

Increased Attentional Bias towards Food Pictures in Overweight and Obese Children

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Received date: April 3, 2014, Accepted date: April 24, 2014, Published date: April 30, 2014

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Keywords: Attentional bias; Childhood obesity; Food interference effect; Overweight; Restrained eating

Abstract

Objective: Childhood overweight is related to higher sensitivity for external food cues and less responsiveness towards internal satiety signals. Thus, cognitive psychological models assume an enhanced food attention bias underlying overeating behavior. Nevertheless, this question has only been sparsely investigated so far in younger children and it remains open whether restrained eating behavior plays a correlative role.

Methods: The present study investigated this specific information processing bias for food relevant stimuli in 34 overweight children between 6 and 10 years and 34 normal weight children matched for age, sex and socioeconomic status. Children completed a computerized food picture interference task that assessed reaction time interference effects towards high and low calorie food pictures. Level of hunger and restrained eating was assessed via self-report.

Results: Results indicated that while finding no group difference in general processing speed or hunger level before the task overweight children showed a higher attentional bias to food pictures than normal weight children. No effect of caloric density was found. However, surprisingly, the interference effect was negatively related to restrain eating in the overweight group only.

Conclusion: The found hypersensitivity for food cues independent of calorie content in overweight children appears to be related to dysfunctional eating, so that future research should consider strategies for attentional retraining.

Introduction

Overweight and obesity in children and adolescents have increased dramatically [1,2]. Childhood obesity is one of the most demanding and challenging public health issues of the 21st century. About 40 to 50 million children under the age of five are considered to be overweight in both developing and developed countries [3]. Obesity is associated with a long list of both immediate and long-term physical as well as psychological health consequences such as cardiovascular diseases, type 2 diabetes, sleep apnea, stigmatization or poor self-esteem [4-8]. Therefore medical and psychological research is especially interested in investigating its causes and mediating factors. The impact of genetic factors [9] and social promotive factors like the socioeconomic status (SES) [10] or a global shift towards an energy-dense diet with less physical activity [11,12] in combination with an increased media use [13] are well explored and replicated. But, these factors are not explanatory on their own.

Possible psychosocial factors in the development and maintenance of childhood obesity have therefore been brought into focus. In general, overweight and obese individuals tend to overeat, especially

high calorie food [14]. Overeating itself is associated with rather uncontrollable variables such as stress [15] or sensitivity to reward [16]. This leads to the assumption that implicit cognitions and attentional processes are underlying obese behavior [17]. Overweight and obese individuals seem to be “hypersensitive” to food cues and thus show an information-processing bias towards food relevant stimuli in the food-rich environment of today [18]. Referring to the incentive sensitization theory [19], dopaminergic reward system sensitization leads to an elevated salience of the reward related food cues which make them more “attention-grabbing”, thereby promoting craving and overeating.

Further, the restraint theory [20-22] explains children and adults’ overeating behavior by postulating that a restrained eating behavior with food restriction - which can usually be found in overweight - rather increases the preoccupation with food and at the same time decreases control over food intake. So restrained eaters seem to make conscious efforts to control their attention and responses to food stimuli without success, but instead an increase of their attention to such cues results [23-25]. However, support for this hypothesis has been mixed with some studies finding evidence for a hyperaccessibility

for food-related information [26,27], whereas other studies did not find support [28,29]. Conflicting findings might be the result of different used task parameters, participants' characteristics such as sex or weight status or motivational variables such as baseline hunger levels.

Nevertheless, behavioral studies revealed that overweight children are highly sensitive towards external food cues [30] but rather insensitive towards internal hunger signals [31]. Consistent with these findings, better memory for food compared to non-food words has been demonstrated in obese relative to lean adolescents, though no interference in attention processing for food words emerged [32]. Obese individuals also orient more quickly toward food pictures and spend more time looking at food than non-food pictures as compared with lean individuals as assessed via eye-tracking [33]. These results support an increased attentional bias with more attentional weights allocated to food than non-food stimuli in overweight and obese children and adults, although research findings are not straightforward.

