Satiety regulation in children with loss of control eating and attention-deficit/hyperactivity disorder: a test meal study

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Abstract

Children with loss of control (LOC) eating and attention-deficit/hyperactivity disorder (ADHD) are at risk for excessive weight gain. However, it is unclear whether or not these children show disturbances in hunger and satiety regulation. The goal was to examine the food intake and sense of LOC over eating as well as LOC eating-related characteristics during test meal in children with LOC eating and ADHD. Children aged 8-13 y with LOC eating (n = 33), ADHD (n = 32), and matched healthy controls (n = 33), consumed a test meal consisting of their chosen lunch food, with the instruction to eat until feeling full. Sense of LOC over eating, desire to eat, feelings of hunger, and liking of food were repeatedly assessed during test meal. Children with LOC eating and ADHD did not show a higher food intake at maximum satiety compared to control children. Sense of LOC over eating was significantly higher in children with LOC eating compared to children with ADHD and matched controls. Secondary analyses revealed that children with LOC eating ate marginally faster than control children. Both children with LOC eating and ADHD reported greater desire to eat, feelings of hunger, and liking of food during test meal than control children. Even though the results did not reveal statistical evidence to support the assumption of a disturbed food intake in children with LOC eating and ADHD, LOC eating related characteristics were significantly higher in these children compared to the control children. Sense of LOC over eating was confirmed as a specific characteristic of LOC eating. The examination of behavioral indicators of hunger and satiety dysregulation should be complemented with physiological indicators in future research.

Keywords: satiety regulation; test meal; LOC eating; ADHD; middle childhood

Words: 277

Introduction

Loss of control (LOC) eating is a common phenomenon in middle childhood with a prevalence of 9.3% (Tanofsky-Kraff et al., 2004). LOC eating is defined as eating an objectively or subjectively large amount of food accompanied by a sense of LOC over eating (American Psychiatric Association, 2013). Children with LOC eating present with increased eating disorder and general psychopathology (Ackard, Neumark-Sztainer, Story, & Perry, 2003; Glasofer et al., 2006; Goossens, Braet, & Decaluwé, 2007; Hilbert & Czaja, 2009; Tanofsky-Kraff et al., 2004) as well as overweight and obesity (Goldschmidt, Aspen, Sinton, Tanofsky-Kraff, & Wilfley, 2008; Tanofsky-Kraff, Yanovski et al., 2009). Childhood LOC eating is predictive of later onset of partial-/full-syndrome binge-eating disorder (BED) (Hilbert & Brauhardt, 2014; Hilbert, Hartmann, Czaja, & Schoebi, 2013; Tanofsky-Kraff et al., 2011) and may predispose for excess weight gain and associated metabolic sequelae (Tanofsky-Kraff, Yanovski et al., 2009).

Laboratory test meal studies showed that children with LOC eating consume more food than their control counterparts (Hilbert, Tuschen-Caffier, & Czaja, 2010; Mirch et al., 2006; Tanofsky-Kraff, McDuffie et al., 2009). Mirch et al. compared the energy intake and satiety ratings in two test meals of 60 6- to 12-year-old children with or without LOC eating (Mirch et al., 2006). The LOC group consumed more energy, and the duration of self-reported satiety was shorter than that of the control group. A higher energy intake was also found in a test meal study by Hilbert et al. with 120 8- to 13-year-old children with or without LOC eating (Hilbert et al., 2010). Tanofsky-Kraff et al. investigated the energy intake in 177 8- to 17-year-old youth and found that those with LOC eating consumed more high calorie foods and a greater percentage of calories from carbohydrates than youth without LOC eating, suggesting a link between consumption of carbohydrates and LOC eating (Tanofsky-Kraff, McDuffie et al., 2009). However, whether or not these children need to eat a greater amount of food in order to feel satiated, remains unclear. Addressing this question in adults, Sysko et al. compared the satiety ratings of 36 individuals with or without BED in two test meals and showed that in order to feel full the individuals with BED ate significantly more than the normal weight and overweight control groups (Sysko, Devlin, Walsh, Zimmerli, & Kissileff, 2007).

Several mechanisms may contribute to the overconsumption of children with LOC eating. It might be triggered by learned associations between eating palatable foods and its physiological consequences, as pointed out for overweight individuals (Jansen, 1998) who overate after tasting bites of palatable food (Jansen et al., 2003). Also, children with LOC eating and adults with BED ate more snack and dessert-type food in a large array meal than their weight-matched control counterparts (Tanofsky-Kraff, McDuffie et al., 2009; Yanovski et al., 1992). Several cross-sectional studies have shown that adults with BED have larger gastric capacity (Geliebter, Yahav, Gluck, & Hashim, 2004; Hellström et al., 2004) and display abnormalities in key appetitive hormones like insulin and ghrelin (Geliebter, Yahav, Gluck, & Hashim, 2004), which could lead to impaired satiety feelings. It is not yet clear whether these abnormalities are consequences of rather than causes of BED, although some literature suggests that such abnormalities are a secondary response to overeating rather than causal (Geliebter, 2002; Tschöp, Weyer, Tataranni, Devanarayan, Ravussin, Heiman, 2001). This disturbance could also exist in children with LOC eating, because of their increased food intake, hunger, and desire to eat compared to control children (Hilbert et al., 2010; Mirch et al., 2006), and since a sense of LOC over eating preceded greater food intake (Hilbert et al., 2010). These LOC eating-related characteristics might be associated with impaired satiety feelings. Increased eating speed might depict another LOC eating-related characteristic contributing to impaired satiety feelings, as authors concluded who found that overweight children ate significantly faster than normal weight children (Barkeling, Ekman, & Rössner, 1992; Laessle, Lehrke, & Dückers, 2007; Overholser & Beck, 1985).

