

# Cognitive deficits in obese persons with and without binge eating disorder. Investigation using a mental flexibility task<sup>☆</sup>

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## ABSTRACT

**Objective:** Studies suggest that cognitive deficits and attentional biases play a role in the development and maintenance of obesity and eating disorders. In this study, we simultaneously examine attentional biases, as well as inhibitory control and mental flexibility, which are keys to controlling unwanted behaviors and thoughts in obese patients with and without binge eating disorder. **Methods:** 16 obese patients with binge eating disorder and 16 patients without binge eating disorder were compared with 16 normal-weight controls on a "food/body-mental flexibility task", which allows the investigation of inhibitory control, mental flexibility and attention for stimuli related to the body and food. **Results:** All obese patients made significantly more errors (i.e., pressing a key when a distracter displayed) and more omissions (i.e., not pressing a key when a target displayed) than controls in both food and body sections of the task. Obese participants with binge eating disorder made significantly more errors and omissions than those without binge eating disorder. No difference between groups was found concerning mental flexibility and cognitive biases for food- and body-related targets. **Discussion:** These results suggest that obese patients have a general inhibition problem and difficulty focusing attention, which do not depend on the types of stimuli processed. The results also suggest that these cognitive deficits are more severe in obese patients with binge eating disorder, which indicates that there is a continuum of increasing inhibition and cognitive problems with increasingly disordered eating. These cognitive deficits may contribute to problematic eating behaviors.

## Keywords:

Mental flexibility; Inhibition; Cognitive deficits; Cognitive biases; Obesity; Binge eating disorder; Food/body-mental flexibility task

## Introduction

Studies suggest that attentional/executive deficits and biases play an important role in the development and maintenance of obesity and eating disorders (e.g., Lena, Fiocco, & Leyenaar, 2004). Attentional/executive deficits refer to dysfunctions affecting basic control processes such as inhibition, shifting and selective attention; these dysfunctions are unaffected by the content of the processed information. Attentional biases can be inferred when individuals process certain stimuli differently than others, in this case, stimuli related to food and body shape. Attentional biases can be evidenced when people detect food- and body-shape-related stimuli faster (speeded detection), focus their attention longer on these stimuli (slower disengagement), or avoid them.

Studies conducted on cognitive deficits indicate that individuals with bulimia have deficits affecting response inhibition, mental flexibility and attention/vigilance (for a review, see Dobson & Dozois, 2004; Lena et al., 2004; Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007). Inhibition deficits may contribute to the loss of control over eating and the consumption of an excessive amount of food, as well as the self-induced vomiting that can follow overeating for weight control. Likewise, as proposed by Roberts et al. (2007), poor mental flexibility may account for rigidity or perseverance in the pursuit of weight loss, which is a highly invested goal in bulimia and a key factor in the development and maintenance of problematic eating behaviors. Problems with mental flexibility may also reduce the bulimic patients' ability to engage in adaptive problem solving: indeed, binge eating is used to cope with a variety of situations, in which more adaptive solutions should be used.

Studies conducted on attentional biases in bulimia reveal that bulimic participants have attentional biases for food and body shape (for a meta-analysis, see Dobson & Dozois, 2004). Smeets, Roefs, van Furth, and Jansen (2008) showed automatic biases

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(speeded detection) for body-related information and more controlled and later attentional biases (increased distraction) for food-related information in bulimia and anorexia patients. Attentional biases for food and body shape may contribute to excessive preoccupation with food and to body dissatisfaction, a core symptom of bulimia (Engel et al., 2006).

Some studies have explored cognitive functions in obese persons. Existing studies suggest that obese adults and children have various deficits affecting executive control, including poor inhibition (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006) poor mental flexibility (Boeka & Lokken, 2008; Cserje' si, Luminet, Poncelet, & L' ena' rd, 2009; Cserje' si, Molnar, Luminet, & L' ena' rd, 2007; Gunstad et al., 2007), poor planning and problem-solving capacities (Boeka & Lokken, 2008), as well as selective and sustained attention deficits (Cournot et al., 2006; Cserje' si et al., 2009, 2007). As such, they resemble bulimic patients. Inhibition deficits may underlie obese persons' overeating and their difficulty controlling their thoughts of food. Poor mental flexibility may account for their perseverance in the use of ineffective strategies to control their weight (e.g., dieting and skipping meals). Some of these results are based on studies that used *multidetermined* tasks to assess executive control, which limits the detection of subtle differences in obese patients. For example, the Trail Making Test and the Wisconsin Card Sorting Test, which were used by Gunstad et al. (2007), Boeka and Lokken (2008) and Cserje' si et al. (2007), call on different cognitive functions such as mental flexibility, selective attention, inhibition and working memory; therefore, patients may be impaired on these tasks for a variety of different reasons (Van der Linden et al., 2000). Using multidetermined tasks does not allow one to identify the specific processes that might affect obese patients or to refine the assessment of their cognitive deficits in order to better understand the psychological processes related to their condition.

To this end, it is also important to investigate cognitive biases in obese patients. However, to the best of our knowledge, this aspect has been explored in only a limited number of studies (Braet & Crombez, 2003; Castellanos et al., 2009; Nijs, Muris, Euser, & Franken, 2010). More specifically, obese people have been reported to automatically direct their visual attention to the sight of foods more than non-obese people in a visual probe task (Nijs et al., 2010). Similarly, Braet and Crombez (2003) found a cognitive bias for food-related information in a Stroop task with obese children, evidenced by a slowing when they named the color of food-related words. Exploration of this aspect of cognitive functioning in obese persons is crucial because, as has been shown in bulimic patients, attentional biases for food and body shape may contribute to excessive preoccupation with food and to body dissatisfaction. These biases, together with lower mental flexibility and poor response inhibition, might be responsible for obese persons' overeating and weight gain (Nijs et al., 2010).

