Computer training of attention and inhibition for youngsters with obesity: A pilot study

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Sandra Verbeken [a, *], Caroline Braet [a], Tiffany Naets [a], Katrijn Houben [b], Wouter Boendermaker [c], Zeepreventorium vzw[d]

[a] Clinical Developmental Psychology, Ghent University, Ghent, Belgium
[b] Clinical Psychological Science, Eating Disorders and Obesity, Maastricht, The Netherlands
[c] Child and Adolescent Studies, Utrecht University, The Netherlands
[d] Zeepreventorium vzw, De Haan, Belgium

ABSTRACT

Obesity is a widespread problem that starts from an early age. Previous studies suggest that obese youngsters have an attentional bias and an automatic approach tendency towards high-calorie food and display difficulties inhibiting impulses, which may result in a higher intake of (high-calorie) food. An interesting idea for improvement of the current obesity treatment is adding a program that enables to train their difficulties. Subjects were 36 youngsters aged 9—15 years old from an inpatient treatment program for obesity, randomized over a training group and an active control group. The training consisted of six training sessions with cognitive tasks aimed at enhancing inhibition towards unhealthy food items (with a go/no-go task), as well as decreasing a food approach bias (using an approach/avoidance task) and a food attentional bias (using a dot-probe task). The current study evaluated the feasibility, acceptability and initial effectiveness of the training and explores if these characteristics helps obese youngsters to maintain weight-loss once they return home at the end of their inpatient treatment program. Results on the cognitive performances were investigated during two measurement sessions, spread over 5 weeks while weight evolution was followed over 13 weeks. Results showed that the training program was feasible and acceptable to the majority of participants and clinicians. Furthermore, the preliminary findings suggest that the training tasks used were ineffective in this group of obese children. Lessons learned and suggestions for future research are discussed.

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1. Introduction

According to the World Health Organization (WHO, 2013), the number of people affected by obesity worldwide has almost doubled since the 1980s. A recent review on childhood obesity (Wang & Lim, 2012) suggests that about 20% of school-age youngsters in Europe struggle with overweight, and that 5% of these youngsters can be classified as obese. Additionally, many obese youngsters will remain obese in adulthood. A review from the early 1990s suggests that about a third of obese preschool youngsters and about half of obese school-age youngsters become obese adults (Serdula et al., 1993).

There is a clear need for programs capable of reducing overweight and obesity, especially in youngsters. Oude Luttikhuis et al., (2009) reviewed sixty-four studies on the treatment of childhood obesity and found that most of them reported positive effects. More in-depth investigation made the authors conclude that treatment programs combining the different facets of diet, physical activity and behavioral change have the most positive outcome. However, it should be noted that these results might be skewed towards the positive because many studies suffered from a high drop-out rate and had to deal with missing data during follow-up. It is assumed that most youngsters regain weight after treatment and therefore decline participation during the study. Several other studies have shown that it is especially amongst the severely obese youngsters that drop-out rates are high and weight regain during follow-up is significant (Braet, Tanghe, Decaluwé, Moens, & Rosseel, 2004; Goossens, Braet, Van Vlierberghe, & Mels, 2009; Levine, Ringham,

Kalarchian, Wisnieuwski, & Marcus, 2001). Therefore, it is indicated to research new ways to improve the currently existing treatment programs.

One explanation for the modest results of existing treatments is the decreased behavioral control capacities of obese individuals. The dual-system model used in addiction research (Bechara, 2005; Strack & Deutsch, 2004; Wiers & Stacy, 2006) could be helpful to understand these problems. The idea behind a dual-system model is that self-regulatory behavior is influenced by two different but interactive systems: one is a fast, impulsive and associative system that evaluates and processes stimuli on their emotional and motivational value (bottom-up), while the other is a slow, reflective and knowledge-based system that controls and inhibits responses in a conscious deliberation (top-down). Similarly, Appelhans et al. (2011) suggested that also regarding overeating two important neuro-behavioral processes are involved: a strong food reward system (bottom-up) and a less developed inhibitory control system (top-down). When both processes are not in balance, strong food responses are observed; and this can explain the lack of resisting temptation that is typical for obese youngsters (Guerrieri, Nederkoorn & Jansen, 2008). Consequently, it is assumed that improvement of their self-regulatory capacity will be crucial so that they are better able to resist immediate temptations and will better adhere to treatment recommendations.

Enhancing the self-regulatory capacity implicates strengthening different Executive Functions (EFs) underlying all kinds of controlled behaviors. EFs are neuropsychological processes that activate and regulate goal-directed behavior and responses to the environment (Riggs, Huh, Chou, Spruijt-Metz, & Pentz, 2012). EFs involve cognitive control tasks, such as planning and execution of behavior, attention, and inhibitory control, all essential for successful self-control. Based on recent research we can now say that failure of self-regulation in obese youth is at least partially based on underlying deficits in EFs needed to overrule automatic behaviors (Riggs et al., 2012). Although future research could show that other EFs are also important, at this moment, evidence is overwhelming on the role of at least two different EFs: inhibitory control (IC) and attention (Appelhans, 2009; Loeber et al., 2011; MacLeod, Mathews, & Tata, 1986; Nigg, 2000; Verbruggen & Logan, 2008).