Further, impulsivity and inattention, both characteristics of attention-deficit/hyperactivity disorder (ADHD) (American Psychiatric Association, 2013) and common in youth and adults with obesity (Altfas, 2002; Cortese et al., 2008; Nederkoorn, Braet, van Eijs, Tanghe, & Jansen, 2006) and adult binge-type eating disorders (ED) (Fernández-Aranda et al., 2013; Rosval et al., 2006; Waxman, 2009), are associated with increased food intake and snack, binge or LOC eating in youth (Hartmann, Rief, & Hilbert, 2012; Nederkoorn et al., 2006; Reinblatt et al., 2015; Wilhelm et al., 2011) and adults (Cortese, Dalla Bernardina, & Mouren, 2007; Fernández-Aranda et al., 2013; Waxman, 2009). Youth with LOC eating are more impulsive than control children (Hartmann, Czaja, Rief, & Hilbert, 2010; Reinblatt et al., 2015). Reward sensitivity and cue reactivity, both common traits of impulsivity, are increased in youth with LOC eating and ADHD (American Psychiatric Association, 2013; Hartmann et al., 2010; Reinblatt et al., 2015) and may elicit binge-eating behaviors which could possibly lead to excessive weight gain (Cortese & Vincenzi, 2012; Davis, Levitan, Smith, Tweed, & Curtis, 2006; Dawe & Loxton, 2004). Since both LOC eating and impulsivity are linked to increased food intake and overweight or obesity, their comorbidity might lead to a disproportionally high weight gain. Even though LOC eating and ADHD are closely linked (Cortese et al., 2007; Fernández-Aranda et al., 2013), a sense of LOC over eating is assumed to differentiate children with LOC eating and ADHD.

In this context, we examined behavioral indicators of the satiety regulation in children with LOC eating and ADHD in a laboratory test meal. We hypothesized that (1) children with LOC eating or ADHD consume more (g) in order to be satiated and (2) that children with LOC eating experience a greater sense of LOC over eating during test meal than ADHD and control children. For secondary hypotheses, we investigated, whether children with LOC eating or ADHD, eat faster, have a higher energy intake (kcal) at maximum satiety and consume more carbohydrates, report greater desire to eat, feelings of hunger, and liking of food than control children.

Material and Methods

Recruitment and Sample

Children aged 8-13 y were recruited in regular schools (2nd to 6th grade) in three cities of Switzerland and surrounding areas. Study languages were German and French. Schools of all socioeconomic backgrounds were included and consent was sought by cantonal boards of education, school boards, and parents. Eligibility criteria were assessed using telephone interviews. Eligible families were invited to the University for in-person diagnostic interviews in order to ensure that the inclusion and exclusion criteria were met. At the outset, informed consent and assent were sought by the participating parent and the child, respectively. The test meal study was part of the Swiss University Study of Nutrition (SUN) and was approved by the Ethics Committees of the Canton of Fribourg and by the departmental committee of Psychology of the University of Fribourg. Participants were recruited between November 2011 and July 2014.

Children with LOC eating were included if they experienced at least three episodes of LOC eating during the last three months, which was accompanied by at least some degree of distress and/or two of five behavioral symptoms (American Psychiatric Association, 2013; Hilbert & Czaja, 2009; Marcus & Kalarchian, 2003). These broadened DSM-5 criteria were based on a classification analysis of childhood LOC eating (Hilbert & Czaja, 2009) and were assessed using the Eating Disorder Examination adapted for Children (ChEDE; Bryant-Waugh, Cooper, Taylor, & Lask, 1996; German version: Hilbert, 2016; French version: Munsch & Hilbert, in prep.), which has a good internal consistency and high interrater reliability (Watkins, Frampton, Lask, & Bryant-Waugh, 2005). The internal consistency in this sample was good with $\alpha = 0.83$. The ADHD group had to fulfill the DSM-IV-TR criteria for ADHD including all subtypes applying the Schedule of Affective Disorders and Schizophrenia for School-age Children – Present and Lifetime Version (K-SADS: Puig-Antich & Chambers, 1978; German version: Delmo, Weiffenbach, Gabriel, & Poustka, 2000; French version: Rothen et al., 2009) with adequate reliability and validity (Kaufman et al., 1997). Inclusion criteria for control children were absence of past or present LOC eating, of compensatory behaviors (such as self-induced vomiting, misuse of laxatives or diuretics, fasting or excessive exercise), of an eating disorder, and of more than 3 symptoms of hyperactivity/impulsivity and inattention. Further inclusion criteria that applied to all groups were ages 8-13 y; availability for study participation; informed consent or assent of parent and child; attendance at a regular school; and sufficient German or French language skills of the child and participating parent. Exclusion criteria were compensatory behaviors (> 1 episode/past 3 months); psychotic disorders of child or parent; current treatment for overweight; medication with an effect on eating behavior; and serious medical conditions with an effect on eating behavior. Children with ADHD receiving stimulant prescriptions had to abstain from medication for at least 48 hrs before study participation. The control group (CG) was stratified to the LOC group for age, sex, and percentile of body mass index (BMI; kg/m^2).

A total of 1741 children were screened in regular schools for the purpose of the SUN study. After the telephone screening, 132 children remained eligible for the diagnostic visit; subsequently another 32 children were excluded from the study according to the above-described criteria. One child with ADHD and one control child were excluded from the analysis because of missing data. Thus, the overall study sample consisted of 98 children (LOC: n = 33; ADHD: n = 32, CG: n = 33), with the majority being female (Table 1). Nine (27.3%) children of the LOC group fulfilled the criteria for both the LOC and the ADHD group.