A frequently used paradigm to study such an attentional bias towards emotional and non-emotional stimuli (commonly words) is the Stroop task [34,35]. Usually there are two classes of stimuli: a neutral class and an emotionally salient class that comprises the stimuli of interest. Participants are required to respond to the stimuli (e.g. naming the color of the words) as quickly as possible. The affective nature of the emotional stimuli captures attention resources and thus results in interferences with the actual task (e.g., color naming of the word) [35]. Hence participants usually respond slower to the emotionally relevant stimulus, which is well known as (attentional) interference effect. Since this interference effect is assumed to represent a rapid bottom-up mechanism, it is thought to reflect sustained attention processes [36]. In adults a food interference effect in eating disorders has constantly been shown using a pictorial emotional Stroop task [37], or a word Stroop task [38]. However, in childhood overweight and obesity the amount of studies concerning a food related interference effect (in a Stroop task) is relatively scarce [17].

To our knowledge, the empirical study by Braet and Crombez [39] is the only study so far that directly compared the information processing bias for food relevant stimuli in 9 to 16 year old obese compared to normal weight children. They used a modified Stroop task that comprised food words, negative emotion words and control words. Obese relative to lean children showed a greater interference effect for food words supporting the assumption of an enhanced information processing bias to food compared to non-food stimuli. The authors did not find an association to restrained eating behavior. Unfortunately, the age-range observed in their study was very broad and did not account for the critical age of school entrance when obesity prevalence rates significantly increase [40,41]. Considering the age group of elementary school children the assessment of information processing via a word related emotional Stroop task is difficult because of insufficient reading abilities. Thus, the use of pictorial stimuli seems to be appropriate to observe food related attentional biases. The use of food pictures instead of words is even more ecologic valid since in the real world adults and children are more often confronted with the actual representation of food (e.g. in advertisements and shops) rather than its lexical representation [for studies which used pictorial Stroop tasks: [42-45]. Furthermore, there are studies showing that it is important to take the caloric density of food into account [14,46-52] since enhanced food-cue reactivity seems to be especially prominent towards high caloric food.

The goal of the present study was to investigate differences in information processing biases for food stimuli in a group of overweight elementary school children compared to age matched normal weight children. Using a Food Picture Interference Task we were able to directly compare interference effects towards high and low calorie food pictures. If the hypothesis of an increased attentional bias to food stimuli holds true, overweight children should exert higher interference effects to food pictures compared to age-matched normal weight children, especially in relation to the high calorie condition. An additional purpose of the study was to explore associations between attention-related measures and dietary restraint in both weight groups, which we expected to be positively correlated.

Material and Methods

Participants

37 overweight children (body mass index (BMI) > 90th BMI percentile, 18 girls, 19 boys) and 37 normal weight children (\geq 24th to \leq 76th BMI percentile, 18 girls, 19 boys) between 6 and 10 years were recruited from a larger ongoing longitudinal study on intrapersonal developmental risk factors in childhood and adolescence (PIER study) in the surrounding area of Potsdam (Germany). The overweight group was chosen according to their BMI and was invited to an additional appointment. The normal weight group was matched for age, sex and SES.

Two children and their matches had to be excluded due to technical problems (behavioral data was not recorded) and one child and its matching partner was excluded due to invalid behavioral data. We obtained 34 overweight and 34 normal weight children (34 girls, 34 boys) for analyses. Table 1 summarizes the demographics and weight status data for both groups. All demographic measures did not differ between groups ($t_s(66) \leq 1.78, p_s \geq 0.10$). Not surprisingly, body status measures differed significantly between the overweight group and the normal weight group ($t_s(66) \geq 9.63, p_s < 0.001, d_s \geq 2.34$). In the overweight group 13 children were classified as overweight (BMI>90th BMI percentile, 4 girls, 9 boys), 17 as obese (BMI>97th BMI percentile, 11 girls, 6 boys) and 4 children as severely obese (BMI > 99.5th BMI percentile, 2 girls, 2 boys).

