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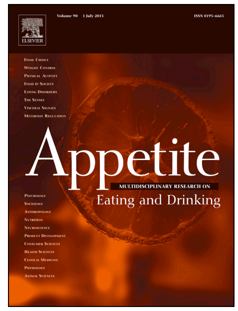

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MULTIPLE MEASURES OF IMPULSIVITY, EATING BEHAVIOURS AND ADIPOSITY IN 7-11-YEAR-OLDS

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Keywords:

Impulsivity; snacking; adiposity

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Abstract

Previous research suggests that the relationship between the multiple aspects of children's impulsivity, eating behaviour and adiposity may depend on measures used. Fifty 7-11-year-olds (28 female, 22 male) completed four impulsivity tasks (Go/No-Go, Door Opening, Circle Drawing, Delay Discounting), consumed a snack, reported on their eating, and were weighed and measured. Parents completed measures of child impulsivity and eating behaviour. Impulsivity and adiposity were positively correlated. Lower rates of delay discounting were associated with lower snack intake. Ability to inhibit a pre-potent response was related to dietary restraint and snack intake. Findings suggest a complex, multifaceted relationship between impulsivity, eating and adiposity, which are measure and respondent dependent.

Keywords

Impulsivity; adiposity; children, dietary restraint.

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MULTIPLE MEASURES OF IMPULSIVITY, EATING BEHAVIOURS AND ADIPOSITY IN 7-11-YEAR-OLDS

Childhood obesity and its associated health complications are a major, global health concern. Impulsivity and inhibitory control have been identified as potential vulnerabilities for weight gain and obesity while also being possible targets for interventions in children and adults. Research with young children has indicated that impulsivity levels measured through inhibitory control, reward sensitivity, delay discounting and delay of gratification tasks, as well as through parent-report measures of child impulsivity, are associated with the risk for overweight and obesity during later childhood and adolescence (Epstein, Salvy, Carr, Dearing & Bickel, 2010; Francis & Susman, 2009; Graziano, Calkins, & Keane, 2010; Seeyave et al., 2009).

Research has highlighted that obese children have higher impulsivity levels than their healthy weight peers and that success in weight reduction programmes is affected by underlying impulsivity levels (Braet, Claus, Verbeken, & Van Vlierberghe, 2007; Bruce et al., 2011; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010). Indeed, imaging studies have shown abnormalities in networks associated with inhibitory control, motivation and the regulation of food intake in overweight and obese children (Batterink, Yokum, & Stice, 2010; Bruce et al., 2010). Nevertheless, some studies have failed to identify links between impulsivity and weight in children, which may be attributable to the measures that were used to assess impulsivity (e.g., Tan & Holub, 2011). Thamotharan et al. (2013) have recently outlined that behavioural tasks assessing the impulsivity facets of decision-making and disinhibition were particularly associated with weight outcomes in studies of paediatric populations, whereas measures of parental report of impulsivity tend to have weaker relationships with children's weight. In several of the studies contained within their review, the relationship between impulsivity and weight was dependent on the measures used. This demonstrates that whilst the likely overall direction of the relationship is that greater impulsivity is associated with greater adiposity (Thamotharan et al., 2013), there is also the need to explore, test and present the pattern of such relationships dependent on measures and facets of impulsivity. Thus studies should explore both parent report and behavioural measures of child impulsivity in relation to children's adiposity.

