolescents (van Hemel-Ruiter *et al.*, 2013) and showed predictive validity for the increase in using illicit drugs from baseline to three years follow up (van Hemel-Ruiter *et al.*, 2015).

Components of the SOT task

Cued versus uncued trials. Each trial within each game begins with the appearance of two vertical black bars on a white background at the possible cue and target locations (i.e. left and right of the participant's score in the middle of the screen). The participants are asked to focus on their score, which is also presented in black on the white background. The score is turned off for 200 ms and then returns for 250 ms, after which the cue appears at the location of one of the two vertical bars (Figures 1 and 2). After 250 ms (i.e. short delay condition) or 500 ms (i.e. long delay condition), the target (i.e. small grey rectangle) is displayed in the middle of the cue (i.e. cued trial) or in the middle of the vertical bar on the opposite side of the cue (i.e. uncued trial) (Figures 1 and 2). This cue acts as a signal of reward or punishment by predicting the chances that the participant will win or lose points.

Hard versus easy trials. Participants are told that a blue arrow pointing upward (Figure 1) predicts that, when the target appears in that location (i.e. cued trial), the participant will be likely to respond in time (i.e. easy trial), whereas if the target appears in the opposite location (i.e. uncued trial) the participant will be unlikely to respond in time (i.e. hard trial). Similarly, participants

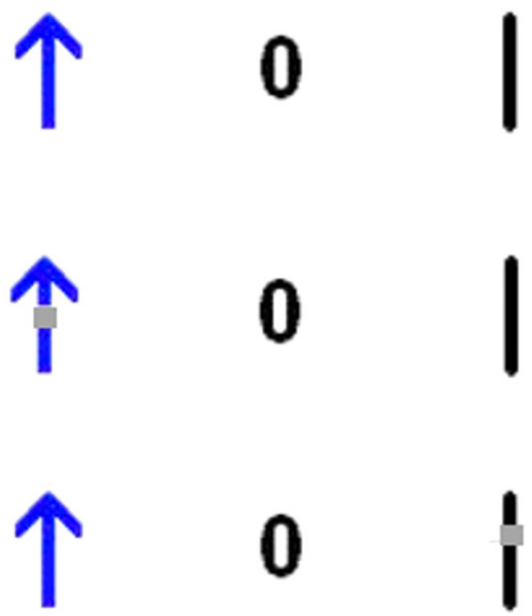

Figure 1. Catch trial (without target), cued easy trial and uncued hard trial [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 2. Catch trial (without target), uncued easy trial and cued hard trial [Colour figure can be viewed at wileyonlinelibrary.com]

are informed that a red arrow pointing downward (Figure 2) predicts that, when the target appears in that location (i.e. cued trial), the participant will be unlikely to respond in time (i.e. hard trial), whereas if the target appears in the opposite location (i.e. uncued trial), the participant will be likely to respond in time (i.e. easy trial). The participants are also told that the cues indicate not only the chances of responding in time but also the probable location of the target. More specifically, during the task, two-thirds of the targets appear in the cued location, and occasionally no target appears (e.g. catch trials) although participants are not informed about these exact numbers. Taken together, this means that blue arrows predict reward (in positive games) or nonpunishment (in negative games), whereas the red arrows predict nonreward (in positive games) or punishment (in negative games). In order to create the hard and easy trials, the time to respond on a cued blue target is equal to the own mean RT + 0.55SD, resulting in a sufficiently fast response in 75% of the time (i.e. easy trial), whereas the time to respond on an uncued blue target is equal to the own mean RT – 0.55SD, resulting in a too slow response in 75% of the time (i.e. hard trial). Analogously to the blue arrow cues, red arrow cued trials result in too slow responses in 75% of the time (i.e. hard trials), whereas red arrow uncued trials result in sufficiently fast responses in 75% of the time (i.e. easy trials). These personal cut-off scores for fast and slow responses are calculated at the end of each game. However, because RTs tend to be 25 ms slower after short delays between the cue and the target, 12 ms were added to the cut-off for trials with a short delay (e.g. 250 ms) and were subtracted from the cut-off for trials with a long delay (e.g. 500 ms) (van Hemel-Ruiter *et al*., 2013).