Considering that obesity and eating disorders occur on a continuum of increasingly disordered eating (see, e.g., Neumark-Sztainer, 2003), the cognitive deficits and attentional biases may be more marked in some obese persons. Indeed, it has been found that 25–50% of obese individuals present binge eating disorder (BED) (Spitzer et al., 1992). BED refers to frequent episodes of binge eating characterized by loss of control over eating and consumption of a large amount of food, accompanied by marked distress. However, until now, only a few studies of the cognitive functions of obese adults and children have compared the cognitive functioning of obese persons without eating disorders with that of obese persons with eating disorders (e.g., Nasser, Gluck, & Geliebter, 2004; Nederkoorn, Braet, et al., 2006).

In this context, the goal of the present study is threefold. The first goal is to re-examine cognitive deficits in obese persons using

a task which allows to separate between general deficits and cognitive biases for food and body. More specifically, we examined mental flexibility (shifting) and inhibition. Inhibitory control is a key to controlling unwanted behaviors and thoughts; mental flexibility is a key mechanism for disengaging from excessive preoccupations with food and weight. The second goal of the study is to explore cognitive biases. The third is to compare the cognitive functioning of obese persons without binge eating disorder with that of obese persons with binge eating disorder. For this purpose, we used an adaptation of the go/no-go affective mental flexibility task (Murphy et al., 1999). Murphy et al. (1999) successfully used this task to characterize deficits and biases in depression and mania. Recently, we adapted and used this task for bulimia (Mobbs, Van der Linden, d'Acremont, and Perroud (2008)). In this go/no-go task, words denoting "forbidden" foods, "negative" body shapes or neutral objects are presented one by one in the center of a computer screen. Half of the words are targets and half are distracters. Participants must respond to targets by pressing the space bar as quickly as possible but must withhold responses to distracters. The aim was to test obese persons' ability to discriminate between food/body-related and neutral words. Sometimes, the food/body-related words were the targets for the "go" response, with the neutral words as distracters, and sometimes the reverse was true. Several shifts in target type occurred during the task. Due to its structure (see "Methods" section for more details), the affective shifting task allows one to examine different levels of inhibitory control: (1) general ability to inhibit behavioral responses and focus attention; (2) ability to inhibit and reverse stimulus-reward associations; and (3) ability to inhibit eating-disorder-congruent cognitive biases (Murphy et al., 1999).

## Methods

### Participants

The study was carried out with obese patients attending the outpatient unit of the Service of Therapeutic Patient Education for Chronic Diseases, who conformed to the following inclusion criteria: (1) Body Mass Index (BMI:  $\text{weight/height}^2$  [ $\text{kg/m}^2$ ]) in the obese range ( $\text{BMI} \geq 30$ ) and (2) no history of neurological or other severe medical illnesses, alcoholism, or drug abuse/dependence. On the basis of a clinical interview using the DSM-IV diagnosis for binge eating disorder (American Psychiatric Association, 1994), obese persons were classified as obese with binge eating disorder if they reported the criteria for binge eating disorder in the last 6 months or as obese without binge eating disorder if they reported no binge eating behavior in the last 6 months. Forty-eight participants were recruited: 16 obese participants without binge eating disorder, 16 obese participants with binge eating disorder and 16 normal-weight controls. There were 12 women and 4 men in the obese without eating disorders group, 11 women and 5 men in the obese with eating disorders group, and 11 women and 5 men in the control group.

The controls were recruited among university students and volunteers. They had no history of eating disorders and were not being treated with medication that might potentially influence cognition (e.g., benzodiazepines and antidopaminergics).

ANOVAs revealed no significant differences between patients and controls in terms of age or years of education and socioeconomic status<sup>1</sup> but significant differences in terms of BMI (Table 1). The controls' mean BMI was in the normal range. The

<sup>1</sup> Socioeconomic status was derived from the patient's current occupation and was classified as recommended by the French national statistic institute ("Institut National Français de la Statistique et des Études Économiques"; INSEE).

**Table 1**

Physical and psychological characteristics of obese patients with and without binge eating disorder and controls. Means (SDs; score ranges) on questionnaires for obese patients and controls with ANOVA comparisons and post hoc tests.

	Obese patients with binge eating disorder (n = 16)	Obese patients without binge eating disorder (n = 16)	Controls (n = 16)	F(2, 45)
Age	45.1 (12.1)	39.3 (12.2)	40.2 (11.3)	1.08
Education Level of Socio-economic st.	14.0 (4.2)	14.1 (2.6)	15.8 (1.5)	1.78
BMI	4.25 (0.86)	4.77 (1.83)	4.25 (1.98)	0.66
DT EDI-2	34.6 (3.5) <sup>c</sup>	33.6 (6.4) <sup>d</sup>	21.3 (1.8) <sup>cd</sup>	46.86 <sup>***</sup>
BN EDI-2	10.4 (6.2; 2–23) <sup>e</sup>	6.4 (4.9; 0–13) <sup>f</sup>	1.0 (1.3; 0–3) <sup>ef</sup>	16.70 <sup>***</sup>
BD EDI-2	2.9 (4.5; 0–10) <sup>gh</sup>	0.3 (0.6; 0–2) <sup>g</sup>	0.2 (0.8; 0–3) <sup>h</sup>	8.82 <sup>**</sup>
MAC-24	18.4 (7.7; 3–27) <sup>ij</sup>	12.5 (7.7; 0–28) <sup>i</sup>	4.9 (6.8; 0–22) <sup>ij</sup>	15.85 <sup>**</sup>
BDI	71.3 (15.1; 52–96) <sup>k</sup>	66.4 (13.6; 45–89)	53.9 (13.2; 32–82) <sup>k</sup>	6.41 <sup>**</sup>
STAI Y-A	20.6 (16.1; 3–58) <sup>mn</sup>	10.9 (8.6; 2–32) <sup>m</sup>	4.0 (4.4; 0–14) <sup>n</sup>	9.34 <sup>***</sup>
STAI Y-B	41.9 (11.5; 28–58) <sup>o</sup>	33.4 (14.2; 20–72)	31.4 (8.8; 20–44) <sup>o</sup>	3.64 <sup>*</sup>
	47.3 (14.1; 28–71) <sup>p</sup>	38.4 (12.5; 23–66)	34.1 (7.3; 23–47) <sup>p</sup>	5.25 <sup>**</sup>