Research has also indicated that more impulsive individuals may be prone to making poorer food choices and to eat in the absence of physiological need, which may lead to weight gain (Davis, Strachan, & Berkson, 2004; Davis et al., 2007; Graziano et al., 2010; Guerrieri et al., 2007; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010). In line with these reports, emotional, external and restrained eating have been found to be linked with impulsivity, indicating that more impulsive children are more prone to eat in response to negative emotions and in response to external food stimuli and variety (Ahern, Field, Yokum, Bohon, & Stice, 2010; Farrow, 2012; Guerrieri, Nederkoorn, & Jansen, 2008; Jasinska et al., 2012; Tan & Holub, 2011). Some studies have also indicated that individuals with greater impulsivity levels may also report more dietary restraint (e.g. Nederkoorn, Van Eijs, & Jansen, 2004). Individuals who experience greater impulse to eat palatable foods, particularly in the absence of hunger, may perceive that they exert more effort in controlling food intake. Indeed, those individuals with high levels of restraint, impulsivity and negative affect are at greater risk of binge-eating (Mason, Smith, Lavender & Lewis, 2018). However, many of the studies of the relationships between impulsivity and eating behavior are based on samples of overweight or obese adults and children, sometimes with clinically elevated impulsivity levels, have relied on self- or parent-reported impulsivity, have used a limited range of tasks to assess impulsivity, or rely on single measures of eating behaviour, including parent report. Using a wider range of tools to assess child impulsivity and eating behaviour within one participant group will also allow us to gain a greater insight into which facets of impulsivity may be particularly crucial for this link, and including laboratory measures of food intake is also key to improving the objectivity of measures of children's eating behaviour.

Aims and hypotheses

This study explored relations between impulsivity, measured through a range of behavioural tasks and parent-report tools, adiposity and eating behaviours, in 7-11-year-olds. It was hypothesized that adiposity, parent-reported impulsivity and impulsivity task performance (inhibitory control, reward sensitivity, delay discounting and motor impulsivity) would be positively linked. It was hypothesized that greater impulsivity would be linked with food approach and avoidance behaviour, external, emotional and restrained eating, and ad libitum snack intake.

Method

Participants

Fifty 7-11-year-olds and their parents participated in this study. Parents and children were recruited through the Infant and Child Laboratory (ICL) database at the University of Birmingham, from schools in and around Birmingham, UK and through an advert in a local parent magazine, requesting participants for a study of 'school stress and eating behaviour'. Therefore, at the point of recruitment, families were not aware that the goal of the study was to examine impulsivity. Exclusion criteria included the presence of known food allergies, of disorders affecting eating, current or recent major illness or diagnosed intellectual disabilities and diagnosed impulsivity-related or anxiety disorders. Overall, 77 parents were contacted of whom 50 agreed to participate in this study (response rate of 65%). Children were, on average, healthy weight for their age and gender. Children had predominantly middle class, White British backgrounds. All families spoke English. The sample's demographic characteristics can be seen in Table 1.

Measures and procedure

Parents gave informed consent and all children provided verbal assent in the presence of the parent before the study commenced. All questionnaires were completed by the children's mothers.

Demographic and adiposity information. Mothers provided information on their child's age and gender, their own age, ethnicity, their annual household income and level of education. Mothers and children were measured and weighed by a trained researcher at the laboratory, wearing light indoor clothing, without shoes. Where fathers attended (*n*=2) mothers were contacted and their self-reported height and weight were recorded. Maternal BMIs and child BMI-z scores, adjusting for age and gender, were calculated using British growth reference data (Cole, Freeman & Preece, 1995). Children also had their waist circumference measured as an additional measure of adiposity (Brambilla et al., 2013).

Measures of Impulsivity:

Temperament in Middle Childhood Questionnaire (TMCQ, version 3.0; Simonds & Rothbart, 2004). The TMCQ measures child temperament and was used to measure parent-perceived child impulsivity. The Cronbach's alpha for the Impulsivity subscale was .9, indicating that it had excellent internal consistency.

Conners' Parent Rating Scale (CPRS-R [L]; Conners, Sitarenios, Parker, & Epstein, 1998). The CPRS was used to assess parents' perceptions of child impulsivity and hyperactivity over the past month. The Cronbach's alpha for the Hyperactivity subscale was .83, and for the Connors Global Index (CGI): Restless-Impulsive was .86, indicating that both subscales had good internal consistency.