Engagement versus disengagement. The attentional bias for cues predicting reward or punishment is then inferred from (i) the participant's difference score based on the reaction time (RT) in cued red *versus* cued blue trials in positive and negative games respectively (i.e. the engagement effect) and from (ii) the participant's difference score based on the RT in uncued red *versus* uncued blue trials (i.e. the disengagement effect) in positive and negative games, respectively (Table 2).

Automatic versus voluntary processes. Summarily, this task allows to measure attentional bias towards both cues predicting reward and cues predicting punishment by including both positive and negative games, in which the emphasis is on reward *versus* punishment, respectively. Moreover, both attentional engagement and difficulty with attentional disengagement are measured by including both cued and uncued trials. The different delays between the cue and the target further allow to discriminate between automatic attentional biases (short delay of 250 ms) and attentional biases that are subject to more voluntary control (long delay of 500 ms).

Feedback

After 500 ms in each response (or 1 s in the case of a catch trial), the cue and target are removed, and the two black bars reappear. A feedback signal is presented below the score. This signal takes the same form as the cues and is thus a blue arrow pointing upward or a red arrow pointing downward (Figure 3). The blue arrow pointing upward implicates that a fast response was given (or no response in the case of catch trials), whereas the red arrow pointing downward implicates that a too slow response was given (or that the participant pressed the 'b' key in a catch trial or that the participant pressed before the target appeared). After 250 ms the score is updated if necessary. Next, a randomly selected delay of 500 ms or 1 s is introduced, after which the next trial begins by removing the feedback arrow as well as the score for 200 ms. The score remains visible during the complete game, after which it is reset to zero at the start of a new game.

Table 2 Calculation of the SOT variables

	Positive games	Negative games
Short delay (250 ms)	reward engagement = RT cued red trials – RT cued blue trials	punishment engagement = RT cued blue trials – RT cued red trials
	reward disengagement = RT uncued blue trials – RT uncued red trials	punishment disengagement = RT uncued red trials – RT uncued blue trials
Long delay (500 ms)	reward engagement = RT cued red trials – RT cued blue trials	punishment engagement = RT cued blue trials – RT cued red trials
	reward disengagement = RT uncued blue trials – RT uncued red trials	punishment disengagement = RT uncued red trials – RT uncued blue trials

RT, reaction time; cued red trials indicate hard trials; cued blue trials indicate easy trials; uncued blue trials indicate hard trials; uncued red trials indicate easy trials.

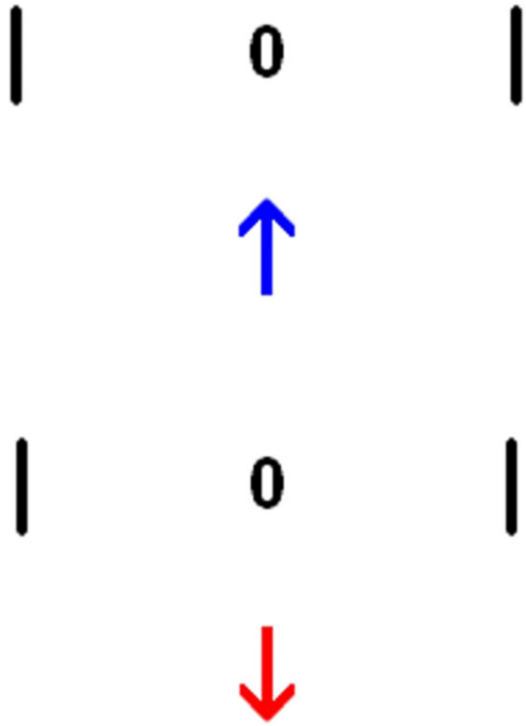

Figure 3. Positive feedback and negative feedback [Colour figure can be viewed at wileyonlinelibrary.com]