Note: education, number of years; BMI, Body Mass Index; DT, Drive for Thinness subscale of the Eating Disorder Inventory-2 score (EDI-2); BN, Bulimia subscale of the EDI-2; BD, Body Dissatisfaction subscale of the EDI-2; MAC-24, Mizes Anorectic Cognition Questionnaire; BDI, Beck Depression Inventory; STAI Y-A/B, State and Trait Anxiety questionnaires, respectively.

Means with the same superscript are significantly different from each other.

\*  $p < .05$ .

\*\*  $p < .01$ .

\*\*\*  $p < .001$ .

two obese groups' mean BMI was in the obese range. The BMI of obese participants with binge eating disorder did not differ from the BMI of obese participants without binge eating disorder. All participants were native speakers of French and had normal or corrected vision (criteria for inclusion).

#### Procedure

Participants were naive to the study hypotheses, and their participation was voluntary. They were asked to complete the shifting/mental flexibility task on an Armada 1500c Compaq laptop with a 12-in. screen running E-Prime presentation software (Psychology Software Tools, Inc.). Each participant was recorded individually. General task instructions were given orally first, then participants were given more detailed instructions on screen. They were not informed explicitly that the instructions would change. It was mentioned that a tone would sound for each error. The same examiner administered the shifting task first and then the self-rating scales. The scales were introduced in random order, except for the STAI, which was completed immediately after the individuals had finished the shifting task.

#### Measures

##### Questionnaires

Patients' psychopathological state was evaluated with the following instruments: (1) the Drive for Thinness, Bulimia and Body Dissatisfaction subscales of the Eating Disorder Inventory-2 (EDI-2; Garner, 1991; French version by Archinard, Rouget, Painot, & Liengme, 2000) and the Mizes Anorectic Cognition Questionnaire (MAC-24; Mizes & Klesges, 1989; French version by Volery, Carrard, Rouget, Archinard, & Golay, 2006) to assess eating disorders; (2) the Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996; French version by Editions du Centre de Psychologie Appliquée, 1998) to investigate depression; and (3) the State and Trait Anxiety tests (respectively, STAI Y-A and STAI Y-B; Spielberger, Gorsuch, & Lushene, 1983; French version by Spielberger, 1993) to evaluate concomitant anxiety symptoms. Comorbidity with anxiety and depression has been reported in obesity (Garipey, Nitka, & Schmitz, 2010; de Wit et al., 2010) and may have influenced performance on the mental flexibility task. ANOVAs revealed significant differences between obese patients with binge eating disorder and controls on all self-rating scales

(Table 1). Moreover, the obese groups differed significantly from one another on eating pathology and depressive symptoms, with obese patients with binge eating disorder having more bulimic symptoms, more body dissatisfaction and more depressive symptoms than obese patients without binge eating disorder. Obese participants without binge eating disorder differed significantly from the controls on measures of body dissatisfaction and drive for thinness. The alpha reliabilities in the present sample were as follows: DT EDI-2, 0.70; BN EDI-2, 0.67; BD EDI-2, 0.86; MAC-24; 0.81; BDI, 0.87; STAI Y-A, 0.76; STAI Y-B, 0.80.

##### Mental flexibility task

To measure shifting and inhibition, participants completed the modified affective shifting task, which was developed by Murphy et al. (1999), modeled on the "set-shifting" paradigm of Dias, Robbins, and Roberts (1996). In this go/no-go task, words are rapidly presented one by one in the center of a 12-in. computer screen; words are shown in 8-mm black letters. Participants must respond to targets by pressing the space bar with their dominant hand as quickly as possible but must withhold responses to distracters. Words are presented for 300 ms, with an interstimulus interval of 900 ms. This presentation time involves controlled processing of the stimuli (Mialet, 1999). A 500-ms, 450-Hz tone sounds for each error, but not for omissions. Errors constitute responses to distracter stimuli while omissions are failures to respond to target stimuli.

The task comprises two sections: one that investigates attention and executive functions in connection with food-related information and one that investigates attention and executive functions in connection with body-related information. Each section consists of 8 test blocks of 16 stimuli each: eight food words (for the food section) and eight object words. In each test block, either food (F) or object words (O) are specified as targets, with targets for the 8 blocks presented in the following order: FFOOFFFOOFFFOO. Because of this arrangement, eight test blocks are "shift" blocks, where participants must begin responding to stimuli that were distracters and cease responding to stimuli that were targets in the previous block (FFOOFFFOOFFFOO), and eight test blocks are "non-shift" blocks, where participants must continue responding to stimuli that were targets and withholding responses to stimuli that were distracters in the previous block (FFOOFFFOOFFFOO). In "Methods" section, food words are replaced by body-related words. This task requires participants to

shift their attention from one word category to the other. Half of the participants started with “Introduction” section, followed by “Methods” section, and half started with “Methods” section, followed by “Introduction” section.

The words are presented in a fixed-randomized format with the constraint that no three words from the same category appear consecutively. Each word appears twice, once each in the shift and non-shift conditions, yielding 128 trials per section. Prior to the experimental trials, participants were given two practice blocks with words unrelated to the experimental word categories (flower and furniture words).