	Overweight children		Normal weight Children	
	M	SD	M	SD
Age (years)	8.47	0.90	8.83	0.78
SES (Blossfeld scale; mean both parents)	1.71	1.06	2.10	0.96
Educational attainment (mean both parents)	4.16	0.77	4.38	0.89
BMI***	22.38	2.48	16.23	0.86
BMI-SDS***	1.97	0.42	- 0.11	0.38
Whole-body percent fat (%)***	30.74	5.31	18.11	2.94
Waist circumference (cm)***	72.35	7.45	57.49	5.04

Legal guardians provided written informed consent after a full explanation of procedures was given before testing. Approval for the study was obtained from the local Ethics Committee. Parents received €10 and children received €5 and a small gift for their participation.

Procedure

Children were tested individually. Their legal guardians waited in a different room and completed a demographics questionnaire. Upon arrival, participants were familiarized with the procedure and body measures were taken. Additional measures concerning facial emotion processing before and an eating behavior test afterwards were administered, which will not be reported here. After rating their level of hunger, children were seated in a sound-attenuated room and completed a Food Picture Interference Task. A trained psychologist or a research assistant who was present for the child the whole time conducted the test session.

Demographic measures

SES was measured according to actual parental occupation following the classification scheme of Blossfeld [53,54]. Here the occupational qualification of each parent is classified from 0 (=unemployed) to 5 (=highest qualified occupation) [55].

Parents' educational attainment was distinguished from 1 (= no educational degree) to 6 (=university degree).

Measurement of body composition

Children's height was determined to the nearest 1.0 cm using a mobile stadiometer (Seca 213). Their weight and percentage of body fat were measured to the nearest 0.1 kg/% by means of a calibrated digital body fat scale (Tanita BC-532). BMI was calculated as the standard ratio of weight in kg divided by the square of height in meters. Individual BMI-values were also converted to z-scores (BMI-SDS values, standard deviation score values) based on the national reference data for German children [56] in order to correct for age and sex. The waist circumference was measured to the nearest 0.1 cm at the midpoint between the lower border of the rib cage and the iliac crest by using a flexible body measuring tape.

Food Picture Interference Task

Inhibitory performance regarding food and non-food stimuli was assessed with a Food Picture Interference Task. The Food Picture Interference Task consisted of three consecutive blocks: block 1 served as training condition, block 2 as baseline condition without any interference of food stimuli, and block 3 officiated as the experimental condition (Figure 1). During the training block ('color block'), participants were asked to respond to red and blue standard illuminant colored boxes presented in the middle of the screen on a black background. During the baseline block ('empty plate block'), participants were asked to respond to red and blue frames in the same size and color as the boxes of block 1. In contrast to block 1, a photograph of an empty white plate in the middle of the frame was presented. In order to exclude any 'food interference' during the baseline, this block was compelled to be before experimental block 3. In this third block ('food interference block') participants were asked to respond to the two colors of the frames in the same way as instructed during both blocks before. Photographs of either high or low calorie food were presented on a plate in the center of the colored frame.

Photographs were taken from the same angle and were matched by color and amount.

The PC-controlled experiment was conducted in a dimly lit, soundproof cubicle. Stimuli were presented on a 17" monitor (1.024 × 768 pixel screen resolution, 70 Hz refresh rate). Pictures with plates without frame were about 144 mm × 216 mm (=13.7° × 20.4°) and pictures with plates within the frame were about 161 mm × 233 mm (= 15.3° × 22°). Participants viewed the monitor from a distance of 60 cm, controlled by the aid of a head and chin rest. Figure 1 shows the sequence of stimuli presented on a given trial for the three different blocks. Participants first fixated a white fixation cross (0.3° × 0.3°) displayed for 500 ms in the center of the screen on a black background. The cross was immediately followed by an equiluminant colored frame (red or blue) with different content depending on the current block. Participants were instructed to press the corresponding color buttons on the keyboard as quickly and as correct as possible with their right forefinger (right arrow key for a blue box and left arrow key for a red box or vice versa). The assignment of the two colors to one of the two arrow keys was pseudo randomized across participants. Following registration of the participants' response, pressing the 'down arrow' key started the next trial. Thus, after each trial the forefinger of a participant was geared back to a neutral midpoint position ('down arrow' key) for the next trial.