Child Eating Disorder Examination Questionnaire

The Child Eating Disorder Examination Questionnaire (ChEDE-Q; Bryant-Waugh *et al*., 1996; Decaluwé & Braet, 1999 adapted from Fairburn & Beglin, 1994) is based on the transdiagnostic model of EDs (Fairburn *et al*., 2003) and was developed to measure pathologic eating behaviour in children and adolescents. This version of the questionnaire was used, because participants were included from the age of 14 years and because there are no substantive differences between the items of the ChEDE-Q and the items of the version developed for adults (EDE-Q; Fairburn & Beglin, 1994). The ChEDE-Q contains 23 items divided into four subscales, namely, restraint (five items), concerns about eating (five items), concerns about body shape (eight items) and concerns about weight (five items). All items consider the last 4 weeks and are to be answered on a seven point scale. The higher the score on the scale, the greater the severity or presence of any given feature. The validity of ChEDE-Q in Dutch adolescents has been shown repeatedly (e.g. Decaluwé & Braet, 2004; Goossens & Braet, 2010). Cronbach's alphas for the ChEDE-Q in the current study were .77 for restraint, .64 for concerns about eating, .94 for concerns about body shape and .90 for concerns about weight. This questionnaire was solely used to exclude participants with heightened ED symptoms that may reflect an ED, from the control group. Therefore, a mean score of four points or more on one or more of the subscales was used as a cut-off, based on the guidelines of previous studies in young adolescent girls (Carter, Stewart, & Fairburn, 2001) and young adult women (Mond, Hay, Rodgers, & Owen, 2006).

Data analytic plan

First, it was tested whether the general response pattern of the participants was in line with the expectations based on the task design. This was performed by conducting paired samples *t*-tests to compare the mean RTs in cued blue (easy) *versus* cued red (hard) trials as well as in uncued blue (hard) *versus* uncued red (easy) trials. A general engagement effect (faster responses in cued blue (easy) trials compared with cued red (hard) trials) was expected, as well as a general disengagement effect (faster responses in uncued red (easy) trials compared with uncued blue (hard) trials). This was performed for both positive and negative games and for short and long delays between the cue and the target.

Next, eight SOT indices were calculated based on the RTs in different trial types. In positive games, attentional engagement towards expected reward as well as difficulty of attentional disengagement from expected reward were measured for short and long delays, resulting in four indices. Higher scores on these variables indicate a larger attentional bias towards cues predicting reward. Similarly, negative games resulted in four indices indicating the level of attentional engagement towards expected punishment and difficulty to disengage attention from expected punishment both for trials with short and long delays. Again, higher scores indicate a larger attentional bias towards cues predicting punishment.

In Table 2, the specific calculation of the eight SOT variables is explained. First, the Reward Engagement scores are calculated for both short and long delays. Because participants generally respond faster to a target that appears in an area that they are attending to than to a target that appears in an area on which they are not focused yet (Posner *et al*., 1987), the difference in RT between easy cued trials (blue) and hard cued trials (red) gives an indication of the level of attentional bias towards cues predicting reward (in positive games). Next, the reward disengagement scores are calculated for both short and long delays. Here, the difference in RT in trials with uncued targets that are preceded by a blue arrow (hard cue) and trials with uncued targets that are preceded by a red arrow (easy cue) gives an indication of the difficulty to disengage attention from locations of expected reward and as such gives a second indication of the level of attentional bias towards cues predicting reward (in positive games). Attentional bias towards punishment is analogously inferred from negative games leading to four new SOT variables: short/long delay punishment engagement and short/long delay punishment disengagement.

Because both the age of the participants and the chronicity of an ED could potentially affect the results, the correlations between age, self-reported illness duration and the SOT outcomes were calculated in order to determine the necessity to include these variables as covariates in the following analyses.