Go/No-Go task (GNG task; Bezdjian, Baker, Lozano, & Raine, 2009). This task assesses a child's ability to inhibit prepotent responses to non-food stimuli. Children were asked to respond to one of two stimuli with a key press (sun) while inhibiting the response to the other stimulus (flower). The task consisted of 12 practice trials and 100 experimental trials. The ratio between targets and non-targets was 3:1. Errors of commission and Go trial reaction time (RT) were recorded, with more errors (poorer inhibitory control) and faster RT (i.e. numerically lower, faster response speed) reflecting higher levels of impulsivity.

Door Opening task (Daugherty & Quay, 1991; Nederkoorn et al., 2006; Verbeken, Braet, Claus, Nederkoorn & Oosterlaan, 2009). This task measures reward sensitivity. Children could open up to 100 sequentially presented doors, through a key-press. Behind each door either a happy face, associated with winning a point or a sad face, associated with losing a point, was displayed. After each block of ten doors the probability of finding a happy face reduced by 10%. The number of doors opened dependent variable (DV) was recorded as an indicator of reward sensitivity, with more impulsive children opening more doors.

Delay Discounting task (Johnson, Parry, & Drabman, 1978). This task measures a child's tendency to depreciate the value of a reward dependent on the time it takes to get the reward. Over 4 practice and 32 experimental trials children selected either an immediate small reward (one token) or a larger delayed reward (two tokens) through a key press. Children were told that at the end of the session they could exchange their tokens for prizes. The number of trials in which a larger delayed reward was selected was recorded (DV) and a greater number of delays were indicative of a lower tendency to discount future rewards and lower levels of impulsivity.

Circle Drawing task (CDT; Bachorowski & Newman, 1990; Verbeken et al., 2009). The CDT measures a child's motor impulsivity. Children traced the outline of a large circle (ø=50.8cm), drawn onto a wooden square, with their index finger, once without instruction and while being told to trace as slowly as possible. The tracing time during the inhibition condition was recorded. Slower tracing (i.e. larger values) indicated lower motor impulsivity.

Measures of Eating Behaviour:

Children's Eating Behaviour Questionnaire (CEBQ; Wardle, Guthrie, Sanderson, & Rapoport, 2001). The CEBQ measures parent-reported Food Approach and Food Avoidance behaviours displayed by children. Cronbach's alpha for the Food Approach subscale (comprising items measuring enjoyment of food, food responsiveness, emotional over-eating, and desire to drink) was .88 and Cronbach's alpha for the Food Avoidance subscale (comprising items measuring satiety responsiveness, food fussiness, slowness in eating and emotional under-eating) was .89, indicating good internal consistency.

Dutch Eating Behaviour Questionnaire-Child version (DEBQ-C; Van Strien & Oosterfeld, 2008). The DEBQ-C assesses self-reported eating behaviour in children from 7 years. The Cronbach's alpha for the Emotional Eating subscale was .67, for the Restrained Eating subscale was .77 and for the External Eating subscale was .8, indicating that all subscales had good internal consistency.

Child-reported hunger. Because time of day of testing varied and children were not fasted, child hunger was measured using the "Teddy" picture rating scale (PRS, Bennett & Blissett, 2014). The scale consists of five black and white cartoon bear silhouettes with labels describing varying levels of hunger ranging from 1 (*very hungry*) to 5 (*not hungry at all/very full*).

Snack session: Children had access to three sweet (chocolate chip cookies, Haribo Gold Bears, green grapes) and three savoury (ready salted crisps, salted pretzels, carrot sticks) snack foods that varied in fat and sugar content during a 10-minute snack session. The snack foods were presented in white square plastic bowls (10x10cm), as part of a 'break' between activities. Children were told they could eat as much as they wanted but were not pressured to eat, and were left alone with the snacks for 10 minutes. Water was available throughout the snack session. Children had access to reading and colouring materials during the snack session. Portions were weighed before and after the snack session using an electronic scale (Kern: EMB 600-2); the calories consumed for each snack food, as well as overall calorie intake were calculated using manufacturer information.