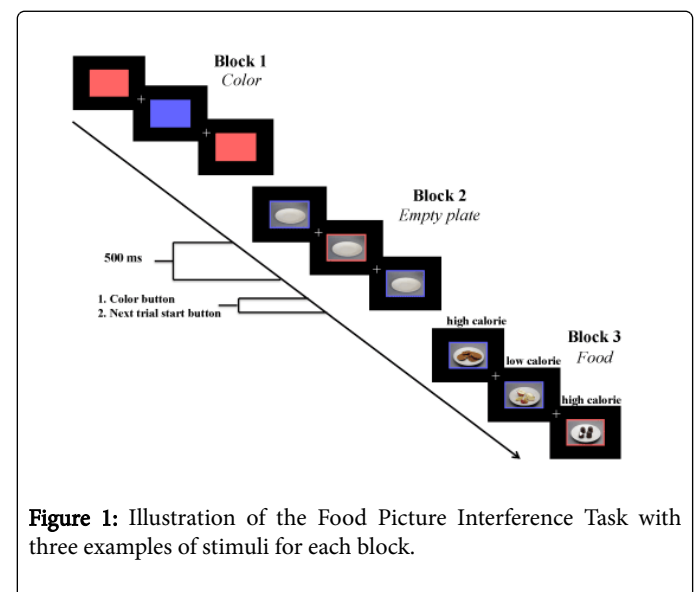


Figure 1: Illustration of the Food Picture Interference Task with three examples of stimuli for each block.

All participants were instructed to use only the forefinger of the right hand and to respond as quickly as possible without making any mistakes. Verbal instructions as well as five practice trials were provided before each of the three blocks in order to ensure that participants had completely understood the task and could execute the responses adequately. Within the same block colored frames (with or without content) were presented in random order. Block 1 and block 2 consisted of 30 trials each, wherein 15 red and 15 blue boxes/frames were presented in a random order. Block 3 consisted of 60 trials, wherein 30 pictures of high calorie food (e.g. potato crisps or muffin) and 30 pictures of low calorie food (e.g. carrots or apples) were together with the two frame colors randomly presented. The task lasted about 10 minutes.

Self-report instruments

Participants were asked to rate their level of hunger on a 4-point Likert scale from 0 (not hungry at all) to 3 (very hungry). Self-reported restrained eating was measured in the large study assessment using the German version of the Dutch Eating Behavior Questionnaire (DEBQ) [57,58]. Due to time constraints, only four items with the highest factor loadings according to Van Strien et al. [59] were included. They were scored on a 4-point Likert scale ranging from 1 (never) to 4 (often) whereas the scale score was obtained by dividing the sum of the item endorsements by the total items endorsed. A high score indicates a high degree of restrained eating behavior. The original authors have shown factorial validity and dimensional stability and the scale's internal consistency as measured by Cronbach's α in our sample is acceptable high (0.74).

Data analyses

We tested group differences in self-reported data, percentage of valid responses, reaction times and interference scores by means of independent samples t-tests as well as repeated measures analyses of variance (ANOVA). If assumption of sphericity was not met (Mauchly's Sphericity Test: $p < 0.05$), degrees of freedom for dependent variables were corrected conservatively by Greenhouse-Geisser. Effect sizes (Cohen's d or η^2) of group differences and interactions are reported. Reaction times for correct trials were included and outliers (more than three SD from the individual mean) were excluded from analyses. Comparable with the approach used for emotional Stroop tasks [60] interference control regarding food and non-food stimuli was assessed for each of the two experimental conditions (high calorie, low calorie) following the formula: food block-neutral (=empty plate block). This resulted in two interference scores and two attentional bias indices. Higher interference scores indicate greater interference in reaction times and therefore more attentional bias towards high and low calorie stimuli pictures. Pre-planned Pearson correlation analyses were carried out to analyze significant associations between DEBQ restrained eating scale as well as hunger level and the interference scores separately in both groups.