Next, differences on the eight SOT variables between AN-R, binge/purge ED and controls were examined first *via* multivariate analysis of variance (MANOVA) and contrast calculations testing the significance of linear and quadratic effects. In addition, separate one-way analyses of variance were conducted to compare the means on the SOT outcomes between specific subgroups. In the first contrast, controls were compared with the total clinical sample in order to examine the hypothesis that patients with an ED have a larger bias towards punishment compared with controls, regardless of the specific ED diagnosis. In the second contrast, patients with AN-R and patients with a binge/purge ED were compared with each other to examine the hypothesis that patients with AN-R are less sensitive for cues predicting reward compared with patients with a binge/purge ED, while no difference in attentional bias towards punishment was expected between patients with AN-R and patients with a binge/purge ED. The method of contrast calculations leads to optimal power, which is especially relevant given the small sample sizes of the clinical groups.

Results

Descriptive statistics

An independent samples *t*-test revealed that there was no significant difference in reaction times between AN-B/P and BN ($t(15) = -.462$, $p = .651$), which is an additional ground to merge these two diagnostic groups in further analyses. Attesting to the validity of the task, participants generally showed enhanced engagement to cues predicting reward (positive games) or nonpunishment (negative games) compared with cues predicting frustrative nonreward (positive games) or punishment (negative games). The pattern of disengagement did not systematically vary as a function of the different trial types. Only one significant disengagement effect was found (Table 3). Age and self-reported illness duration were not associated with attentional bias to reward or punishment in the SOT (Table 4). The mean scores on each SOT variable for controls, patients with AN-R and patients with a binge/purge ED can be found in Table 5.

Attentional bias regarding signals predicting reward

Only for the long delay disengagement index, the MANOVA showed a significant main effect of group (Table 6). This effect seems mainly carried by the relatively high scores of the AN-R group as was supported by the finding that the quadratic but not the linear contrast was significant (see also Table 5). Accordingly, analyses of the *a priori* contrasts indicated that patients with AN-R scored significantly higher than patients with a binge/purge ED (Table 7). This indicates that patients with AN-R showed a stronger difficulty to disengage their attention from places of expected reward (stronger SR) than patients with a binge/purge ED.

Table 3 Results of the paired samples *t*-tests

		M (SD)	t (df)
Short delay	Reward engagement	23.21 (34.23)	5.25 (59)***
	Reward disengagement	−10.25 (55.24)	−1.44 (59)
Long delay	Reward engagement	18.82 (42.27)	3.45 (59)**
	Reward disengagement	−15.28 (57.19)	−2.07 (59)*
Short delay	Punishment engagement	−17.03 (29.83)	−4.42 (59)***
	Punishment disengagement	3.99 (53.01)	.58 (58)
Long delay	Punishment engagement	−14.61 (35.78)	−3.16 (59)**
	Punishment disengagement	−2.68 (56.67)	−.37 (59)

M, mean; SD, standard deviation.
Engagement refers to comparisons between cued blue *versus* cued red trials, while disengagement refers to comparisons between uncued blue *versus* uncued red trials.
*$p < .05$,
**$p < .01$,
***$p < .001$.

Attentional bias regarding signals predicting punishment

Only for the long delay disengagement index there was a significant main effect of group (Table 6). This effect was mainly carried by the relatively high scores of the binge/purge ED group, which was supported by the finding that only the linear contrast was significant (see also Table 5). Accordingly, analyses of between group contrasts indicated that patients with binge/purge ED showed significantly higher disengagement scores than patients with AN-R (Table 7). Thus, patients with binge/purge ED showed a stronger difficulty to disengage their attention from places of expected punishment (higher SP) than patients with AN-R.

For the short delay engagement trials, there was a non-significant trend of group ($p < .07$). The groups did tend to show differential attentional engagement on the short delay trials, suggesting that patients with an ED tend to show higher engagement scores than the control group.