The test blocks for the food section comprise 128 stimuli of two types: 32 food words (which appear twice) and 32 object words (which appear twice), which are used as controls. The test blocks for the body section comprise 128 stimuli of two types: 32 body words (which appear twice) and 32 object words (which appear twice), which are used as controls. The words used were selected from an original list of 300 food, object and body words because they were consistently rated on a 9-point Likert scale, by 20 unrestrained eaters (tested with the Restraint Scale; Polivy, Herman, & Warsh, 1978; French version by Lluch, 1995) who were blind to the purpose of the study, as being neutral (control words), forbidden (food words) or negative (shape words connoting a large physique or emotionally charged body parts; Jansen, Nederkoorn, & Mulken, 2005). They also rated the words in terms of imageability. Research emphasizes that the foods that trigger binges are those which the patients view as prohibited (Rodin, Mancuso, Granger, & Nelbach, 1991). The food, body, and object words do not differ in terms of word length (number of characters per word) ( $F(2, 125) = 1.10, p = .34$ ); frequency ( $F(2, 125) = 1.16, p = .32$ ), as determined using the Lexique database (New, Pallier, Ferrand, & Matos, 2001) or imageability ( $F(2, 125) = 2.13, p = .12$ ). The words presented to participants were French words. Examples of the three word categories are given in the appendix with their English translations.

### Statistical analyses

Measures of interest were response times (RTs) to targets, number of errors (responses to distracter stimuli) and number of omissions (failure to respond to target stimuli). Only RTs on correct responses were retained. RTs of less than 100 ms, reflecting anticipation, were excluded from our analyses. These measures allow for the examination of different levels of inhibitory control: (1) by examining overall performance irrespective of target valence and shift condition, general ability to inhibit behavioral responses and focus attention can be assessed; (2) by comparing overall performance on shift relative to non-shift blocks, individuals' ability to inhibit and reverse stimulus-reward associations can be determined; and (3) by contrasting performance measures for food/body-related targets, the presence of eating-disorder-congruent cognitive biases can be evaluated (Murphy et al., 1999).

<sup>2</sup> The 128 measures of response time for each participant were analyzed with a mixed effects model (MEM) with crossed random effects (subjects and words). This method has the advantage of including both word and subject information in a single statistical model. The model first allows one to handle missing data correctly, whereas ANOVAs are biased by incomplete data. Usually we treat missing response times as if they were missing completely at random. If the responses are not missing at random, the statistical inference is erroneous. If a response is missing because some words in some conditions are harder to answer, responses will not be missing completely at random. Taking the full structure of design of the study into account and using MEM has been proven to correctly handle this type of missingness. Second, the main goal of testing procedures is to generalize the findings to other possible subjects (i.e., to the population of subjects) and at the same time to other possible words (i.e., to the population of words). Not generalizing across both subjects and items at the same time will have consequences for the statistical inferences, increasing type I errors.

Statistical analyses compared obese groups and controls on four types of score, namely reaction times, number of errors, number of omissions, and cognitive biases. Comparisons between all obese participants and controls and between obese participants with and without binge eating disorder were done using predefined contrasts.

The statistical design is a repeated measures ANOVA with group as between-subject factor (control versus obese participants without binge eating disorder and obese participants with binge eating disorder), target type (interest versus neutral) and shift condition (shift versus non-shift) as repeated-measures factors. We analyzed response times with a linear mixed model (a mixed effects model [MEM]) with crossed random effects that allows one to handle missing data, which is not possible with traditional ANOVAs.<sup>2</sup> A regular ANOVA with repeated measures could not be used to analyze the number of omissions and errors due to the nature of the distribution of these variables: these scores constituted a sum of success/failure (between 0 and 16) that followed a binomial distribution. For this reason, numbers of errors and omissions were analyzed with a generalized linear mixed model (GLMM, McCulloch & Searle, 2001). Moreover, we investigated whether any learning effect on the 128 measures took place within both sections of task using MEM with cross random effects on response times and GLMM with cross random effects for omissions and errors. We also tested for order effects.

Finally, cognitive bias scores were calculated for each participant by subtracting the predicted RTs for stimuli of interest (including the subject effect, obtained with the MEM due to the missing pattern in the food section or in the body section) from the predicted RTs for neutral stimuli. This allowed us to investigate cognitive biases independently of baseline response time. Pearson's product moment correlation coefficients were then employed to test the relationship between the cognitive bias scores and the questionnaire measures in the three groups.

Note that the residuals for our data were normally and identically distributed. Statistical analyses were performed using R (R Development Core Team, 2006) and Statistica.

## Results

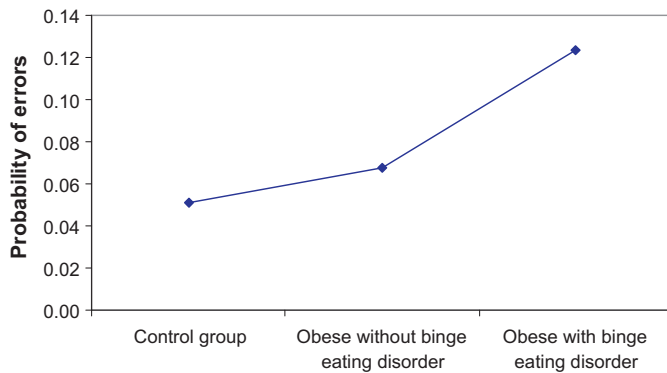
### Mental flexibility task

Because body information and food information represent different aspects of eating psychopathology, statistical analyses were done on the two sections of the task separately.<sup>3</sup> We first report the results concerning the comparisons between all obese participants and controls, and then the results of the comparisons between obese patients with binge eating disorder and obese patients without binge eating disorder.