Body height and weight for calculating BMI and BMI standard deviation scores (BMI-SDS) were measured using a calibrated scale and a stadiometer. According to the definition of the Workgroup for Adiposity in Childhood and Adolescence (Arbeitsgemeinschaft für Adipositas im Kindes- und Jugendalter, 2014), 6.1% of the children were underweight (BMI $< 10^{th}$ BMI percentile), 69.4% were normal weight ($10^{th} – 90^{th}$ BMI percentile), 15.3% were overweight ($> 90^{th}$ BMI percentile), and 9.2% were obese ($> 97^{th}$ BMI percentile). Sociodemographic and anthropometric characteristics did not differ between the LOC group and the matched CG ($p > 0.01$; Table 1). However, the LOC group had a significantly higher BMI than the ADHD group ($p < 0.01$), and the CG was significantly older than the ADHD group ($p < 0.01$). Of the 32 children with ADHD 17 (and 2 of the 9 children with a mixed diagnosis) had the inattentive type, 4 (and 1 of the children with mixed diagnosis) had the impulsive type, and 11 (6 of the children with mixed diagnosis) had the mixed type. Of the 32 children with ADHD 13 (and 1 of the children with mixed diagnosis) had a mild symptomatology, 13 (and 5 of the children with mixed diagnosis) a medium symptomatology, and 6 (3 of the children with mixed diagnosis) a severe symptomatology.

Procedure

After an overnight fast, the child and parent arrived at the laboratory at 8.30 a.m. and the child was asked to eat a standardized breakfast consisting of 35 g of Choco Flakes or Corn Flakes together with 150 ml of whole milk and 150 ml of orange juice (300 kcal). Hunger and satiety ratings were assessed before and after breakfast (see control variables). Both the child and the parent had to ensure that the child did not consume any additional food or liquid (other than water) before returning to the laboratory 4 hrs later. Prior to the test meal, the child was asked to select from a list of typical lunch foods (Pizza prosciutto, Pizza formaggi, Cannelloni, Lasagne verdure, Oven-fries) his or her favorite food. Energy content and macronutrient composition are displayed in Table 2. The child was seated in a chair in a light- and temperature-controlled laboratory and was offered 700g of the chosen food with the instruction to “eat until you feel full.” The food was placed upon a universal eating monitor (Kissileff, Klingsberg, & van Italie, 1980) that continuously weighed the remaining food with a calibrated balance that was hidden under the table (MSU5201S-000; Sartorius Cubis balance; Switzerland). Before and after the meal, the food was additionally weighed on a calibrated tabletop scale (CPA223; Sartorius, Switzerland). Prior to the test meal, at 50g intervals during the meal, and after the meal the child was asked to rate feelings of LOC over eating, of desire to eat, satiety, hunger, and liking of the food on a Visual Analog Scale (VAS) ranging from 0 = “not at all” to 6 = “extremely” using the Sussex Ingestion Pattern Monitor software (SIPM; University of Sussex). The test meal was recorded and observed with a video monitor, in order to assess the time spent eating. After the test meal children rated the representativeness of their eating behavior and of the test meal (see control variables).

Measures

Main Dependent Variables

The main outcome variable for food intake at maximum satiety was defined as the amount of food eaten (g) at the time point of the highest individual satiety rating on the VAS scale. The second main outcome variable for LOC eating-related characteristics was the VAS-rating of sense of LOC over eating.

The repeated assessments of sense of LOC over eating featured a zero-inflated and skewed distribution. To adjust to these data characteristics, this variable was transformed into a dichotomous measure (0 = no sense of LOC over eating; 1 = at least some sense of LOC over eating). The code 1 comprises previous codes >0 to 6.

Secondary Dependent Variables

Secondary variables for the analyses of the food intake included the eating speed, defined as the food intake (g) or energy intake (kcal) at maximum satiety divided by the eating duration (s) at maximum satiety. The start and end point of eating were assessed with the help of the video recording (time of VAS ratings was subtracted from the time eaten).

Further secondary variables included the total food intake (g), energy intake (kcal), and carbohydrate intake (g) at maximum satiety. Food intake after maximum satiety is not presented, since only a total of 5 children (2 children with LOC eating, 2 control children, 1 child with ADHD) continued eating after their maximum satiety rating.

Similar to the variable sense of LOC over eating, secondary LOC eating-related characteristics desire to eat, feelings of hunger, and liking of food also had to be transformed due to a zero-inflated and skewed distribution. Therefore, the raw scores of desire to eat, feelings of hunger, and liking were transformed into rank scores, using 1 standard deviation unit from the mean. The resulting variables reflected a rank ranging from low to extreme. Different methods for sense of LOC eating and the secondary LOC eating-related characteristics were applied because of their specific distributions. Distribution analyses showed that data reliably represented the different degrees of secondary LOC eating-related characteristics. In contrast, sense of LOC eating was rarely endorsed, and only by a few children (almost only children with LOC eating). For the variables desire to eat and feelings of hunger, 4 ranks were obtained (1 = low; 2 = medium; 3 = high; 4 = extreme), and for liking 3 ranks resulted (1 = low; 2 = medium; 3 = high).

Classificatory Variables: Dual Diagnosis and High vs. Low Recurrent LOC Eating

As 9 children of the LOC group had ADHD as a comorbid diagnosis, this group with a dual diagnosis of LOC eating and ADHD was compared to the other groups (LOC, ADHD, CG) for all dependent variables in separate analyses. In order to compare children with LOC eating with clinical versus sub-threshold levels of LOC eating, differences between those with high versus low recurrent LOC eating were analyzed for all dependent variables in secondary analyses. Children with high and low recurrent LOC eating were originally derived in a laboratory test meal study through a cluster analysis based on DSM-IV-TR criteria of BED (Hilbert et al., 2010). As the behavioral features and distress were part of the inclusion criteria for this, but not the preceding study; in the current study, the two groups were formed based on frequency of LOC eating only. Thus, children with high recurrent LOC eating were defined as reporting LOC eating at least once per week for the last 3 months (n = 15/33; corresponding to the DSM-5 criteria of BED) (American Psychiatric Association, 2013) and those with low recurrent LOC eating were defined as reporting LOC eating once to twice per month for the last 3 months (n = 12/33).