Discussion

The present pilot study sought to investigate temperamental differences in SR and SP between non-symptomatic controls, patients with AN-R and patients with a binge/purge ED *via* a performance-based measure. This enabled us to measure the sensitivity for cues predicting reward or punishment rather than measuring the intensity of the effect that is experienced in rewarding or punishing situations, which was the main focus of previous research. To the best of our knowledge, the task used here to operationalise SR and SP has not been used before in patients with an ED. As such, an important goal was to evaluate the relevance and potential of this task for future research regarding SR and SP in EDs. The major findings can be summarised as follows: (i) patients with AN-R showed a relatively strong difficulty to redirect their attention away from signals of rewards compared with patients with a binge/purge ED and (ii) specifically patients with a binge/purge ED showed a stronger difficulty to direct their attention away from places of expected punishment compared with patients with AN-R.

The results show that the SOT is sensitive to differences between groups and may provide relevant complementary information regarding individuals' sensitivity to signals of punishment or reward. The pattern of findings in terms of differential SR and SP as a function of ED seems slightly different from the results based on self-report questionnaires (e.g. Harrison *et al.*, 2010). This could be both related to potentially different roles for attention allocation towards signals predicting reward/punishment *versus* affective responses to actual reward/punishment as well as to difficulties with assessing SR and SP on a self-report basis.

The results also show that there may be differences in attentional bias towards cues predicting reward and punishment between the different ED categories. First, regarding SR, a significant difference was found in the long delay reward disengagement trials, indicating that patients with AN-R tended to show a stronger difficulty to disengage from cues predicting

Table 4 Pearson correlations between age, self-reported illness duration and the SOT variables

	Short delay reward engagement	Short delay reward disengagement	Long delay reward engagement	Long delay reward disengagement	Short delay punishment engagement	Short delay punishment disengagement	Long delay punishment engagement	Long delay punishment disengagement
Age	−.18	.12	−.04	−.02	−.05	−.08	.08	.05
Self-reported illness duration	−.14	.11	−.24	−.01	−.27	−.04	−.14	.02

*$p < .05$,
**$p < .01$,
***$p < .001$.

Table 5 Mean scores on the SOT variables for the control group, patients with AN-R and patients with a binge/purge ED

		Control sample (n = 23) M(SD)	AN-R (n = 20) M(SD)	Binge/purge ED (n = 16) M(SD)
Short delay	Reward engagement	32.09 (49.45)	16.41 (14.18)	22.34 (19.72)
	Reward disengagement	−24.26 (70.73)	3.46 (43.39)	−10.45 (39.39)
Long delay	Reward engagement	29.12 (43.96)	9.14 (38.12)	19.83 (42.77)
	Reward disengagement	−20.43 (41.13)	9.81 (41.55)	−21.14 (41.06)
Short delay	Punishment engagement	−26.18 (33.19)	−6.95 (19.88)	−18.23 (32.61)
	Punishment disengagement	2.06 (66.41)	.28 (34.30)	11.42 (53.16)
Long delay	Punishment engagement	−26.80 (45.30)	−5.63 (25.78)	−10.01 (27.85)
	Punishment disengagement	−12.83 (67.41)	−13.34 (48.77)	27.84 (39.18)

AN-R, anorexia nervosa—restrictive type; ED, eating disorder; M, mean; SD, standard deviation.
Binge/purge ED comprises patients with anorexia nervosa—binge/purge type and bulimia nervosa.