The Statistical Package for Social Sciences (SPSS, version 21) was used for all analyses.

Results

Self-reports

Before task execution, groups did not differ significantly with regard to self-reported level of hunger (overweight group $M=1.97$, $SD=0.94$; normal weight group $M=1.88$, $SD=0.98$; $t(66)=0.38$, $p=0.71$). In comparison to the normal weight group ($M=2.38$, $SD=0.99$) overweight children scored significantly higher on the DEBQ restrained eating scale ($M=2.92$, $SD=0.78$; $t(66)=2.50$, $p < 0.05$, $d=0.61$).

Food picture interference task

In Table 2 mean reaction times and the percentage of valid responses for each block and for both experimental conditions in block 3 are presented.

	Overweight children	Normal weight children

	M	SD	% valid	M	SD	% valid
Block 1	920.51	168.85	99.70	942.50	212.06	99.60
Block 2	947.85	186.27	98.53	924.01	165.78	99.02
Block 3	1231.16	342.33	97.78	1119.13	226.64	98.91
High calorie	1235.01	353.56	97.83	1128.57	230.77	98.61
Low calorie	1227.31	335.79	97.77	1109.69	231.77	99.21

Table 2. Mean reaction time (ms) and percentage of valid reactions for every block and condition for both groups.

Valid responses

First we tested whether response performance differed across the two groups in the three blocks. A Group (normal weight, overweight) \times Block (Color, Empty Plate, Food) repeated measures ANOVA revealed a main effect of Block ($F(2,132)=6.12$, $p < 0.01$, $\eta^2=0.09$). Neither a significant main effect of Group ($F(1,66)=1.31$, $p=0.26$) nor a significant interaction effect ($F(2,132)=1.29$, $p=0.28$) could be found. Post hoc tests (with Bonferroni's correction for multiple testing) showed that the mean percentage of valid responses in the food block ($M=98.35$, $SD=3.15$) was significantly lower than for the color block ($M=99.65$, $SD=1.32$, $p < 0.01$), indicating that both groups made significantly more mistakes in the food block than in the color block, but not in contrast to the empty plate block ($p > 0.10$).

Reaction times

Second we tested whether reaction time performance differed across the two groups in the three blocks by conducting a Group (normal weight, overweight) \times Block (Color, Empty Plate, Food) repeated measures ANOVA. A main effect of Block was found ($F(1.60, 105.76)=92.01$, $p < 0.001$, $\eta^2=0.58$). Post hoc tests (with Bonferroni's correction for multiple testing) showed that the mean response time for the food block ($M=1175.15$, $SD=293.61$) was significantly higher than for the color block ($M=931.51$, $SD=190.56$) and the empty plate block ($M=935.93$, $SD=175.42$; all comparisons, $p < 0.001$) in both groups, whereas no difference between color and empty plate block emerged ($p > 0.99$). Since also no significant main effect of Group could be found ($F(1,66)=0.60$, $p=0.44$), we concluded that there was no basic difference in general processing speed (first two blocks) between the two groups. However, there was a significant Group \times Block interaction effect ($F(1.60, 105.76)=5.49$, $p < 0.01$, $\eta^2=0.08$), indicating that in contrast to the first two blocks, overweight children showed a higher response time than normal weight children in the food block only (Table 2 for Ms and SDs).

Figure 2 summarizes the results of the two interference scores for overweight and normal weight children separately.