Control Variables

Prior to the test meal, the Barratt Impulsiveness Scale 11 (BIS-11: Fossati, Barratt, Acquarini, & Di Ceglie, 2002; German version: Hartmann, Rief, & Hilbert, 2011; French version: Baylé et al., 2000) was applied with sufficient internal consistency ($\alpha = 0.73$). Significant group differences were found (Table 1) and post hoc analyses indicated that children with LOC eating and ADHD scored significantly higher on the BIS-11 total score compared to control children (both $p < 0.001$), but did not differ from each other ($p > 0.05$). Hunger and satiety ratings were assessed before and after the standardized breakfast. The groups did not differ in their ratings of hunger and satiety, neither before nor after breakfast (all $p > 0.05$). The macronutrient composition of the test meal foods (carbohydrate, fat, protein) was determined based on the nutritional information provided by the food producer (Table 2). Further, a semi-structured, post-experimental interview was conducted in order to assess the ecological validity of the experiment, asking about the representativeness of the child’s eating behavior and food selection as well as the tastiness of the food offered (0 = “not at all” to 6 = “very similar/good”).

Manipulation Check

The experimental procedure was piloted in 15 9- to 12-year-old non-clinical children, prior to the first experimental test meal reported in this study.

The test meal food offered and chosen by the children did not differ between groups in terms of kcal and macronutrient composition (carbohydrates, protein, fat; all $p > 0.05$).

Concerning ecological validity, during the post-experimental interview children rated the test meal food and their eating behavior at the test meal as medium representative (2.68 ± 1.87 and 3.89 ± 1.72, respectively). However, the control children rated the test meal food and their eating behavior as more representative than the children with LOC eating or ADHD (4.64 ± 0.25 compared to 3.39 ± 0.30 and 3.55 ± 0.32, respectively; both $p < 0.01$). All the children in each group rated the test meal food as very tasty (5.01 ± 1.17; $p > 0.05$).

Data Analytic Plan

Data on the individual VAS ratings were missing for 3 children due to technical problems. Since the missing data had no effects on the results we kept these children in all analyses. Multiple general linear regression analyses were used to test group differences in total food intake at maximum satiety (hypothesis 1) as well as in the secondary variables eating speed, energy intake at maximum satiety, and carbohydrate intake. The three groups were entered into the regression with dichotomous indicators, where the CG served as the baseline group. All analyses were adjusted for age, sex, and BMI-SDS.

Given the categorical nature of the variables, we analyzed group differences of the variable sense of LOC over eating (hypothesis 2) and the other secondary LOC eating-related characteristics during the test meal using generalized linear mixed model (GLMM) analyses. GLMM analyses have the advantage that they can handle multinomial distributions and repeated measures with missing data and that they can take into account the clustering and serial correlations for each individual’s measurements. Dichotomous indicators were used to reflect the three groups, where the LOC group served as the baseline group for the analysis of sense of LOC over eating, in order to compare the LOC group to the ADHD and CG. For the secondary GLMM analyses of desire to eat, feelings of hunger, and liking of food the CG served as the baseline group, in order to compare the CG to the LOC and ADHD groups. These dichotomous group indicators were then tested along with the covariates age, sex, and BMI-SDS, which were reported only when significant. Due to sequential data of repeated measures, a first-order autoregressive structure was used, assuming a systematic correlation between each adjacent pair of data points in the series (Field, 2009).

Regarding the classificatory variables, we explored effects of the dual diagnosis in both the multiple linear regression analyses and in the GLMM, in order to test whether the dual diagnosis of LOC eating symptoms and ADHD was of added predictive value. Using an equivalent strategy, we explored differences within the LOC group, comparing children with high vs. low recurrent LOC eating. A power analysis for multiple linear regression analyses revealed an adequate power for medium effects (.80) and an excellent power for large effects (.99). For hypotheses with repeated measures, we used the Optimal Design Software (Raudenbush, et al., 2011) to approximate the statistical power for a group comparison based on the current study design. The estimated power was good (>.80) for medium effects and excellent (> .99) for large effects. Statistical testing was performed assuming a two-tailed α of 0.05. All analyses were performed with SPSS 23 (SPSS Inc, Chicago, IL).

Results

Primary Variables

The mean maximum satiety rating was 5.75 (± 0.62; $p > 0.05$). As displayed in Table 3, children with LOC eating and children with ADHD did not show a higher food intake (g) at maximum satiety than control children (both $p > 0.05$).

As displayed in Table 3 and Figure 1, sense of LOC over eating during the test meal was significantly higher in the LOC group than in the ADHD group and CG (both $p < 0.01$).

Secondary Variables

Concerning the eating speed (Table 3), there was a trend towards statistical difference with children with LOC eating eating faster (g/s) than control children ($p = 0.054$), but the ADHD group did not differ in eating speed compared to the CG ($p > 0.05$). Also, there was a trend towards statistical difference, according to which children with LOC eating consumed more kcal/s than control children ($p = 0.065$), but no group differences were found for the total time eaten (s) (all $p > 0.05$). The total food intake (g) did not differ significantly between groups (all $p > 0.05$). Further, children with LOC eating showed a higher carbohydrate intake (g) than CG (both $p < 0.05$) in the first model without the covariates, whereas no significant group differences were found for carbohydrate intake in the complete model (all $p > 0.05$). Secondary analyses concerning the LOC eating-related characteristics (Table 4, Figure 1) revealed, that children with LOC eating and those with ADHD showed a greater desire to eat, greater feelings of hunger, and greater liking of food during test meal than control children (all $p < 0.05$, after the Bonferroni correction was applied). With respect to control variables, age and BMI-SDS emerged as significant predictors of liking of food, suggesting that younger children and children with higher BMI reported greater liking of food irrespective of diagnostic status ($p < 0.05$).