Procedure: Parents and children visited the ICL together as part of a larger study of school stress and children's eating behaviour. Children visited the laboratory twice. In one session they completed a maths test designed to induce stress, as part of the wider study (data not reported here) and in the other session they engaged in non-stressful games with the researcher. Data on children's eating behaviour in this paper are taken from the non-stressful condition only. Children completed the questionnaires as a block, and the impulsivity tasks as a block, in a counterbalanced order. The researcher was present at each testing and questions were generally read to children, unless the child specifically requested to complete the questionnaire independently. However the researcher was still present with the child to clarify the meaning of any questions. Parents completed the questionnaires in an adjacent room while children were working with the researcher. Parents could see their child through a one-way mirror at all times. Children were aware that their parent was 'next door' but could not see their parent and were not explicitly told that their parent could see them. After completing the questionnaire and impulsivity tasks children had a 10-minute snack session. Following the snack session children chose a toy and stickers as a thank you for taking part. Parents were debriefed after the second visit and reimbursed (£5) for their travel expenses at each visit. The visit duration was approximately one hour. The Ethical Review Committee of the University of Birmingham approved this study (ERN 12-0465P).

Statistical analysis

SPSS version 20 statistical software was used to analyse the data. Histograms were inspected and indicated that the majority of data were normally distributed. Descriptive statistics for impulsivity were calculated and gender differences explored using independent samples *t*-tests. The association of potential covariates like child age, BMI-z score, maternal BMI and family annual income with impulsivity, eating and adiposity variables was assessed using Pearson correlations. Bootstrapped Pearson's correlations with 95% confidence intervals (controlling for covariates where appropriate) were carried out to examine relations between parent-reported impulsivity and impulsivity task performance and child adiposity and eating behaviours.

Results

Descriptive statistics

Demographic characteristics. Table 1 shows the demographic characteristics of the overall sample. There were no gender differences in age (t(48)=-.135, p=.89), waist circumference (t(38)=-.237, p=.81), or BMI-z scores (t(41.78)=-1.53, p=.13). Children's waist circumference and BMI-z scores were significantly correlated (r(44)=.72, p<.0001).

Table 1

Demographic characteristics of the sample overall (N=50)

Variables	Parent Characteristics	Child Characteristics
Gender	48 female, 2 male	28 female, 22 male
Age, mean (*SD*)	38.44 (5.41)	8.22 (1.05)
Age range	27 – 50	7 – 11
BMI, mean (*SD*)	25.84 (4.9)	.35 (1.07)*
Range	18.86 – 45.79	-2.19 – 2.71
Waist Circumference mean *(SD)*	-	59.7 (6.4)
Waist circumference range	-	52-81
Educational level	30% Completed University/College/Undergraduate degree (*n*=15) 26% Completed High School to 18 years (*n*=13) 24% Further Educational/Professional Qualification (non-University) (*n*=12) 18% Completed Graduate School/Postgraduate degree (*n*=9) 2% Completed High School to 16 years (*n*=1)	
Ethnicity	82% White Caucasian (British/Irish) (*n*=41) 6% South Asian (*n*=3) 6% Black (African/Caribbean) (*n*=3) 2% Chinese (*n*=1) 2% Mixed (*n*=1)	

Variables	Parent Characteristics	Child Characteristics
	2% Other (*n*=1)	

* For children BMIs (mean and *SD*) are adjusted for their age and gender (BMI-z scores).

Impulsivity measures. Table 2 shows that parent-reported impulsivity scores had a wide variety, suggesting that impulsivity levels in the current sample had a sufficient range to allow explorations of associations with eating variables. There was similar variability in impulsivity task performance, indicating that performance varied widely across children and that the majority completed all tasks. One child refused to complete the Door Opening task, while for three children data on the GNG task were lost due to a technical error. *T*-tests indicated that there were no gender differences in impulsivity across any measure (see Supplementary Table 1).