First, inhibitory control (IC) contributes to the self-regulation of behavior as it creates a delay in which one can think before acting. IC refers to top-down processes for intentional control in the service of higher order or longer term goals (e.g., resisting temptations, delaying gratification), and is believed to be at the heart of impulsive behavior (Davids et al., 2010). It becomes particularly manifest when observing people's restraint standards. The fact that we can restrain ourselves in the presence of palatable food while still finding this food very tempting indicates that the capacity to resist eating is a distinct process. This suggests that inhibiting food intake is not simply a matter of reducing the drive to eat: it involves active self-regulation of behavior despite the strong drive to eat (Nigg, 2000). Several longitudinal studies have shown that toddlers who are less able to inhibit their impulses are more likely to be overweight later on in childhood (Graziano, Calkins, & Keane, 2010; Seeyave et al., 2009). Behavioral studies in obese youngsters suggested that compared to average weight youngsters, obese youngsters have problems with behavioral inhibition, as assessed with two well-validated computerized measures to assess behavioral inhibition: the Stop Signal Task and the Go/No-Go Task (Appelhans, 2009; Logan, Cowan & Davis, 1984; Verbeken, Braet, Claus, & Oosterlaan, 2009). Additionally, it was shown that difficulties with impulse control obstruct weight loss during treatment (Nederkoorn, Jansen, Mulkens, & Jansen, 2007), and that subjects leaving the treatment program score higher on impulsiveness and lower on inhibition (Hjördis & Gunnar, 1989). Research in adults also demonstrate that poor inhibitory control is associated with higher body weight and leads to more failure in resisting food temptations (Guerrieri et al., 2008; Verbruggen & Logan, 2008).

Second, behavioral self-control is also related to bottom-up attentional salience of food cues and impulsive approach behavior. Calorie-rich food stimuli automatically capture attention (Freijy, Mullan, & Sharpe, 2014; Loeber et al., 2011; Mann & Ward, 2004; Nederkoorn Guerrieri, Havermans, Roefs & Jansen, 2009) and drive action-tendencies to approach and consume palatable food (Kemps, Tiggemann and Hollitt, 2014; Kemps Tiggeman, Martin & Elliot, 2013; Kemps & Tiggemann, 2014). Recently, new studies indeed confirmed that some children have strong reward traits, related with strong food responsiveness and approach behavior which is associated with overeating and weight gain (Verbeken, Braet, Lammertyn, Goossens, & Moens, 2012). The assumption that in obese individuals overeating is triggered by exaggerated reactivity to stimuli associated with high-caloric food, is also supported by neuro-imaging research. Compared to average weight controls, in obese individuals a greater activation was found to high-caloric food images within a wide range of brain regions mediating motivational and attentional salience of food cues (Brignell, Griffiths, Bradley, & Mogg, 2009; Yokum, Ng, & Stice, 2011). Furthermore, a high brain activation to high-calorie food pictures in obese individuals predicts less weight loss during therapy and poorer weight-loss maintenance post-treatment (Stoeckel et al., 2008). Consequently, previous findings suggested that obese people have a high attentional bias for food-cues, which is detrimental for their weight control.

Interestingly, recent pilot studies suggest that cognitive self-control indeed can be trained in a highly feasible and effective way. The largest amount of evidence for this statement can be found in literature about obese adults. For example, a number of authors found that active inhibition training significantly facilitated weight loss in (young) adults (Veling, van Koningsbruggen, Aarts, & Stroebe, 2014; Stice, Yokum, Veling, Kemps, & Lawrence, 2017; Lawrence et al., 2015). It appears that those inhibition trainings create automatic stop-associations, that reduce the direct evaluations of unhealthy food items (Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017). In the field of attention training, there are also studies to suggest the effectivity of EF-training. For example, Bazzaz, Fadardi, and Parkinson (2017) found that a Food Attention Control Training Program (FOOD-ACTP) significantly reduces food-related attentional biases, diet failures and weight gain (Bazzaz et al., 2017).

Even though the evidence in children and adolescents is rather scarce, there are recent studies that show EF-training can be also relevant in a younger target group. The study of Folkvord, Veling, and Hoeken (2016) shows that children who completed an inhibition game (with the go-no-go task) only once, already consumed fewer calories directly after it (Folkvord et al., 2016). In the field of attention training, a study with obese youngsters participating in an attention modification program (AMP) or control program (CC) showed that in a free access session, youngsters in the CC condition significantly increase their caloric intake over time whereas youngsters in the AMP group demonstrate decreased caloric intake, providing evidence for the effects of such a training on eating behavior in obese youngsters (Boutelle, Kuckertz, Carlson, & Amir, 2014).