Classificatory Variables: Dual Diagnosis and High vs. Low Recurrent LOC Eating

Secondary analyses concerning the children with comorbid LOC symptoms and ADHD indicated that the dual diagnosis was not of added predictive value for either of the models. However, children with a dual diagnosis descriptively showed the highest mean food intake (g) at maximum satiety (dual diagnosis: 479.67 ± 63.92; LOC only: 393.79 ± 25.66; ADHD only: 387.31 ± 29.01; CG: 360.06 ± 21.87). Children with high recurrent LOC eating consumed a greater amount of food (g) at maximum satiety than those with low recurrent LOC eating in the model without the covariates (high: 466.63 ± 44.60; low: 344.33 ± 21.28; $p < 0.05$) but were not significantly different with the covariates ($p = 0.07$). Sense of LOC over eating did not differ between children with high vs. low recurrent LOC eating (high: 1.71 ± 0.18; low: 1.06 ± 0.16; $p > 0.05$). Concerning secondary variables, children with high recurrent LOC eating had a higher carbohydrate intake (g) than children with low recurrent LOC eating (high: 91.00 ± 6.35; low: 75.90 ± 4.49; $p < 0.05$). For all other secondary dependent variables, there were no differences between children with high vs. low recurrent LOC eating (all $p > 0.05$).

Discussion

This study investigated the satiety regulation and sense of LOC over eating as well as other LOC eating-related characteristics of children with LOC eating and ADHD in a laboratory test meal. The main findings did not reveal any differences in food intake at maximum satiety in children with LOC eating compared to control children, in contrast to the finding of Sysko et al., showing that women with BED consumed significantly more in order to feel satiated than overweight and normal weight control women (Sysko et al., 2007). However, the descriptive difference between the groups was noticeable with a higher food intake at maximum satiety in the LOC eating and the ADHD group compared to the control group. One explanation for the fact that this difference was not statistically significant is that only a subgroup of the children with LOC eating and ADHD might show this excessive eating behavior. Another observation was that children with LOC eating experienced a greater sense of LOC over eating during test meal compared to ADHD and control children. Hilbert and colleagues also found a greater sense of LOC over eating at test meal in children with LOC eating compared to control children (Hilbert et al., 2010), but no prior study has compared this variable between children with LOC eating and children with ADHD in a laboratory test meal. As hypothesized, the sense of LOC over eating appears to be a distinctive feature of those with LOC eating, supporting LOC eating as syndrome distinct from ADHD.

Secondary results revealed that children with LOC eating showed a trend towards eating faster (g/s and kcal/s) than control children, which is reflected in the DSM-5 behavioral characteristic (B) “eating more rapidly than normal” (American Psychiatric Association, 2013). Previous research found that children with LOC eating did not show a greater bite velocity than control children but that bite velocity and bite size were predictive of increased food intake at both test meal and snack eating and a greater sense of LOC over eating while snack eating (Hilbert & Czaja, 2011). The resulting differences might be explained by the more stringent inclusion criteria for the LOC group in this study than in the previous study (see Classificatory Variables). Further, research showed that overweight children tended to eat faster than their normal weight counterparts (Barkeling et al., 1992; Waxman & Stunkard, 1980). This is the first study to show that LOC children possibly eat faster than control children, even after accounting for BMI-SDS, possibly leading to overconsumption. Replication studies should be conducted in order to verify this marginally significant finding.

Further, children with ADHD and LOC eating did not show a greater energy intake (kcal) at maximum satiety than control children, similar to the findings of Tanofsky-Kraff et al., showing that 8- to 17-year-old children with LOC eating did not consume more energy at either the binge or the normal meal (Tanofsky-Kraff, McDuffie et al., 2009). In contrast, Hartmann and colleagues documented a greater snack food intake (kcal) in 10- to 14-year-old youth with ADHD compared to the LOC group or CG (Hartmann et al., 2012), and other test meal studies showed greater energy intake in the LOC group compared to the CG (Hilbert et al., 2010; Mirch et al., 2006). All of these studies used a multi-item meal. It is possible that a multi-item meal increases food intake, especially in children with LOC eating and ADHD, because of their increased reward sensitivity (Nederkoorn et al., 2006). Also, the test meal or snack food offered was much larger in terms of quantity and energy in these studies than in this study. Even though in this study the amount of food offered was comparatively large to what children normally eat at this age range, and no child asked for more food during test meal, it is possible that a larger portion might have enlarged the group differences (Gosnell et al., 2001), which could be considered in future test meal studies.

The results on energy intake at maximum satiety also revealed distinctive descriptive differences between the groups as was explained above. Further, children with LOC eating but not those with ADHD consumed significantly more carbohydrates than control children, which is in line with previous results, showing a higher carbohydrate intake in children with LOC eating compared to control children (Lourenço et al., 2008; Tanofsky-Kraff, McDuffie et al., 2009) and a higher percentage of calories from carbohydrate in LOC episodes compared to non-LOC episodes (Hilbert, Rief, Tuschen-Caffier, Zwaan, & Czaja, 2009; Theim et al., 2007). However, this higher carbohydrate intake in children with LOC eating than in the control children disappeared when controlling for relevant covariates.