Table 6 Results of the MANOVA testing the association between diagnosis and SOT outcomes and the linear and quadratic contrast effects

		Diagnosis					
		F(2)	η^2	Linear contrast estimate	95% coincidence interval	Quadratic contrast estimate	95% coincidence interval
Short delay	Reward engagement	1.19	.04	−6.89	−22.41; 8.63	8.82	−6.41; 24.05
	Reward disengagement	1.36	.05	9.77	−15.58; 35.11	−17.00	−41.86; 7.86
Long delay	Reward engagement	1.23	.04	−6.57	−25.81; 12.68	12.52	−6.37; 31.40
	Reward disengagement	3.62*	.12	−.50	−19.53; 18.52	−24.98*	−43.64; −6.32
Short delay	Punishment engagement	2.33+	.08	5.62	−7.83; 19.08	−12.46+	−25.66; .75
	Punishment disengagement	.22	.01	6.62	−18.17; 31.40	5.28	−19.04; 29.59
Long delay	Punishment engagement	2.16	.07	11.88	−4.36; 28.11	−10.43	−26.36; 5.49
	Punishment disengagement	3.25*	.10	28.76*	3.49; 54.03	17.02	−7.77; 41.81

*$p < .05$,
**$p < .01$,
***$p < .001$,
+$p = .06$.

reward than patients with a binge/purge ED. This suggests, opposite to the expectations, that patients with a restrictive ED are more sensitive to cues predicting reward than patients with a binge/purge ED. However, this tendency in patients with AN-R of showing a greater difficulty to redirect their attention away from signals of reward, compared with patients with a binge/purge ED, was not paralleled with an enhanced initial orientation towards these cues nor with an increased score on short delay reward disengagement trials. Thus, different from earlier findings in the context of substance use (e.g. van Hemel-Ruiter *et al.*, 2013), in which it was found that substance use was related to attentional bias for appetitive cues, only weak evidence was found regarding decreased/enhanced sensitivity for cues signalling potential reward in specific diagnostic ED categories. The absence of evidence for increased SR in patients with a binge/purge ED and decreased SR in patients with AN-R is contrary to

Table 7 Results of the one-way ANOVA contrast tests

		Contrast value (SE)	t (df)
Short delay reward engagement	Control *vs*. ED	−28.56 (21.60)	−1.32 (26.27)
	AN-R *vs*. binge/purge ED	2.79 (6.43)	.44 (25.70)
Short delay reward disengagement	Control *vs*. ED	44.57 (29.18)	1.53 (57)
	AN-R *vs*. binge/purge ED	−10.89 (18.10)	−.60 (57)
Long delay reward engagement	Control *vs*. ED	−32.82 (22.38)	−1.47 (57)
	AN-R *vs*. binge/purge ED	7.13 (13.89)	.51 (57)
Long delay reward disengagement	Control *vs*. ED	12.83 (29.14)	.44 (57)
	AN-R *vs*. binge/purge ED	−47.65 (18.08)	−2.64 (57)*
Short delay punishment engagement	Control *vs*. ED	28.92 (15.51)	1.86 (57)+
	AN-R *vs*. binge/purge ED	−9.55 (9.62)	−.99 (57)
Short delay punishment disengagement	Control *vs*. ED	7.58 (28.76)	.26 (56)
	AN-R *vs*. binge/purge ED	11.14 (18.03)	.62 (56)
Long delay punishment engagement	Control *vs*. ED	39.28 (18.62)	2.1 (57)*
	AN-R *vs*. binge/purge ED	−3.07 (11.55)	−.27 (57)
Long delay punishment disengagement	Control *vs*. ED	35.91 (29.30)	1.23 (57)
	AN-R *vs*. binge/purge ED	−36.94 (18.18)	−2.03 (57)*

SE, standard error; ED, eating disorder; AN-R, anorexia nervosa—restrictive type; binge/purge ED, patients with a diagnosis of anorexia nervosa—binge/purge type or bulimia nervosa.
*$p < .05$,
**$p < .01$,
***$p < .001$,
+$p < .07$.