### Comparisons between all obese patients and controls

**Response time, food section.** The MEM done on the food section revealed a significant main effect of target type, with all participants being quicker to detect food-related targets than

<sup>3</sup> However, before doing the separate analyses, we ran two analyses on the whole task to determine whether there were differences between the two sections of the task. Actually, the MEM done on RTs for the whole task (food and body sections) revealed a significant main effect of section of task, with all participants reacting faster in the section of the task related to food than in the section related to the body ( $\beta = -7.95, \chi^2(1) = 6.58, p < .05$ ). Moreover, the GLMM done on errors for the whole task revealed a significant main effect of section of task on errors, indicating that the probability of making errors was higher in the section of the task related to the body than in the section related to food ( $\beta = -0.34, z = -7.27, p < .001$ ). The GLMM for omissions also revealed a significant main effect of section of task, indicating that the probability of making omissions was higher in the section of the task related to the body than in the section related to food ( $\beta = -0.37, z = -5.03, p < .001$ ).



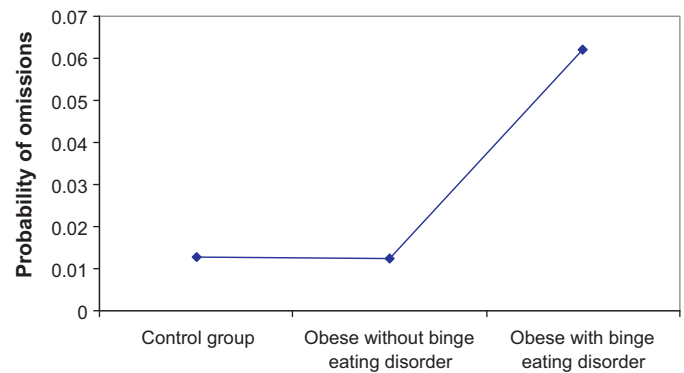
**Fig. 1.** Group effect for the number of errors in the food section of the mental flexibility task. In these graphs of the logit transformation, the y axis refers to the probability of making errors. When dealing with the logit form, the graph could be misleading, because the interaction can only be seen in the linear part, but in our case, because of the very small probability, this graph and the one showing only the linear part are very close. Therefore, and for reasons of space, we only present the logit transformation.

neutral targets ( $\beta = -30.66$ ,  $\chi^2(1) = 45.51$ ,  $p < .001$ ). In addition, the analysis revealed a significant main effect of shift condition, with all participants being quicker in the shift condition than in the non-shift condition ( $\beta = -4.44$ ,  $\chi^2(1) = 5.17$ ,  $p < .05$ ). A significant interaction between shift condition, target type and group ( $\beta = 4.74$ ,  $\chi^2(1) = 4.75$ ,  $p < .05$ ) was observed, indicating that obese participants with binge eating disorder were slower than obese participants without binge eating disorder when they had to detect neutral targets in the shift condition; however, all obese participants (with and without binge eating disorder) had the same reaction time in the non-shift condition. No other effects were significant. The model with all the variables explained 7.63% of the variance of response time in the food section.

*Response time, body section.* The MEM done on the body section revealed also a significant main effect of target type, with all participants being quicker to detect body-related targets than neutral targets ( $\beta = -18.86$ ,  $\chi^2(1) = 13.62$ ,  $p < .001$ ). No other effects were significant. The model with all the variables explained 1.92% of the variance of response time in the body section.

*Errors, food section.* The GLMM on errors in the food section revealed a significant main effect of group ( $\beta = -0.21$ ,  $z = -2.41$ ,  $p < .05$ ). This effect indicated that all obese participants (with and without binge eating disorder) had a higher probability of making errors<sup>4</sup> than control participants (see Fig. 1). Moreover, the statistical analysis revealed a significant main effect of shift condition, indicating that all participants made more errors in the shift condition than in the non-shift condition ( $\beta = 0.22$ ,  $z = 3.24$ ,  $p < .01$ ). There was also a significant effect of type of target, with all participants making fewer errors for neutral targets than for food-related words ( $\beta = -0.20$ ,  $z = -2.85$ ,  $p < .01$ ). No other effects were significant. The model with all the variables explained 28.13% of the variance of errors in the food section.

*Errors, body section.* The GLMM on errors in the body section revealed a significant main effect of group ( $\beta = -0.21$ ,  $z = -2.66$ ,  $p < .01$ ), indicating that all obese participants made more errors than control participants. The statistical analysis also showed a significant main effect of target type, with all participants making fewer errors for neutral targets than for body-related words ( $\beta = -0.48$ ,  $z = -7.59$ ,  $p < .001$ ). No other effects were significant.



**Fig. 2.** Group effect for the number of omissions in the food section of the mental flexibility task (see comment in Fig. 1).

The model with all the variables explained 26.87% of the variance of errors in the body section.

*Omissions, food section.* The GLMM on omissions in the food section revealed a near significant main effect of group ( $\beta = -0.27$ ,  $z = -1.74$ ,  $p = .08$ ). This effect indicated that all obese participants tended to make more omissions than controls (see Fig. 2). Moreover, there was a significant main effect of shift condition ( $\beta = 0.51$ ,  $z = 4.09$ ,  $p < .001$ ), indicating that the all participants made more omissions in the shift condition. No other effects were significant. The model with all the variables explained 35.98% of the variance of omissions in the food section.

*Omissions, body section.* The GLMM on omissions in the body section revealed a significant main effect of group ( $\beta = -0.22$ ,  $z = -2.00$ ,  $p < .05$ ), indicating that all obese participants made significantly more omissions than control participants. Moreover, there was a significant main effect of shift condition ( $\beta = 0.39$ ,  $z = 4.89$ ,  $p < .001$ ), with all participants making more omissions in the shift condition. A significant interaction between target type and group ( $\beta = 0.17$ ,  $z = 2.80$ ,  $p < .01$ ) was observed, indicating that all obese participants (with and without binge eating disorder) made more omissions for neutral targets than the control participants. No other effects were significant. The model with all the variables explained 12.79% of the variance of omissions in the body section.