Concerning the secondary LOC eating-related characteristics, children with LOC eating and ADHD reported greater desire to eat, feelings of hunger, and liking of food during the test meal than control children. Mirch and colleagues also found that overweight children with a history of binge eating reported a greater desire to eat before a test meal than overweight children without a history of binge eating, but feelings of hunger and satiety before and after the test meal did not differ between groups (Mirch et al., 2006). In contrast, Hilbert and colleagues found a greater hunger before the test meal in children with LOC eating compared to control children (Hilbert et al., 2010). No comparable studies were found for children with ADHD. Because of increased reward sensitivity and cue reactivity in youth with LOC eating and ADHD (American Psychiatric Association, 2013; Hartmann et al., 2010; Hartmann et al., 2012; Reinblatt et al., 2015), these children might be more prone to hedonic eating, possibly interpreting their increased desire to eat as feeling hungry. Future studies are needed to test these hypotheses.

Results on increased desire to eat, feelings of hunger, and liking in both children with LOC eating and ADHD further suggest an overlap in LOC eating related symptomatology between LOC eating and ADHD. Increased reward sensitivity and impulse control deficits, both common aspects of impulsivity (American Psychiatric Association, 2013), might account for this overlap between LOC eating and ADHD, making overconsumption likely to occur (Nederkoorn et al., 2006; Reinblatt et al., 2015). In fact, children with binge eating or LOC eating showed higher reward sensitivity and impulse control deficits than control children

(Nederkoorn et al., 2006; Reinblatt et al., 2015), and impulse control deficits were linked to LOC eating (Hartmann et al., 2012; Reinblatt et al., 2015). In this study, not only children with ADHD but also those with LOC eating revealed significantly higher BIS-11 scores than control children, similar to previous studies (Hartmann et al., 2010; Hartmann et al., 2012). Additionally, the obesogenic environment with easily available high caloric palatable food in industrialized countries is assumed to promote food intake due to hedonic eating impulses instead of internal hunger cues (Stice, Spoor, Ng, & Zald, 2009).

Even though the results did not reveal statistical evidence to support the assumption of a disturbed hunger and satiety regulation in children with LOC eating and ADHD, LOC eating related characteristics were significantly higher in these children compared to the control children. Therefore, a replication of the study and a further examination of a possible disturbance in food intake and satiety regulation are indicated (Mirch et al., 2006). Our behavioral test meal approach should be complemented by research on genetic or physiological indicators such as appetite-stimulating peptides or gastric capacity when further examining disturbances in hunger and satiety regulation in children with LOC eating and ADHD. It has been shown that the appetite-stimulating hormone leptin was higher in children with LOC eating compared to controls (Miller et al., 2014). In adults with BED, abnormalities in appetite-stimulating peptides insulin and ghrelin have been detected (Geliebter, Hashim, & Gluck, 2008; Geliebter, Yahav, Gluck, Hashim, 2004).

Children with comorbid LOC eating and ADHD did not differ significantly from the other groups, although descriptive analyses showed the highest food intake at maximum satiety in those with a dual diagnosis. Recent evidence proposes that children with comorbid LOC eating and ADHD are at a specifically high risk for adverse health outcomes like increased weight (Reinblatt et al., 2014; Reinblatt et al., 2015). The small number of children in this subgroup might have prevented the effect of being significant. Therefore, a replication of the results with a larger comorbid LOC eating and ADHD group is warranted. When addressing the frequency of LOC eating, children with high recurrent LOC eating showed a significantly greater food intake at maximum satiety as well as a greater carbohydrate intake compared to children with low recurrent LOC eating, suggesting that the DSM-5 threshold for binge eating for diagnosis of BED (American Psychiatric Association, 2013) is indicative of a closer link with excess weight, when applied to childhood LOC eating. Hilbert and colleagues (Hilbert et al., 2010) similarly found a greater food intake in children with high compared to low recurrent LOC eating, suggesting that children with high recurrent LOC eating carry a particularly high risk for weight gain.

Several strengths and limitations of this study need to be addressed. The community-based study sample provided sufficient power for detecting medium and large effects. A larger sample size could have been useful to detect small effects as well. State-of-the-art diagnostics including validated semi-structured interviews and self-report questionnaires were used for sample selection. The controlled laboratory setting allowed for an objective assessment of food intake and eating behavior following a thoroughly pretested protocol. Even though pre-experimental hunger and satiety were well-controlled for with a standardized breakfast and the parental control for fasting 4 hrs prior to test meal, children with LOC eating and those with ADHD were more hungry at baseline than control children. In addition, possible individual differences in hunger and satiety due to age, sex, or BMI were controlled for in all analyses. Also, test meal intake was conducted with the instruction to “eat until full.” Therefore, no conclusions can be drawn regarding food intake and LOC eating-related characteristics during binge eating compared to non-binge meals. Further, the child was eating alone so that the influence of interactions during the meal with others could not be assessed (Hilbert et al., 2010). The use of a large quantity of lunch food (700 g per serving) could have influenced the child’s intake. Previous research indicates an increased food intake when large amounts of food are presented (Gosnell et al., 2001). Also, taste, texture, as well as the different macronutrient composition of the different test meal foods to choose from might have influenced satiety (Gerstein, Woodward-Lopez, Evans, Kelsey, Drewnowski. 2004; Guinard, Brun, 1998), which was not assessed in this study. Even though the children rated the test meal food and their eating behavior as fairly comparable to their everyday life and the relatively small range of typical lunch food simplified comparisons on the food intake, future research could include a range of test meal foods for greater ecological validity.