Furthermore, there is also evidence that EF-training for children can book success even for a longer period. Verbeken, Braet, Goossens, and van der Oord (2013) reported that adding an inhibitory control training indeed results in better weight outcomes in obese youngsters. Enhancing EFs helped them to maintain their weight loss more effectively, at least for a period of two months after their inpatient treatment (Verbeken et al., 2013).

However, Guerrieri et al. report that focusing on inhibitory control alone will not be enough, without taking into account also attentional and approach bottom-up processes (Guerrieri et al., 2008). This is also in line with the view of Rollins, Dearing, and Epstein that bottom-up processes may be a more powerful independent predictor of food intake than the ability to inhibit (Rollings, Dearing, & Epstein, 2010). Therefore, with the present study we aim to evaluate the feasibility, acceptability and initial effectiveness of a cognitive-bias training focusing on both bottom up and top down processes for weight maintenance in obese youth after following an inpatient weight control program.

To conclude, as obese youngsters have both strong attentional bottom-up reactivity and a decreased top-down ability to inhibit the automatic impulses (Nigg, 2000), they are at highest risk for the plaything of environmental stimuli. For them, a CBT weight control program will not be sufficient. Hence, it is meaningful to evaluate a training to strengthen EFs in this specific patient group of obese youth.

2. Method

2.1. Participants

The participants of this study were youngsters of an inpatient obesity treatment program of a rehabilitation center ("Zeepreventorium") in Belgium. Youngsters were included in the study if they were: (1) between the age of 9 and 15 years old, (2) fluent in Dutch and (3) if their IQ was within the normal range as measured with the Raven (RPM; Raven, 1941). Forty-six youngsters and their parents received information about the research project. The parents received a passive consent form, while the youngsters received an active consent form. The training program was added as part of the care, and thus all forty-six youngsters participated in the training. However, parents of three youngsters and four youngsters themselves did not give consent for the use of data. Further, three youngsters provided informed consent but didn't start the training (because of illness or motivational problems) and were treated as drop-outs. The data of the remaining thirty-six youngsters was used in the analyses below (age in years $M = 12.06$; $SD = 1.47$; girls $= 52.8\%$).

2.2. Treatment

Youngsters with obesity are usually admitted in the inpatient treatment program in the first week of July, and discharged in the last week of June the next year. During the treatment, the youngsters receive therapy from a multidisciplinary team consisting of a doctor, a dietician, a physiotherapist, a psychologist, and a social worker. The center also provides the facilities necessary for all aspects of their therapy, including a swimming pool and fitness room, small kitchens to learn how to cook, psycho-social services, etc.

During treatment, youngsters learn about healthy and unhealthy food choices and how they can balance their meals and become more active. The psychologist uses cognitive behavioral therapy to help the youngsters adapt to their new lifestyle and to maintain it after leaving the treatment facility. Youngsters are also guided to learn skills such as planning and organizing. The program consists of three phases of approximately 3 months each: introduction phase, maintenance phase, termination phase. In the last phase, the children were prepared for 'returning home'. More details on the treatment program can be found in Braet et al. (2004); Braet, Tanghe, De Bode, Franckx and Van Winckeld (2003)

2.3. Cognitive assessment and training

Three tasks were used to train and assess inhibition, attentional bias and approach bias. All training tasks used the same format of 78 healthy and 78 unhealthy food-related trials during each training session. These trials used six unique pictures of healthy food, and another six pictures of unhealthy food per session, divided equally over the trials. The evaluation of the different pictures was not tested separately, but structurally and stylistically based on the Amsterdam Beverage Picture Set (ABPS, Pronk, Van Deursen, Beraha, & et al, 2015).

Additionally, another 16 filler trials were mixed with the training trials, where the picture showed various office supplies. This was done in order to slightly mask the contingency between the response-cues and the picture content. In the control training, exactly the same pictures were used. In contrast, the assessment versions of the tasks described below and defined as 'measurement sessions' did not include filler trials and consisted only of 84 food-related trials.

2.3.1. Inhibition

The inhibition training was based on the Go/No-Go paradigm used by Houben, Havermans, Nederkoorn, and Jansen (2013). With this task, participants were trained to consistently withhold a behavioral response in the presence of stimuli related to unhealthy food. During the task, the youngsters were shown series of pictures of healthy or unhealthy food with the letter "p" or "f" superimposed in one of the corners. The picture remained on screen for 1.5 s, and youngsters were instructed to respond as quickly as possible, by pressing the space bar if they saw the letter "p" (Go-trials), or doing nothing if they saw the letter "f" (No-go-trials) (Fig. 1). The contingency between letter and instructed response was counterbalanced over participants. In the active training, the Go-related letter cue was always paired with healthy food pictures and the No-go-related letter was related with the unhealthy food pictures. In the control condition, however, the letter-cues were matched fifty-fifty with healthy and unhealthy food pictures, thus training only general inhibition unrelated to the (food) content of the pictures. As described supra, the number of trials was the same in every task.