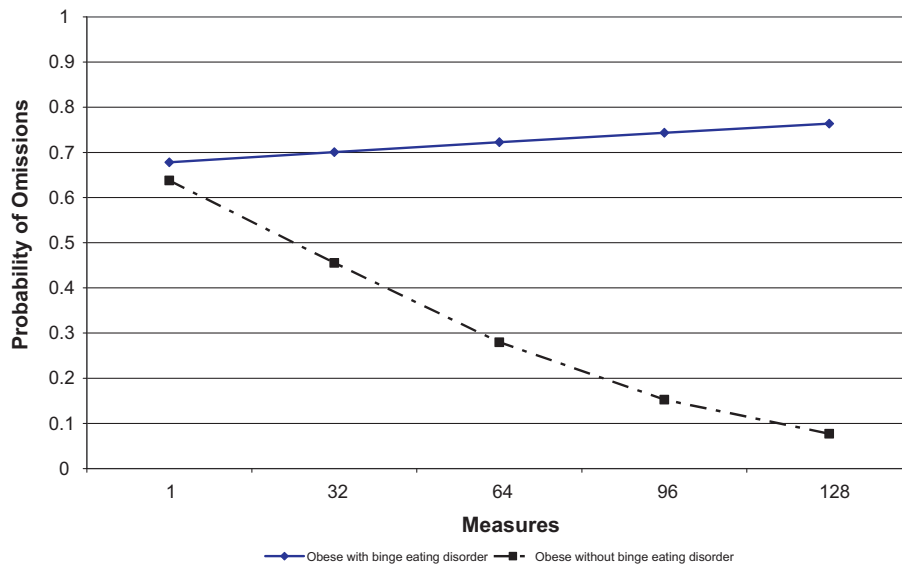
#### *Comparisons between obese patients with and without binge eating disorder*

*Response time, food and body sections.* No difference between obese patients with binge eating disorder and obese patients without binge eating disorder was significant. The model for the food and the body sections with all the variables explained 8.46 and 0.91% of the variance of response time in the food and body section, respectively.

*Errors, food section.* The GLMM on errors in the food section revealed a significant main effect of group ( $\beta = -0.33$ ,  $z = -2.34$ ,  $p < .05$ ), indicating that obese participants with binge eating disorder made more errors than obese participants without binge eating disorder (see Fig. 1). The model with all the variables explained 17.92% of the variance of errors in the food section.

*Errors, body section.* The GLMM on errors in the body section revealed a significant main effect of group ( $\beta = -0.33$ ,  $z = -2.51$ ,  $p < .05$ ), again indicating that obese participants with binge eating disorder made more errors than obese participants without binge

<sup>4</sup> From now on, for the ease of reading, we will omit the term "probability".



**Fig. 3.** Number of omissions by groups within the food section of the mental flexibility task (see comment in Fig. 1).

eating disorder. The model with all the variables explained 14.90% of the variance of errors in the body section.

*Omissions, food section.* The GLMM on omissions in the food section revealed a significant main effect of group ( $\beta = -0.83$ ,  $z = -3.26$ ,  $p < .01$ ). This effect indicated that obese participants with binge eating disorder made more omissions than obese participants without binge eating disorder (see Fig. 2). Moreover, a significant interaction between shift condition and group ( $\beta = 0.34$ ,  $z = 2.40$ ,  $p < .10$ ) was observed, indicating that the difference between the two shift conditions (shift and non-shift) was more pronounced for obese participants without binge eating disorder than for those with binge eating disorder. The model with all the variables explained 23.31% of the variance of omissions in the food section.

*Omissions, body section.* No difference between obese patients with binge eating disorder and obese patients without binge eating disorder was significant. The model with all the variables explained 4.95% of the variance of omissions in the body section.

#### *Investigation of the learning effect*

We investigated whether any learning effect took place within the two sections of the task. Analysis of the food section of the task revealed a significant main effect of time on RT ( $\beta = -0.32$ ,  $\chi^2(1) = 8.30$ ,  $p < .01$ ) and number of errors ( $\beta = -0.011$ ,  $z = -2.99$ ,  $p < .01$ ). An improvement (both RTs and number of errors decreased during the course of the task) by all participants was observed throughout the food section, indicating that a learning process was taking place. Of interest was the presence of a significant interaction between time and group ( $\beta = -0.014$ ,  $z = -1.96$ ,  $p < .05$ ) concerning the number of omissions. Whereas the obese patients with binge eating disorder kept their omission rate constant through the food section of the task, obese patients without binge eating disorder's omission rate decreased during the course of this section (in other words, for obese patients without binge eating disorder, the probability of making omissions decreased as the task progressed) (cf. Fig. 3).

The analysis on the body section of the task also revealed a main effect of time on RT ( $\beta = -0.94$ ,  $\chi^2(1) = 63.8$ ,  $p < .001$ ). No other effects were significant.

When we included the order effect variable in the models, this variable did not reach statistical significance and did not explain

much additional variance. As such, order did not significantly affect our results.

#### *Cognitive biases for food and body*

The groups do not differ significantly in their cognitive biases for food and body, and all persons showed a positive bias for food and body-related words relative to control words; in other words, they favored food and body words over control words.