Overall, this study provides valuable information for the understanding of LOC eating in childhood and its association with ADHD, indicating an overlap in LOC eating related symptomatology between LOC eating and ADHD. Further, our results provide support for the construct validity of LOC eating in middle childhood, since a sense of LOC over eating emerged as a specific impairment of children with LOC eating. Asking about the sense of LOC eating more specifically when studying eating behavior in ADHD could provide valuable information on the psychopathology and could therefore have an important clinical impact. These findings highlight a substantial association of LOC eating and ADHD with overweight. In terms of clinical implications, clinicians should be aware of this association when treating either children with LOC eating or ADHD (Hartmann et al., 2012; Martinez de Velasco, Barbudo, Pérez-Templado, Silveira, & Quintero, 2015), because comorbid ADHD might impede the treatment of binge-eating behaviors (Nasser, Gluck, & Geliebter, 2004; Nazar et al., 2014), and binge eating might mediate the relationship between ADHD and BMI (Reinblatt et al., 2014). Treatment may focus on improvement of the perception of hunger and satiety signals when trying to normalize food intake in LOC eating and ADHD (Hilbert & Tuschen-Caffier, 2004; Hilbert et al., 2010; Sysko et al., 2007). Since increased impulsivity might impair hunger and satiety regulation through its two behavioral mechanisms, lack of inhibitory control and high reward sensitivity (Nederkoorn et al., 2006; Rolls, 2007), the impact of a specific food-related impulse control intervention could be evaluated as an adjunct to the treatment of LOC eating and ADHD. Children with high levels of LOC eating deserve special clinical attention, as they showed the greatest food intake at maximum satiety, with the possible detrimental effect on excess weight gain. For classification of LOC eating in children, it seems crucial to further study common and distinct features of LOC eating and ADHD, such as sense of LOC over eating, reward sensitivity or impulse control deficits, as important factors for overconsumption of highly palatable food.

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Tables and Figures

Table 1. Sociodemographic and clinical characteristics.

	LOC (n = 33)		ADHD (n = 32)		CG (n = 33)			
	N	%	*N*	%	*N*	%	χ^2 (df = 2)	p^2
Sex, girls	20	60.61	13	40.63	22	66.67	4.83	0.089
	M	*SD*	*M*	*SD*	*M*	*SD*	F (df = 2, 95)	*p*
Age, years	11.82[a]	1.12	10.88[b]	1.44	11.85[a]	1.09	6.54	0.002
BMI, kg/m^2	21.49[a]	4.15	18.67[b]	3.60	19.65[ab]	3.01	5.13	0.008
BMI-SDS	0.86[a]	1.12	0.21[b]	1.17	0.42[b]	0.92	3.12	0.049
	N	%	*N*	%	*N*	%	H (df = 2)	*p*
Underweight	2	6.1	3	9.4	1	3.0	4.61	0.100
Normal weight	18	54.5	22	68.8	28	84.8		
Overweight/Obese	13	39.4	7	21.9	4	12.1		
	M	*SD*	*M*	*SD*	*M*	*SD*	H (df = 2)	*p*
BIS-11 total	68.91[a]	8.97	67.26[a]	7.13	61.05[b]	7.31	17.42	<0.001

Note. LOC, group with loss of control over eating; ADHD, group with attention-deficit/hyperactivity disorder; CG, control group; BMI, body mass index; BMI-SDS, body mass index standard deviation score; BIS-11, Barratt Impulsiveness Scale 11.Chi-square test, ANOVAs and Kruskal-Wallis tests were used for group comparisons ($p < 0.05$). [a,b] Different superscripts indicate significant post-hoc tests ($p < 0.05$).

Table 2. Energy, energy density, and macronutrient composition of the test meal foods offered (700 g).

Lunch foods	Energy (kcal)	Energy density (kcal/g of food)	Carbohydrates (g)	Fat (g)	Protein (g)
Pizza: Toscana / prosciutto e pesto (Buitoni)	1519	2.17	154	70	70
Pizza: Toscana / due fromaggi (Buitoni)	1435	2.05	163.1	54.6	67.2
Cannelloni alla Fiorentina (Findus)	1239	1.77	133	56	35
Lasagne con verdura (Findus)	1099	1.57	102.9	61.6	31.5
Oven-fries (Findus)	1260	1.80	210	42	21

Table 3. Linear regression analyses for the food intake (g) at maximum satiety (hypothesis 1), as well as for secondary hypotheses concerning the eating speed (g/s, kcal/s), the energy intake (kcal) at maximum satiety, the carbohydrate intake (in g), and the factor for food intake.

	B	*SE*	ß	*p*	95% CI	R^2	R^2 change
Amount eaten (g)[a]							
LOC vs. CG	46.14	35.33	0.149	0.195	-24.022 to 116.304	0.124	0.077
ADHD vs. CG	45.03	37.56	0.144	0.234	-29.573 to 119.631		
Constant	95.27	144.41			-191.538 to 382.068		
Eating speed for amount eaten (g/s)							
LOC vs. CG	0.17	0.09	0.231	0.054	-0.003 to 0.333	0.073	0.021
ADHD vs. CG	0.02	0.09	0.027	0.829	-0.155 to 0.194		
Constant	0.21	0.34			-0.473 to 0.882		
Energy intake (kcal)[b]							
LOC vs. CG	69.38	59.16	0.133	0.244	-48.109 to 186.876	0.131	0.084
ADHD vs. CG	68.41	62.90	0.130	0.280	-56.519 to 193.334		
Constant	248.69	241.82			-231.585 to 728.960		

Table 3 (continued).