Table 2

Impulsivity scores on parent-report measures of impulsivity and impulsivity task performance scores

	Mean (*SD*)	Min	Max	*N*
TMCQ Impulsivity	2.7 (.7)	1.3	3.8	49
CGI: Restless-Impulsive	4.9 (3.8)	0	14	47
CPRS Hyperactivity	4.8 (3.6)	0	18	47
GNG task: Go trial RT (msec)	370.0 (29.0)	295.6	423.4	47
GNG task: Errors of Commission	8.3 (3.1)	2	15	47
Door Opening task:	43.7 (32.1)	1	100	49

Doors Opened				
Delay discounting task: Number of delays chosen	9.7 (8.6)	0	32	50
CDT: Slow Tracing Time (s)	90.0 (83.8)	4.6	419.0	50

Covariates

Pearson's correlations were carried out to assess associations between the variables of interest (impulsivity, BMI-z score and waist circumference, eating behaviour) and confounding variables such as child age, maternal BMI and parent education level (Supplementary Table 2). The analyses indicated that none of the potential confounds were associated with parent-reported impulsivity. Performance on the GNG task was related to child age. Performance on the Door Opening task was associated with maternal BMI. None of the potential confounds were associated with eating behaviour except that child dietary restraint was correlated with maternal BMI. Waist circumference was related to child age and maternal BMI. Subsequent analyses controlled for these covariates as necessary.

Child hunger ratings before the snack session were examined and the relation between hunger and intake was explored. Children's self-reported hunger ratings ranged from 1 (*very hungry*) to 5 (*not hungry at all/very full*), with a median hunger rating of 3 (*just right, not too hungry and not too full*). As the variable was not normally distributed, Spearman's correlations were carried out to assess whether pre-snack hunger was associated with intake. The analysis showed that there was no association between hunger and snack intake ($r_s(49)=-.21$, $p=.14$). Therefore, hunger was not included in further analysis.

Table 3. *One tailed Pearson's bootstrapped correlations between impulsivity, child adiposity, and observed eating behaviour*

Measure		Child BMI-z score+	Child waist circum-ference∞	Snack Intake (kcal)
TMCQ Impulsivity	r	0.48**	.43**	-.06
	95% CI	.15 to .75	.03 to .70	-.34 to .31
CGI: Restless-	r	0.30	.24	.06
Impulsive	95% CI	-.08 to .57	-.10 to .51	.20 to .32
CPRS	r	0.26	.11	-.01
Hyperactivity	95% CI	-.01 to .51	-.25 to .39	-.29 to .29
GNG task: Go trial	r	-0.26	-.28	-.57**
RT°	95% CI	-.60 to .18	-.62 to .23	-.76 to -.32
GNG task: Errors	r	.12	.11	.19
of commission°	95% CI	-.36 to .57	-.35 to .42	-.07 to .47
Door Opening	r	-0.09	-.15	-.24
task+	95% CI	-.43 to .21	-.42 to .20	-.52 to .04
Delay discounting	r	-0.06	-.01	-.30*
task	95% CI	-.32 to .19	-.33 to .45	-.50 to -.05
Circle Drawing	r	.13	-.13	-.12
task	95% CI	-.13 to .41	-.43 to .21	-.39 to .17

**p*<.05, **p<.01, + controlling for maternal BMI ∞ controlling for child age and maternal BMI °controlling for child age

Impulsivity, adiposity and snack intake

Table 3 shows that Pearson's bootstrapped correlations revealed positive associations between adiposity (BMI-z and waist circumference) and TMCQ impulsivity; children who were rated by their parents as more impulsive were heavier and had greater waist circumference. Children with lower GNG task Go trial Reaction Time showed greater snack intake in the laboratory. Poorer performance on the delay discounting task was also associated with greater snack intake.