Supplementary analyses were conducted to investigate whether the cognitive biases differed between groups throughout testing. In order to explore this possibility, we divided the 128 bias measures (calculated with MEM, including missing data) into four separate periods: the response times for items 1–32, 33–64, 65–96, and 97–128. The repeated measure ANOVA with order (items 1–32; 33–64; 65–96; 97–128) as within-subject variable, and group as a between-subject variable revealed no significant interaction between the four measurement periods and the group, indicating that the cognitive biases do not differ between groups throughout testing.

When considering the correlation between eating disorder symptoms, eating-disorder-related cognitions, depression and anxiety scores, and cognitive biases in the modified affective shifting task, we found significant positive correlations between the bias for body-related cues and the Drive for Thinness ( $r = 0.54$ ,  $p = .032$ ) and Bulimia subscales ( $r = 0.51$ ,  $p = .045$ ) of the EDI-2, and a significant negative correlation between the bias for food-related cues and the BDI ( $r = -0.50$ ,  $p = .048$ ) in obese patients with binge eating disorder. Unexpectedly, we found a significant negative correlation between the Body Dissatisfaction subscale of the EDI-2 and the bias for food-related cues ( $r = -0.52$ ,  $p = .037$ ). No other correlations reached significance.

#### **Discussion**

In this study, we simultaneously examined cognitive deficits and biases towards weight/shape- and food-related words in obese patients with and without binge eating disorder by means of a modified affective shifting task. To our knowledge, this is the first study to simultaneously assess cognitive deficits and biases towards weight/shape- and food-related words in obese patients and to compare obese patients with and without binge eating disorder on these variables.

The results indicated that all participants (obese persons with and without binge eating disorder and controls) responded faster in the section of the task related to food than in the section related to the body. In addition, they made more omissions and errors in the section of the task related to the body than in the section related to food. In the food section of the task, all participants made more errors for neutral stimuli than for food-related words. Moreover, all participants made more omissions and errors in the shift condition, showing that a shift effect was induced experimentally. Furthermore, all participants (obese persons with and without binge eating disorder and controls) responded faster to high-calorie food and weight/shape-related stimuli, indicating biases for high-calorie food and negative shape/weight words. The results also indicate significant group differences. A significant difference was observed between all obese persons and controls: all obese patients made more errors and omissions for all types of stimuli in both sections of the task. Unexpectedly, obese participants had no more shifting problems than controls and there were no differences in cognitive biases between normal-weight persons and obese patients. A significant difference was found between obese persons with and without binge eating disorder: obese persons with binge eating disorder made more errors for all types of stimuli in both sections of the task. Moreover, obese persons with binge eating disorder made more omissions than obese persons without binge eating disorder in the food section of the task. Furthermore, it was found that obese patients with binge eating disorder kept their number of omissions constant throughout the food section of the task, unlike obese participants without binge eating disorder, who improved throughout this section of the task. There were no differences in shifting and cognitive biases between obese persons with and without binge eating disorder either.

Concerning our first objective regarding the comparisons between obese patients and normal-weight controls, the pattern of results (increased errors and omissions for obese patients for all types of stimuli) suggests that obese patients have a global impairment affecting inhibition processes (manifested by an increased number of errors on all types of distracter stimuli), as well as a global impairment affecting the ability to focus attention on relevant stimuli (as indicated by an increased number of omissions of all types of target stimuli), which is consistent with earlier research linking obesity to poor cognitive performance on several types of tasks (e.g., Cournot et al., 2006; Cserjé et al., 2009, 2007; Nederkoorn, Braet, et al., 2006; Nederkoorn, Smulders, et al., 2006).

It remains to interpret the nature of these general deficits. If we refer to the existing literature that shows differences in cognitive functioning between obese and non-obese people (e.g., Nasser et al., 2004; Nederkoorn, Braet, et al., 2006), it could be argued that obese persons have a fundamental inhibition problem, corresponding to a high level of impulsivity (Horn, Dolan, Elliott, Deakin, & Woodruff, 2003; Stein, Hollander, DeCaria, & Trugold, 1991; Visser, Das-Smaal, & Kwakman, 1996; White et al., 1994). However, the modified shifting task does not allow one to characterize the precise nature of the inhibition deficit: it may be a deficit affecting prepotent response inhibition and/or a deficit affecting resistance to proactive interference (Friedman & Miyake, 2004). These deficits may contribute differentially to the eating disorder symptomatology. More specifically, a deficit affecting prepotent response inhibition might be related to the occurrence of compulsive eating, while a deficit affecting resistance to proactive interference (or inhibition of irrelevant thoughts) might be related to the occurrence of unwanted food- and weight/shape-related thoughts.

Concerning our second objective, namely to compare obese patients with and without binge eating disorder, the pattern of results (increased errors for all types of stimuli in the whole task,

increased omissions for all types of stimuli in the food section of the task and absence of performance improvement in the food section for obese patients with binge eating disorder) suggests that obese patients with binge eating disorder have a more severe global impairment of inhibition and more difficulty focusing their attention. This result raises the possibility that there is a continuum of increasing inhibition and cognitive problems with increasingly disordered eating among obese patients. If we refer to the interpretations concerning our first objective, the difference between obese persons with binge eating disorder and obese persons without binge eating disorder suggests that the former have a more severe fundamental inhibition problem. The differences in cognitive functioning between obese patients with and without binge eating disorder are consistent with studies reporting more disturbances in eating attitudes (more severe loss of control over eating, more weight fluctuation, and more body dissatisfaction) in obese patients with binge eating disorder. The finding of a more pronounced inhibition problem in obese persons with binge eating disorder is of crucial practical importance. Some authors have shown that impulsivity, which is related to inhibitory difficulties (Horn et al., 2003; Stein et al., 1991; Visser et al., 1996; White et al., 1994), predicts overeating (Guerrieri, Nederkoorn, & Jansen, 2007). This tendency to overeat can, in turn, lead to weight gain and to the development of maladaptive strategies to control weight (e.g., dieting, skipping meals). As such, it may help explain why certain obese individuals develop an eating disorder.