During the 'measurement sessions', before and after the training, food-related inhibition was assessed using the same paradigm, with a fifty-fifty matching between letter-cues and picture content like in the control condition. Outcome included whether or not the child could inhibit the response during the No-go trials (error rate), and the average time it took them to respond during the go trials, both for healthy and unhealthy food, specifically.

2.3.2. Attentional bias

Attentional bias was re-trained using a visual-probe attention task (VPT), adapted from MacLeod et al. (1986). Here, youngsters were shown a series of two side-by-side pictures of healthy and unhealthy food, with a small arrow pointing up or down superimposed on one of the pictures. The instruction was to press the corresponding arrow on the keyboard (up or down) as fast as
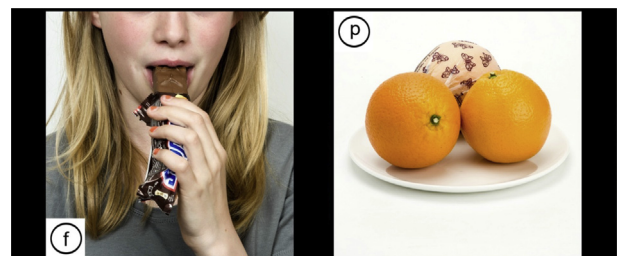

Fig. 1. Example of the go/no go task.

possible (Fig. 2). In the training condition, the arrow always appeared on the picture of healthy food, whereas in the control condition, the matching between the arrow placement and the content of the pictures was fifty-fifty. As described supra, the number of trials was the same in every task.

During the 'measurement sessions', before and after the training, attentional bias towards unhealthy food was assessed using the same paradigm, following the same specifications like in the control condition. A bias score was calculated as the median RT for correct trials where the arrow appeared on a healthy food picture minus those where the arrow was on an unhealthy food picture, with a positive bias score indicating an attentional bias towards unhealthy food.

2.3.3. Approach bias

Approach tendencies towards unhealthy food were re-trained using an approach/avoidance task (AAT), adapted from Wiers, Rinck, Kordts, Houben, and Strack (2010). In the AAT, youngsters were shown a series of slightly tilted pictures of healthy or unhealthy food. They were instructed to press the up arrow on the keyboard when the picture was tilted to the right, whereupon the picture became smaller (zoomed out, mimicking an avoidance) until it disappeared (Fig. 3), or press the down arrow key when the picture was tilted to the left, making the picture increase in size (zooming in, mimicking an approach).

In the training condition, pictures of unhealthy food were always tilted so that they had to be pushed away, while pictures of healthy food needed to be pulled closer. In the control condition, the matching between the tilt and the content of the pictures was randomized fifty-fifty. As described supra, the number of trials was the same in every task.

During the 'measurement sessions', before and after the training, approach bias towards unhealthy food was assessed using the same paradigm, following the same specifications, like in the control condition. The bias score was calculated as the median RT for correct unhealthy food pictures that were pushed away minus those that were pulled in, with a positive bias score indicating an approach bias towards unhealthy food.

2.4. Measurements

2.4.1. Body weight

The Body Mass Index (BMI) was calculated by dividing weight (in kg) by the square of the height (in m). This index was determined for each child at the beginning of treatment at the facility, pre-training, at discharge from the clinic, and during follow-up. To be able to compare the BMI of youngsters of different ages, adjusted BMI was used. This adjusted BMI was calculated by dividing the actual BMI by the Percentile 50 of BMI for age and gender, and then multiplying that number with 100. Normative data was used to determine the Percentile 50 of BMI for age and gender (Fredriks et al., 2004), and a person was considered overweight if they had

Fig. 2. Example of the visual probe task.

an adjusted BMI score greater than (or equal to) 120%, and obese if the adjusted BMI score was greater than (or equal to) 140% (Van Winckel & van Mil, 2001).

2.4.2. Executive functioning

Executive functioning was measured by the Dutch version of the Behavior Rating Inventory of Executive Functioning (Smidts & Huizinga, 2009a), consisting of 75 items and was filled in by a caregiver of the facility. The questions directed attention towards daily behavior of the child that is relevant for executive functioning, using a 3-point Likert scale ranging from "never" to "often". The questionnaire consists of eight subscales, but in this study we will focus only on the subscale: Inhibition. Research has shown that the Dutch version of the BRIEF has a very high internal consistency, and that test-retest stability is high (Smidts & Huizinga, 2011).

Executive functioning was also measured using the self-report version of the BRIEF (Smidts & Huizinga, 2009b). The answering format was the same as in the caregiver version of the BRIEF. In the BRIEF-SR, however, 68 items are spread over 8 subscales. Again, we will focus only on Inhibition. Importantly, neither the amount of items per subscale, nor the items itself matched between the caregiver versions and the self-report version. Internal consistency for the BRIEF-SR is also very high (Smidts & Huizinga, 2011).

Internal consistency was very high in this sample, with pre- and post-training alphas for the BRIEF Inhibition 0.858 and 0.939 respectively and BRIEF-SR Inhibition 0.881 and 0.677 respectively.