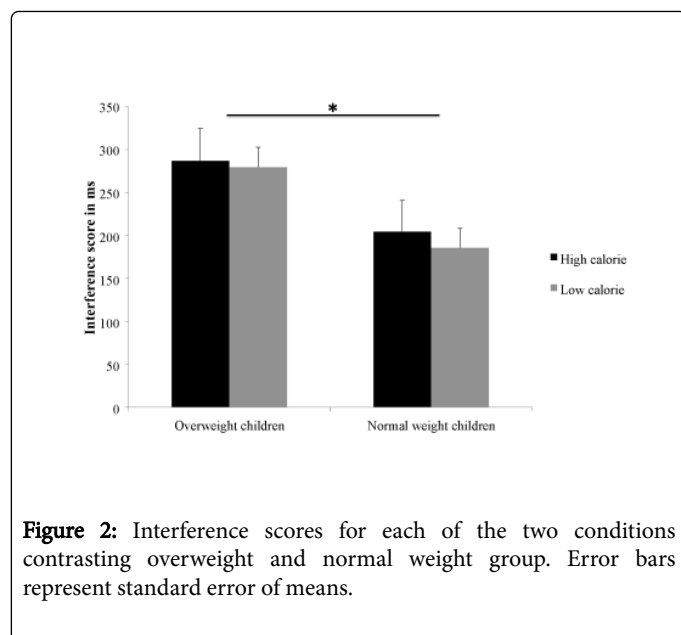


Figure 2: Interference scores for each of the two conditions contrasting overweight and normal weight group. Error bars represent standard error of means.

The Group (normal weight, overweight) \times Condition (high calorie, low calorie) repeated measures ANOVA on the dependent measure of interference score revealed a significant main effect for Group ($F(1,66)=4.36, p<0.05, \eta^2=0.06$), indicating that the overweight group showed significantly higher interference scores in both calorie conditions compared to the normal weight group. There was no significant main effect for Condition ($F(1,66)=1.58, p=0.21$) and no significant interaction effect ($F(1,66)=0.28, p=0.60$).

Associations to individual difference measures

In the overweight group a significant negative correlation between the DEBQ restrained eating scale and the food interference score was found for high calorie food pictures ($r=-0.29, p<0.05$). A trend towards an inverse correlation for low calorie food pictures ($r=-0.26, p=0.07$) was also observed in the overweight group only.

There was no such significant correlation in the normal weight group in response to high calorie pictures ($r=0.06, p=0.36$), while a trend towards a positive correlation between the interference score for low calorie pictures ($r=0.24, p=0.09$) occurred.

The interference scores did not significantly correlate with the rated level of hunger in both groups ($r_s \leq 0.21, p_s \geq 0.11$).

Discussion

The main purpose of this study was to investigate whether overweight children show differential processing of food pictures in a Food Picture Interference Task compared to normal weight children. Concerning the valid responses, overweight and normal weight children had more mistakes in the Food block as compared to the baseline and training. We assume that this decreasing amount of valid responses in the Food Picture Interference condition probably reflects an increased attentional demand due to the complexity and affective nature of the food pictures in the experimental block. Importantly, overweight and normal weight children did not differ with regard to valid responses in none of the three blocks. Both groups were also significantly slower in their reaction time in the Food block than in the

other two preceding blocks, which again supports the assumption of an increased difficulty in the experimental block. Again, there was no basic difference in general processing speed between the two groups. Thus, the general cognitive processing capacity did not differ between groups and therefore cannot explain possible group differences in the experimental condition (food block).