	B	*SE*	ß	*p*	95% CI	R^2	R^2 change
Eating speed for energy intake (kcal/s)							
LOC vs. CG	0.27	0.15	0.222	0.065	-0.018 to 0.561	0.062	0.009
ADHD vs. CG	0.03	0.15	0.022	0.862	-0.274 to 0.327		
Constant	0.46	0.59			-0.703 to 1.627		
Carbohydrate intake[c] (g)							
LOC vs. CG	9.36	5.80	0.182	0.110	-2.164 to 20.889	0.145	0.098
ADHD vs. CG	9.65	6.17	0.186	0.121	-2.610 to 21.901		
Constant	56.94	23.72			9.823 to 104.056		

Note. *B*, regression coefficient; *SE*, standard error; ß, standardized coefficient; CI, confidence interval; R^2, adjusted multiple R^2 (cumulative); R^2 change, adjusted multiple R^2 (by predictor); LOC, group with loss of control over eating; ADHD, group with attention-deficit/hyperactivity disorder; CG, control group. Multiple linear regression analyses were used for group comparisons ($p < 0.05$).

[a] The covariate age was significant (ß = 0.261, p = 0.018).

[b] The covariate age was significant (ß = 0.239, p = 0.029).

[c] The covariate BMI-SDS was significant (ß = 0.247, p = 0.019).

Table 4. Generalized linear mixed models for the sense of LOC over eating (hypothesis 2) and secondary eating-related characteristics during test meal.

	ß	95% CI	*SE*	OR	*p*
Sense of LOC over eating					
LOC vs. CG	0.875	0.489 to 1.262	0.197	2.399	0.000
LOC vs. ADHD	0.680	0.271 to 1.090	0.208	1.974	0.001
Desire to eat					
LOC vs. CG	0.607	0.267 to 0.947	0.173	1.835	0.000
ADHD vs. CG	0.434	0.086 to 0.782	0.177	1.543	0.014
Feelings of hunger					
LOC vs. CG	0.631	0.255 to 1.008	0.192	1.879	0.001
ADHD vs. CG	0.498	0.112 to 0.885	0.197	1.645	0.012
Liking of food					
LOC vs. CG	0.919	0.514 to 1.325	0.206	2.507	0.000
ADHD vs. CG	0.985	0.573 to 1.397	0.210	2.678	0.000

Note. ß, standardized coefficient; CI, confidence interval; *SE*, standard error; OR, odds ratio; LOC, group with loss of control over eating; ADHD, group with attention-deficit/hyperactivity disorder; CG, control group, statistical significance at $p < 0.05$.

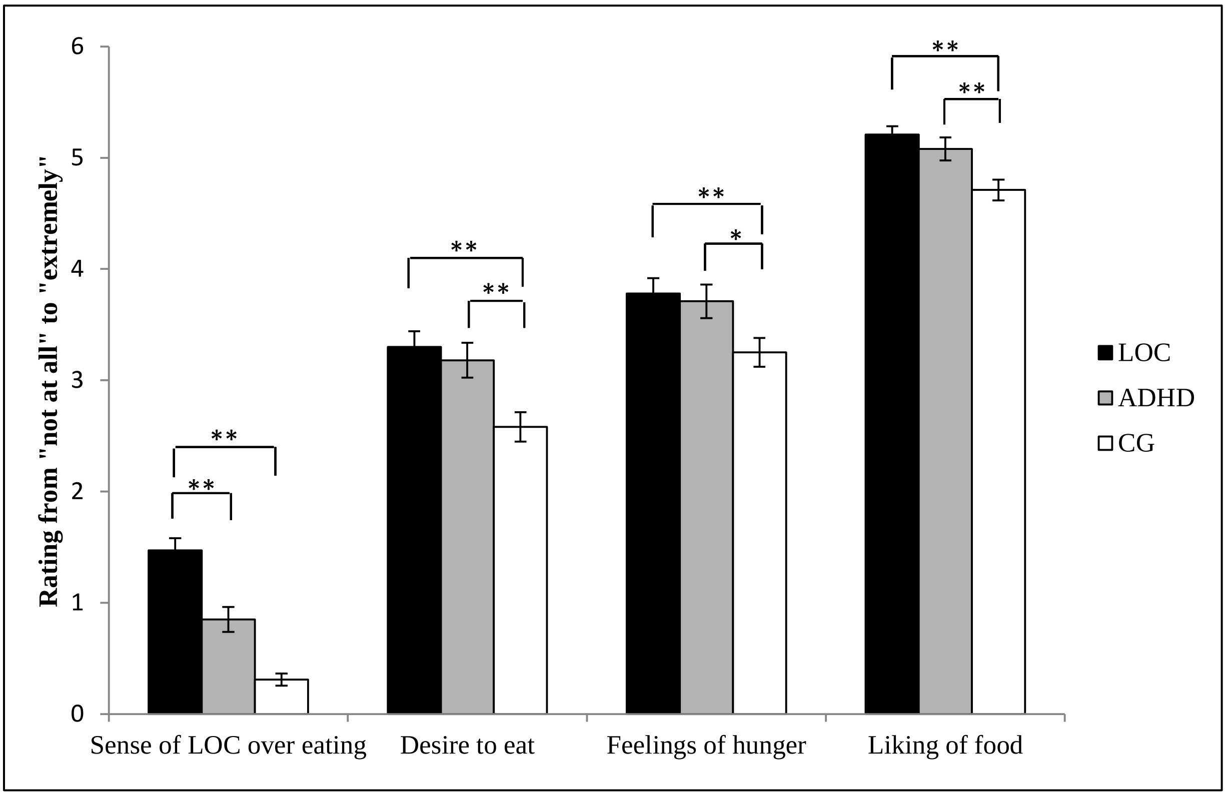

Figure 1. Group differences in LOC eating-related characteristics during test meal. LOC, group with loss of control over eating; ADHD, group with attention-deficit/hyperactivity disorder; CG, control group. Displayed are mean scores (± SE) and significance of generalized linear mixed model analyses. Variables are presented on a scale from 0-6. $^{*}p < 0.05$, $^{**}p < 0.01$