2.5. Procedure

After 6 months of treatment, in April 2014, all Dutch-speaking youngsters between the ages of 9 and 15 were invited to join the training program ($N = 46$). Youngsters were randomly assigned to either the control or training condition (with stratification for gender and age). When participants were randomized to a condition, given consent (IC) was not taken into account. After IC, this lead to 15 participants in the control condition and 21 in the active training condition of 6 computer sessions spaced out over 5 weeks. The training took place on weekdays with approximately two non-training days in between, dependent on the therapeutic and school program of the children,. During every training session, which lasted for about 30 min, two of the training tasks were completed using a counterbalanced schedule, so every EF was trained four times over the course of the study. During the training sessions, youngsters had 3 min breaks between each task. During this time, they were allowed to go online or read a book. Most youngsters spent this time on Facebook.

The youngsters filled in the BRIEF-SR on paper before participating. At the same time, educators filled in the BRIEF. Cognitive performances were evaluated during two measurement sessions, immediately preceding the training and immediately after the computer training (June 2014) and were not connected to the training tasks in the schedule. Next, the youngsters filled in the BRIEF-SR again (this time online). Additionally, the educators filled in the BRIEF again. Intake, pre-training and post-training measurements of BMI were done by a dietician at the center, while a 2 month-follow-up measurement of weight was collected by telephone (August 2014) (see also Fig. 4).

2.6. Statistical analyses

Baseline differences between conditions were tested with independent samples T-tests. Long term effects of the training on weight were assessed with repeated measures ANOVA, with weight as a 3-level within-subjects factor (pre-test, post-test, follow up) and condition as the between-subjects factor. To assess the
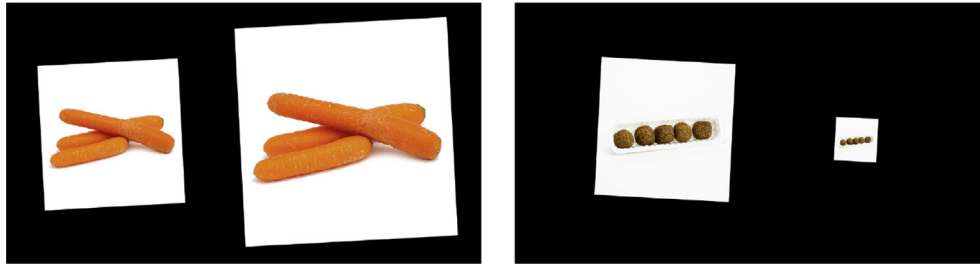
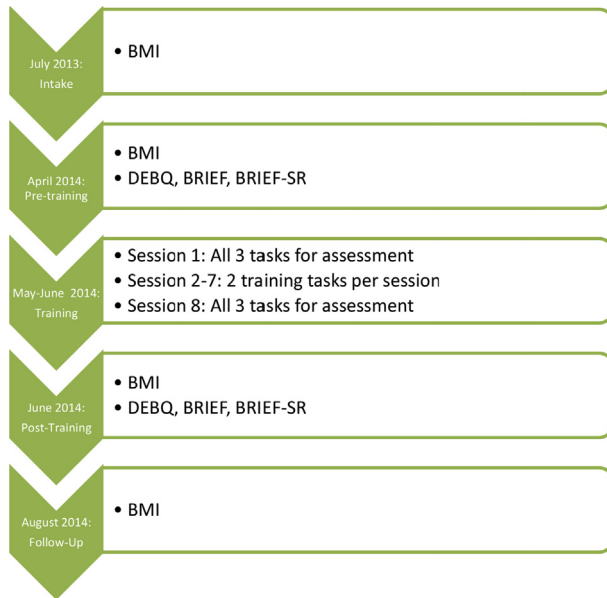**Fig. 3.** Example of the approach/avoidance task (AAT).

Fig. 4. Procedure.

differences between pre- and post-training scores on the BRIEF inhibition, and BRIEF-SR inhibition, two repeated measures ANOVA's were used, using assessment time as a 2-level within-subjects factor (pre-test vs. post-test) and condition as a 2-level between-subjects factor (control vs. training). A significance-level of 0.05 was used on all tests. Effect sizes were also calculated for the evolutions on the cognitive tasks. As the power in this study was arguably too low to detect significant effects, we chose not to report inferential statistics for these measures.

3. Results

3.1. Acceptability and feasibility

Forty-six obese participants were enrolled, and 43 completed the training program and the post-treatment assessment. We received no information about why the children who withdrew did not complete the program. The sessions were completed accurately and were rated as moderately acceptable to the participants. The clinicians reported the training as acceptable as it required a minimum of time and resources. There were no outliers and the data were normally distributed.

3.2. Descriptive statistics

Sex ratio (girls/boys) was 9/12 in the training and 7/8 in the control condition. The X^2 was not significant with $p = .736$.

Independent samples T-tests were used to analyze differences at baseline in BMI, executive functions, eating behavior, and training tasks between participants of the different treatment conditions. There were no significant differences between the conditions for any of the variables (Table 1).