expectations based on studies with self-report measures (Glashouwer *et al*., 2014; Harrison *et al*., 2010; Jappe *et al*., 2011; Matton *et al*., 2015a). Some of these studies did indeed find that patients with AN-R scored lower on SR compared with patients with BN (Harrison *et al*., 2010; Matton *et al*., 2015a), yet other studies reported heightened levels of SR in AN-R (Glashouwer *et al*., 2014; Harrison *et al*., 2010; Jappe *et al*., 2011). Together, the available evidence seems to converge to the conclusion that there is no straightforward relationship between SR and EDs. A partial explanation might be that the SOT uses a form of reward that is not ED specific: the cues, the target and the reward have no meaningful association with EDs. It is possible that the results would be different when stimuli would be used that are relevant in the context of an ED, for example, cues predicting reward in the domain of food and weight or cues predicting social reward (Cardi, Di Matteo, Corfield, & Treasure, 2013). This is also in line with a more recent perspective in the field of reinforcement sensitivity and EDs, suggesting that patients with an ED are not more or less sensitive for reward *per se* but that there is a change in the nature of the stimuli that are experienced as rewarding (Keating, Tilbrook, Rossell, Eticott, & Fitzgerald, 2012). This means that examining attentional bias for cues predicting different types of reward might be an important goal in future research to test whether different results are obtained depending on the nature of the reward.

Secondly, regarding SP, it was found that patients with a binge/purge ED showed more difficulty to redirect their attention away from cues predicting punishment than patients with AN-R. This interdiagnostic difference was only evident for the long delay trials and thus seems to imply some top-down voluntary control. This may be due to a more general difference in effortful control between restrictive and binge/purge EDs. More specifically, patients with a restrictive ED without binge/purge episodes have been found to show higher levels of effortful control than patients with a binge/purge ED (Claes, Mitchell, & Vandereycken, 2012). For the short delay trials, especially the reactive traits of SR and SP might determine individuals' pattern of responding, while for long delay trials, the level of effortful control might play an additional role. This might explain why specifically for long delay trials patients with AN-R experienced less difficulty to disengage their attention from places of expected punishment than patients with a binge/purge ED.

In the short delay engagement trials, patients with an ED showed a non-significant tendency towards an enhanced sensitivity for cues predicting punishment compared with non-symptomatic controls. However, because this tendency did not reach the preset level of statistical significance, it requires replication and further exploration to determine if it is really consistent with previous results showing heightened SP in patients with an ED based on self-report instruments (Harrison *et al*., 2010; Matton *et al*., 2015a).

Taken together, the present findings are inconclusive and require further research with regard to the hypothesis that heightened SP is involved in EDs. Moreover, the results cast further doubts on the role of SR within the context of EDs. Although the SOT has been used in the domain of substance abuse before (van Hemel-Ruiter *et al*., 2013) and parallels have often been drawn between EDs and substance abuse (Loxton & Dawe, 2007; Hodgins, von Ranson, & Montpetit, 2015), the present findings suggest that there are also important differences between addiction and EDs with regard to the attentional processes involved. While attentional bias towards signals predicting reward has been found to be positively associated with substance abuse (van Hemel-Ruiter *et al.*, 2013), it seems that both attentional bias towards signals predicting punishment and reward might be positively associated with disordered eating, depending on which specific ED is considered (AN-R in which attentional disengagement towards signals predicting reward seems to play an important role or B/P in which attentional disengagement towards signals predicting punishment seems to be a key factor). This is in line with previous results indicating that different motives are involved in alcohol use compared with motives underlying disordered eating (Hodgins *et al.*, 2015).

This study has several strengths. By using the SOT as a measure of individuals' sensitivity for cues predicting reward/punishment, the current study was able to provide important information about mechanisms of information processing in patients with an ED. This complements previous studies that focused on experienced affect in response to actual reward/punishment. In addition, because SR is assumed to be involved in binge eating (Schag *et al.*, 2013), differences between AN-R and AN-B/P patients regarding SR may be masked when including both ED types into one category. Therefore, in the present study, patients with a purely restrictive ED were compared with patients with a binge/purge ED.