We then calculated interference scores that indicate greater interference in reaction times and therefore more attentional bias towards high or low calorie food as contrasted to the neutral condition (empty plate). The main results show that the two groups significantly differed in reaction times and their interference scores in both food conditions. As we did not find a difference in the interference scores between the different calorie conditions in between groups, this means that overweight children showed a significant higher slowdown in response time compared to normal weight children no matter what kind of food pictures (high or low calorie) were presented on a plate. Our results fit quite nicely to the incentive-sensitization model of obesity [19,51]. This model postulates that repeated pairings of reward from food intake and cues that predict impending food intake result in a hyper-responsivity of dopamine-based reward circuitry to food cues, contributing to craving and overeating. The model suggests that abnormalities in responsivity of the dopamine-based reward circuitry could contribute to an enhanced attentional bias and thus to elevated approach tendencies toward food and food cues. Interestingly, the amount of dopamine released in the dorsal striatum was shown to be positively associated with meal pleasantness ratings [61]. This might explain the general information-processing bias found towards food relevant stimuli in overweight [18].

In support of this assumption the present study was able to demonstrate that exposure to food pictures results in an increased interference effect in overweight children compared to normal weight children. This hypersensitivity to stimuli with high incentive salience (food pictures) produced a pronounced bias in attentional processing toward food-related pictures. This possibly triggered the release of dopamine in the overweight and obese children group. The activation of the dopamine-reward circuit when confronted with food cues then could lead to an elevated feeling of pleasures and an overall positive connotation of all food related stimuli in the group of overweight children. In daily life such a maladaptive response to food and food cues might result in overeating, overweight and obesity. This supports earlier findings that being overweight in childhood is associated with a higher responsiveness to external food cues and that this attentional hypersensitivity is initiating or maintaining a dysfunctional and excessive eating behavior in adulthood [30,39].

Furthermore, we found a significant negative correlation between the DEBQ restrained eating scale and the interference score for high calorie food pictures and a similar trend for low calorie food pictures in the overweight group who also scored significantly higher on the scale. This underlines the assumptions of the restraint theory regarding higher incidence of restrained eating behavior in overweight [23-25]. However, the interesting and surprising result was that in the overweight group rather restrained eaters demonstrated less attentional bias towards low and high calorie food pictures than rather unrestrained eaters, given that they are believed to be susceptible to overconsumption of palatable foods. In contrast to the overweight group, the control group exhibited the expected positive correlation between restrained eating and the interference score on a trend level (only for low calorie food pictures). But there is other research showing that in some situations, restrained eaters may be successful in directing

their attention away from food related cues [62,63] or research failing to find a relation between cognitive restraint and attentional biases for food [28,29,39]. One possible explanation for the found negative relation especially to high calorie stimuli in overweight could be attentional avoidance, whereby overweight restrained eating children have greater weight concerns and therefore try to avoid food stimuli because of their potential 'dangerous' representation of weight gain. This avoidance response in attentional bias tasks is known from anxiety research studies [64]. But since findings on the relation between attentional biases and restrained eating are still very heterogeneous, more research is needed to further evaluate this question.

To conclude, for the first time we developed and tested a new Food Picture Interference Task for the assessment of an attentional bias towards food of different calorie content. By using pictures instead of words we built up on the one hand a more age appropriate and on the other hand a more external valid task. So, the simplicity of the task makes it well suited for further use in developmental as well as in clinical studies in younger children and in adults and thus provides the opportunity to expand research on psychological risk and cumulative factors for childhood obesity. A methodological limitation of this study refers to the fact that the baseline condition was executed before the food condition. But since every food interference due to earlier food pictures had to be eliminated the task design offered no other possibility. A further limitation is that body measures were taken before instead of after the task, which likely can result in priming effects, particularly in weight-concerned participants. But since some additional measures were administered in between we assume that this influence was not tremendous. We conclude that the apparent association of childhood overweight with cognitive interference effects may be used for treatment implications like a greater focus on cognitive techniques that can change underlying processes leading to a heightened preoccupation with food or strengthening the reliance on own internal body signals. Further research should further focus on antecedents, correlates and consequents of this hypersensitivity for food cues.

Conflict of interests

The authors have no conflict of interest

Acknowledgement

We thank all participants and collaborators for supporting this study. We thank Jennifer Meyer for programming and preparation of data analysis, Kevin Görsch for creating the stimuli and Marina Fischer for her assistance in data collection.

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