3.3. Cognitive training effects

Table 2 features the mean values before and after training, and 95% confidence intervals (CI - mean differences) and effect sizes (ES) for the evolutions on the cognitive tasks. For all three tasks, there were no significant changes over time between the pre- and post-training measurements.

3.4. Evolution of weight

The assumption of sphericity was violated, and therefore a Greenhouse-Geisser correction was applied. There was no significant interaction effect between time (pre-post) and condition on weight ($F(1,34) = 0.765$, $p = .388$; partial $\eta^2 = 0.022$). There was also no significant interaction effect between time (pre-post-FU) and condition on weight, but there was a significant effect of weight over time ($p = .009$, partial $\eta^2 = 0.247$). Pairwise comparisons (Fig. 5) showed that there was a significant difference in weight between pre-training and post-training measurement ($p = .000$; Mean difference $= -5.241$; $SD = 0.514$) and between post-training and follow-up measurement ($p = .035$; Mean difference $= 3.980$; $SD = 1.781$). There was no significant difference in weight between pre-training and follow-up measurement ($p = .433$; Mean difference $= -1.261$; $SD = 1.781$). Only 25 youngsters responded at the collection of follow-up data; with N = 12 for the control group and N = 13 for the training group. Therefore, analyses were repeated with intention to treat analyses: this revealed neither a significant interaction effect ($F (2.33) = 0.583$; $p = .631$).

3.5. Inhibition

The BRIEF Inhibition subscale showed a significant interaction between time and condition ($F (1,34) = 12,343$, $p = .001$, partial $\eta^2 = 0.266$; Fig. 6), with the inhibition score decreasing (indicating less inhibitory problems) in the training group from pre-training ($M = 15.524$, $SD = 1.125$) to post-training ($M = 14.286$, $SD = 1.165$), while inhibition increased (indicating more inhibitory problems) in the control group from pre-training ($M = 18.133$, $SD = 1.331$) to post-training ($M = 19.267$, $SD = 1.379$). Between-group difference at posttest was also significant ($t (34) = 2.760$, $p = .009$), while at baseline this was not significant (see Table 1). For the BRIEF-SR Inhibition subscale, there was no significant interaction effect ($F < 1$; $p = .928$).

Table 1
Baseline comparisons between conditions.

	Control (N = 15)		Training (N = 21)		Independent T-Test	
Age	Mean	SD	Mean	SD	Mean Diff.	Sign.
Pre-test	12.00	1.41	12.00	1.55	-.10	.851
Adjusted BMI	Mean	SD	Mean	SD	Mean Diff.	Sign.
Pre-test	130.67	18.59	136.18	18.78	−5.51	.389
BRIEF: Educators	Mean	SD	Mean	SD	Mean Diff.	Sign.
Inhibition	18.13	5.94	15.52	4.52	2.61	.143
BRIEF: Self-report	Mean	SD	Mean	SD	Mean Diff.	Sign.
Inhibition	19.06	4.26	17.14	4.00	1.91	.178

Table 2
Task related outcome measures.

	Training (N = 21)		Control (N = 15)		ES & CI; change over time
	Mean	SD	Mean	SD	
AAT approach unhealthy food bias (ms)					
Pre-training	41.71	147.05	−3.67	108.40	$\eta_p^2 = .063$
Post-training	−35.52	155.91	−23.27	142.77	[-16.4;113.3]
ES & CI between conditions	$\eta_p^2 = .006$ [-89.3;56.2]				
VPT attention towards unhealthy food bias (ms)					
Pre-training	6.30	24.34	8.86	29.30	$\eta_p^2 = .004$
Post-training	9.40	34.56	12.00	39.50	[-20;13.7]
ES & CI between conditions	$\eta_p^2 = .004$ [-12.6;17.8]				
Go/No-go mean reaction times on Go trials with unhealthy food (ms)					
Pre-training	738.39	87.77	743.86	98.09	$\eta_p^2 = .098$
Post-training	773.26	103.93	770.34	109.84	[-63;1.8]
ES & CI between conditions	$\eta_p^2 = < .001$ [-58.9;61.5]				
Go/No-go mean reaction times on Go trials with healthy food (ms)					
Pre-training	730.23	69.81	721.89	82.97	$\eta_p^2 = .064$
Post-training	745.98	98.50	753.97	76.12	[-56.4;8.6]
ES & CI between conditions	$\eta_p^2 = < .001$ [-47.8;47.5]				
Go/No-go total number of errors on no-go trials with unhealthy food					
Pre-training	0.95	0.95	0.80	0.78	$\eta_p^2 = .085$
Post-training	0.60	0.82	0.40	0.74	[-.062;0.812]
ES & CI between conditions	$\eta_p^2 = < .001$ [-47.8;47.5]				
Go/No-go total number of errors on no-go trials with healthy food					
Pre-training	0.80	0.89	0.67	0.62	$\eta_p^2 = .012$
Post-training	0.80	0.83	0.47	0.52	[-.222;0.422]
ES & CI between conditions	$\eta_p^2 = .039$ [-.646;0.179]				