However, it is also important to note several limitations of the present study and the related suggestions for future research. First, the current work represents the first study using the SOT in a clinical sample of patients with EDs. Several concerns regarding the task design warrant further research on the usability of the SOT in EDs. Some important issues here that require further exploration are, for example, the lack of a general disengagement effect and possible age effects. First, the general pattern of heightened engagement towards cues predicting reward (or nonpunishment) was not completely paralleled by a heightened difficulty to disengage from cues predicting reward (or nonpunishment). This means that the results on the disengagement trials should be interpreted with caution because it is not clear whether the task performed as expected in these trials. Previous research also failed to confirm this disengagement effect in short delay trials, but did find this effect in the long delay trials (van Hemel-Ruiter *et al.*, 2013), which is similar to the present results. Further research exploring possible methodological issues explaining this lack of a disengagement effect seems necessary. Regarding the effect of age, it might be necessary to compare the performance on the SOT between adolescents and adults. Although the present results revealed no correlation between the participants' age and the SOT outcomes, it should be kept in mind that SR has been shown to be increased during adolescence (Galvan, 2013), which could have influenced the results on the SOT. In addition, the sample sizes were small and as such, it seems useful to assess the SOT in larger samples, to test the hypotheses with more statistical power. In the current study, the small size may have obscured some effects, such as the age effect. Future research on this task might also want to test the correlations of the SOT with self-report measures of SR and SP and with other performance-based measures, such as the card-sorting task previously used by Loxton and Dawe (2007). Finally, it should also be kept in mind that the reward and punishment used in the SOT was artificial in the sense that only points were added or subtracted. How this might influence the results might be an important research topic as well, for example, by comparing these results with the results when using more concrete forms of reward or punishment, such as real gadgets that can be won or lost.

On top of these concerns regarding the SOT, some additional limitations should be noted. First, no patients with Binge Eating Disorder (BED) were recruited for the study. It will be important to include this diagnostic category in future research to obtain a more comprehensive understanding of the way SR and SP are involved in EDs. A second limitation concerns the fact that participants within the control sample were only assessed for the current presence of an ED and not for a lifetime diagnosis of an ED. It might be important for future research to take this into account. Finally, the inclusion of both adolescents and young adults can be considered both a strength and a limitation, because more research in adolescents seems necessary given the incidence and prevalence rates for EDs in this age group (Hoek & van Hoeken, 2003), but at the same time age might have had an effect on concentration and on SR (Galvan, 2013), thereby influencing the results. As previously mentioned, this hypothesis was not supported by the correlational analyses, but warrants further research given the small sample sizes in the present study.

It should also be acknowledged that the cross-sectional design of the present study does not allow any firm conclusions regarding the direction of the relationship between attentional bias and disordered eating. Therefore, it is important for future research to test the proposed relationship in a longitudinal design. Regarding the inconclusive role of SP, this would give the opportunity to test whether attentional bias for cues signalling punishment has predictive value for future ED problems (e.g. Glashouwer *et al.*, 2016). To more directly examine the alleged causal role of attentional bias for punishment in the persistence of symptoms, it would be critical to bring attentional bias under experimental control. Previous research in the context of eating behaviour has shown that domain-specific attentional biases can be successfully reduced following an attentional bias modification procedure and can result in meaningful reduction of ED symptoms (Kemps, Tiggemann, Orr, & Grear, 2014; Smith & Rieger, 2009). It would be interesting to see whether a similar attention bias modification procedure applied to attentional bias for cues predicting punishment would similarly result in a reduction of ED symptoms. This would not only be relevant to test the role of attentional bias for cues predicting punishment in the persistence of ED symptoms but may also provide theory derived starting points for new clinical interventions.

To conclude, the present findings did not provide consistent evidence to indicate that patients with ED generally show a heightened attentional bias for signals of punishment. However, patients with AN-R showed a stronger difficulty to redirect their attention away from signals of reward, whereas patients with a binge/purge ED have more problems with directing their attention away from signals of punishment. Together, the findings not only demonstrate interdiagnostic differences but also show that the SOT is sensitive for individual differences in SP/SR within the context of EDs, thereby sustaining its usefulness as a behavioural measure of reinforcement sensitivity.

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