In sum, we found evidence of inhibition deficits and difficulties focusing attention in obese persons, particularly those with binge eating disorder, and general cognitive biases for food and shape/weight (all participants were faster to respond to words referring to high-calorie food and negative shape/weight), which is consistent with some of the earlier literature. Regarding the cognitive biases, cross-cultural studies suggest that fatness is evaluated negatively in both Western and non-Western cultures. Previous work also suggests that weight and shape concerns are very common in societies that place excessive emphasis on thinness (Chen & Jackson, 2005). In these societies, both women and men frequently experience body dissatisfaction. It has also been shown that worrying about one's weight and figure is often associated with dieting, probably to modify the unsatisfactory appearance. In this context, high-calorie food stimuli may be experienced as negative because of this body dissatisfaction and the related fear of gaining weight by eating them. Food information may also capture attention because it has a particular adaptive significance and because it is very familiar (Pothos, Calitri, Tapper, Brunstrom, & Rogers, 2008).

However, contrary to the present study, which showed no difference in cognitive biases between obese persons and controls, some studies have shown differences between obese persons and controls (Nijs et al., 2010), between women with bulimia and controls (e.g., Jansen et al., 2005; Rieger et al., 1998; Shafran, Lee, Cooper, Palmer, & Fairburn, 2007), as well as between non-clinical women with high and low levels of problematic eating (e.g., Johansson, Ghaderi, & Andersson, 2004). Part of this heterogeneity is probably a result of procedural differences between studies that used different tasks, different presentation times and different types of stimuli (high-calorie food versus low-calorie food, stimuli related to thinness versus stimuli related to fatness). Indeed, the mental flexibility task assesses only early engagement-induced biases, given that the stimuli were presented for 300 ms. Shorter (100 ms, as in Nijs et al., 2010) and longer presentation times might have been necessary for group differences in attentional biases to emerge. Smeets et al. (2008) found that a later component in attentional processing accounted for a bias for food in bulimia and anorexia patients, whereas an early component of attentional processing accounted for an attentional bias for body-related

information. The inconsistency may also be due to the fact that obese persons have less severe eating psychopathology (less drive for thinness and less dietary restraint, both of which are known to influence attentional biases) than bulimic patients (Barry, Grilo, & Masheb, 2003; Tapper, Pothos, Fardari, & Ziori, 2008).

Procedural differences between studies that found shifting difficulties in obese or bulimic patients and our own might also explain the failure of the present study to find shifting difficulties. The failure to find shifting differences between normal-weight and obese participants could be explained by the fact that the shifting rule was quite easy in the present task. In more widely used shifting paradigms, such as the Trail Making Task, the shifting rules are more difficult. In addition, some studies that revealed shifting difficulties in obese and bulimic patients used *multidetermined* tasks, which make it difficult to identify the specific processes that might affect participants' performance.

In this context, future studies should further explore cognitive deficits and biases in obese persons with and without binge eating disorder by varying the stimuli (by including stimuli connoting a thin physique and low-calorie food) and by manipulating the presentation times. More specifically, it would be pertinent to explore unconscious biases with short and masked presentation of the stimuli, as well as controlled and later attentional biases. Some studies suggest that automatic biases (Boon, Vogelzang, & Jansen, 2000; Nijs et al., 2010; Smeets et al., 2008) and more controlled biases (Smeets et al., 2008) could underlie eating disorders and obesity. Additional studies are necessary, first to further measure initial automatic attentional orientation and more controlled attention using attention-related tasks such as the dot-probe paradigm (MacLeod, Mathews, & Tata, 1986) or a visual search paradigm (Rinck, Reinicke, Ellwart, Heuer, & Becker, 2005), and then to further explore inhibition mechanisms using tasks specifically designed to assess specific inhibition mechanisms (prepotent response inhibition and resistance to proactive interference). Moreover, given the small amount of variance explained by the models tested in the present study, future studies should increase the sample size to check that the results are solid.

This study contributes to a better understanding of the processes underlying obesity and dysfunctional eating behavior and may have implications for the clinical management of these conditions. Indeed, obese patients with cognitive deficits may benefit from mindfulness techniques (Kristeller, Baer, & Quillian-Wolever, 2006) and implementation intention techniques (Achtziger, Gollwitzer, & Sheeran, 2008). In this context, another promising direction could be an examination of the relationship between cognitive deficits and biases and dysfunctional eating before and after a cognitive treatment. Research has shown that high impulsivity significantly predicted treatment drop-out in a long-term behavioral treatment program for obesity (Hjoridis & Gunnar, 1989). Interestingly, it has also been shown that obese children who were less effective at inhibiting responses lost less weight during treatment (Nederkoorn, Braet, et al., 2006). Further work along these lines could therefore be of value.

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## Appendix A

### Some sample lists of words

Food words			
Biscuit	Cookie	Bonbon	Candy
Cacahuètes	Peanuts	Chocolat	Chocolate
Croissant	Croissant	Fromage	Cheese
Glace	Ice cream	Mayonnaise	Mayonnaise
Pizza	Pizza	Sandwich	Sandwich
Body words			
Bourrelet	Roll of fat	Cellulite	Cellulite
Cuisse	Thigh	Fesse	Buttock
Hanche	Hip	Jambe	Leg
Joue	Cheek	Menton	Chin
Mollet	Calf	Poitrine	Chest
Object words			
Boulon	Bolt	Boussole	Compass
Calculatrice	Calculator	Clé	Key
Ciseau	Scissors	Compas	Compasses
Crayon	Pencil	Disquette	Diskette
Jeton	Token	Parapluie	Umbrella
Pinceau	Brush	Punaise	Thumbtack