VPT=Visual Probe Attention Task; AAT = Approach Avoidance Task; Go/No-Go = Inhibition Task. ES = Effect Size; CI= Confidence Interval of mean differences.
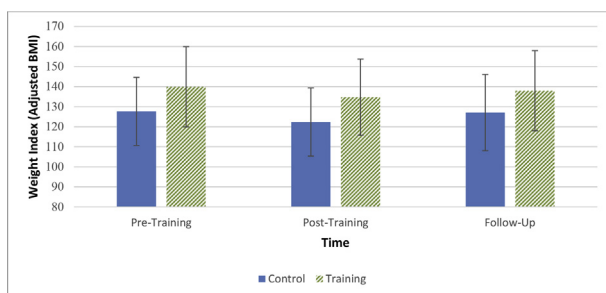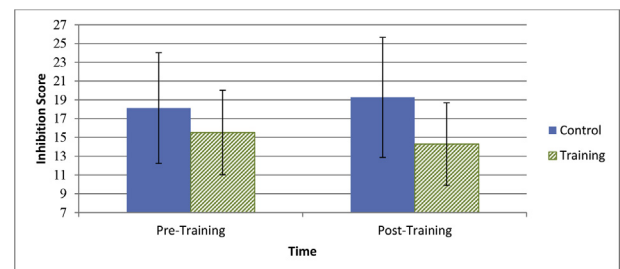

Fig. 5. Evolution of weight.

Fig. 6. Inhibition as scored on the BRIEF by the educators.

4. Discussion

The goal of the current study was to evaluate the acceptability, feasibility and initial effectiveness of a training program of attention, inhibition and automatic approach tendencies for weight-loss maintenance in obese youth after being discharged from an inpatient treatment. We found that the training program was feasible and acceptable to the majority of participants and clinicians. The sessions were acceptable to most participants. Only 3 youngsters withdrew from the program. The sessions were completed accurately by the 43 completers, with reaction times within the normal range. The clinicians in the residential setting perceived the program as feasible with only minimal required time, training and resources. However, the follow up assessments suffered from considerable drop outs.

Furthermore, although this study was designed as a pilot and not adequately powered to identify group differences, the initial findings suggest that the training did not result in changes in inhibition, attention or automatic approach tendencies: on average, youngsters performed no better on the tasks after 6 training sessions than they did before. Therefore, we have to assume that the

training tasks used in this pilot study were ineffective in this group of obese children. Additionally, given that the initial findings show no indication of improving the targeted mechanisms, it is not surprising that there was neither a significant effect in the maintenance of weight loss of youngsters who received the training compared, to youngsters in the active control condition.

Several lessons for future research can be drawn from these results. As previous research provided repeatedly evidence for the trainability of these mechanisms (Simons et al., 2016), it seems justified to consider potential explanations for the current results. There appeared to be a broad variance in the scores at pre-training in both the attention task and the automatic approach task: some youngsters had scores indicating a bias towards unhealthy food, some youngsters scored as having a bias towards healthy foods, and some youngsters scored reasonably neutral. The same variance was found at post-training. This indicates that some youngsters had no attentional bias for unhealthy food before the training sessions and will not benefit from a training. However, it is also possible that the tasks were not successful in correctly measuring attentional bias in obese children. (1) While previous research has shown that obese people might be more sensitive to external food cues than average weight people (e.g. Nijs, Muris, Euser, & Franken, 2010; Werthmann et al., 2011), these studies compared all food cues to neutral cues, and not healthy food cues to unhealthy food cues. It is possible that the participants of the current study were biased towards food in general, and therefore showed such varied based results, ranging from a bias for healthy food cues to a bias for unhealthy food cues. (2) It is also possible that the training insufficiently follows the principles of category-level training. This means that the training has to tackle types of unhealthy eating behaviors belonging to one category, including all kinds of products of a certain category (i.e. fast-food) (Veling et al., 2017). Category-level training is the opposite of stimuli-level training, which aims to tackle specific unhealthy eating behaviors (i.e. trying to avoid overeating in hamburgers). Stimuli-specific interventions can be helpful; however, it needs an individually tailored approach with very specific stimuli (Chen et al., 2016). After all, when the individual is not frequently tempted by a certain food it is unlikely that the training will have any effect because it is not targeting a problematic behavior (Chen et al., 2016). The advantage of category-level training is that transfers can be made to all kinds of daily situations. In future research it is needed to be more clear about the distinction, and to pay more attention to the transfer between products when category-level training is chosen. For example, it can be helpful to train with clearly-defined categories of stimuli that include different kinds of matching stimuli (i.e. fast-food: hamburgers, fries, etc.), and to contrast it to non-food items (i.e. animals or clothes) rather than different food stimuli (Folkvord et al., 2016; Lawrence et al., 2015; Adams et al., 2017). (3) It is also possible that the pictures used in the task were too ambivalent. While some food cues were clearly unhealthy (such as fast-food) and some food cues were clearly healthy (such as fruit), many others could be considered more neutral (e.g. the pictures of chocolate paste and jam; both foods that the youngsters are allowed to choose from for breakfast in the clinic). Furthermore, some pictures show an individual eating the food, while others display only the food itself. This variation could therefore cause unwanted noise in the data. This could be solved in future research by pre-testing the stimuli, and specifically ask for personal relevance or by consulting a dietician so that the training stimuli did not overlap with the specific diet of the youngsters during treatment.

(4) In this study, the instructed response contingencies between healthy versus unhealthy food was more similar between the instructions in the control training and the post-training assessment (with a fifty-fifty matching) than between the instructions in the active training and the post-training assessment. The switch between these contingencies may have had a negative influence on participants' performance on the post-training assessments in the active training group. As such, future research should consider including additional validated outcome measures that are different from the training task altogether, such as stimulus devaluation. (5) Several youngsters indicated that looking at pictures of food — whether healthy or unhealthy — made them hungry. In an effort to combat this effect, some youngsters indicated that they made a conscious effort not to look at the pictures and to keep their focus on the corners in the attention task and on the tilt of the picture in the automatic approach task.

(7) Training inhibitory control as the sole top-down process may be insufficient. Previous studies investigating the effects of training executive functions in youngsters used not only an inhibition training but also a working memory training (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009; Verbeken et al., 2013). Although studies suggest that the ability to control impulses is a possible factor in maintaining weight (Braet, Claus, Verbeken, & Van Vlierberghe, 2007; Nederkoorn, Jansen, Mulkens, & Jansen, 2006), it is possible that training working memory has a more general effect on improving executive functions (and therefore also inhibitory control) than the specific training of inhibition has. (8) Although studies training inhibitory control (Houben & Jansen, 2011) and automatic approach tendencies (e.g. Wiers et al., 2010) suggest that these training programs can be effective, it should be noted that they are generally done with adults. It is possible that, to gain similar positive effects with youngsters, the training should be longer or contain other elements, such as a gaming environment (Boendermaker, Prins, & Wiers, 2015). (9) It is also possible that we tested a very specific inpatient population, since the youngsters at the Zeepreventorium are often confronted with many comorbid problems, at a medical as well as a psychological level. There is a possibility that the target group of this kind of programs are different from other obese, treatment-seeking youngsters. For example, it is possible that they already start with a higher amount of impulsivity, attentional or other behavior regulation problems. In future research, it is necessary control for this kind of baseline problem-levels, and also to test this types of training with other (outpatient) programs in different groups of obese youngsters.

Lastly, the only significant difference found post-training between the training group and the control group was on inhibition as measured by the educators via the BRIEF. Educators were asked to focus on the last month of treatment to answer the BRIEF post-training. However, it should be noted that the last month of treatment is a very emotional and stressful month in the center. The fact that the youngsters in the control condition had more problems with regulating their emotions, combined with the fact that it was a very emotional and stressful last month, might have caused the educators to see larger differences between the youngsters than they did before.

The current study was set up as a pilot, and generalization of the findings is not warranted as the study sample was small with only 36 participants. Additionally, only 25 youngsters responded to inquiries at follow-up. Power calculations suggest that for an effect size of $f = 0.10$ a total number of 128 patients randomized 1:1 ($n = 90$ in each group) to two active intervention groups is needed to detect significant between group (EF vs CC) over time differences with a significance level of 0.05 and statistical power of 0.80. However, the pilot-study delivers us important lessons about implementation issues as well: First, youngsters in elementary school received the training sessions after school hours and were clearly less motivated than the youngsters in high school, who received the training during school hours. Although age was taken

into account at randomization of the conditions, the lower motivation of half the participants might influence the training effect. These statements were made based on daily reported observational data of the researcher monitoring the training sessions. It forms a limitation of the study that motivation was not explicitly measured. In future research, it might be very important to change the age requirement from age 10 to 16 to age 12 to 18, and to add game-elements and motivational enhancement activities as was done by Verbeken et al. (2013). Second, because of limitations in time to use the computers in the treatment setting (3 h a day on 3 days a week), up to 6 youngsters followed the training in the same room. This led to some distraction. Therefore, individualized training is recommended.

In conclusion, the current pilot-study failed to demonstrate the effectivity of a EF-training in obese children to improve weight-loss maintenance after residential therapy. However, the pilot-study provides us clear lessons regarding unresolved questions to be answered on the delivery of the training and the implementation. Further research is now ongoing to study an optimized training of attentional bias, inhibition and automatic approach tendencies relevant for youngsters with obesity.

Declaration of interest

All authors do not have any (financial) interests that might be interpreted as influencing the research. The reported data were collected as part of a larger research project. There is however no prior publication with these data. Ethical standards were followed in the conduct of the study. The local Ethical Committee of Ghent University has approved the study. Informed consent was obtained from both the children (active) and their parents (parents).

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