Table 4.
Pearson's bootstrapped correlations between impulsivity and reported eating behaviour

Measure		Food Approach	Food Avoidance	Emotional Eating	External Eating	Restrained Eating
TMCQ Impulsivity	r	.19	.17	.28*	.17	-.12
	95% CI	-.22 to .57	-.18 to .50	-.05 to .54	-.15 to .42	-.36 to .15
CGI: Restless-Impulsive	r	.24	.31*	.18	.05	-.15
	95% CI	.06 to .53	-.04 to .58	-.15 to .47	-.20 to .28	-.37 to .10
CPRS Hyperactivity	r	.32*	.32*	.19	.09	-.19
	95% CI	.02 to .62	.02 to .57	-.18 to .50	-.21 to .36	-.42 to .06
GNG task: Go trial RT°	r	-.22	.02	-.01	-.12	.43**
	95% CI	-.47 to .15	-.29 to .33	-.32 to .31	-.44 to .22	.11 to .71
GNG task: Errors of commission°	r	-.06	.19	-.06	.10	-.19
	95% CI	-.37 to .31	-.15 to .47	-.40 to .30	-.32 to .48	-.57 to .22

Door Opening task+	r	-.05	.19	.01	-.09	.12
	95% CI	-.30 to .22	-.10 to .48	-.35 to .32	-.40 to .23	-.22 to .44
Delay discounting task	r	.23	-.16	.10	.11	-.07
	95% CI	.01 to .47	-.39 to .13	-.17 to .38	-.20 to .44	-.31 to 41
Circle Drawing task	r	-.10	.09	.28*	.22	-.18
	95% CI	-.34 to .15	-.30 to .57	-.01 to .54	-.02 to .42	-.43 to .13

*p<.05, **p<.01 + controlling for maternal BMI °controlling for child age

Impulsivity and parent and child reported eating behaviour

Pearson's bootstrapped correlations indicated that there were some associations between impulsivity and eating behaviour (see Table 4). Children's food approach and food avoidance behaviours, as reported by the parent, were positively correlated with parent ratings of child hyperactivity. Food avoidance behaviours were positively correlated with CGI restless-impulsive scores; children's reports of their emotional eating were positively correlated with both parental perception of impulsivity as measured by the TMCQ and impulsivity as measured by the circle drawing task, but the confidence intervals for all of these relationships includes zero, suggesting they are not significant. There were no significant associations between impulsivity task performance and food approach or avoidance behaviours, or external eating. GNG task go trial RT was positively associated with self-reported restrained eating indicating that children who responded more slowly and were less impulsive reported more restrained eating.

Discussion

The current study aimed to explore links between impulsivity, eating and adiposity, measured through a range of parent-report tools and behavioural tasks, in a sample of typically developing, healthy 7-11-year-olds. Research in children and adults has indicated that impulsivity and inhibitory control are linked with body weight (Braet et al., 2007; Bruce et al., 2011; Graziano et al., 2010; Thamotharan et al., 2013), eating behaviour and snack food intake (Guerrieri et al., 2008; Riggs et al., 2010). Nevertheless few studies have used a variety of impulsivity and eating behaviour measures to capture the many potential facets of this relationship. In this study, children with greater adiposity were reported by their parents to be more impulsive, but none of the behavioural measures of impulsivity showed reliable significant relationships with measures of adiposity. However, observations of greater snack intake were associated with greater impulsivity as measured by GNG task reaction times and greater delay discounting. GNG task reaction time was also related to children's own reports of their ability to restrain their eating, with greater ability to inhibit pre-potent responses to non-food stimuli being associated with greater restrained eating behaviour.

Based on previous research we hypothesized that impulsivity would be associated with child adiposity (e.g., Nederkoorn et al., 2006; Nederkoorn et al., 2010). This hypothesis was partly confirmed; children of parents who reported greater impulsivity using the TMCQ had higher BMI-z scores and waist circumference. We were surprised not to find relationships between behavioural measures of impulsivity and adiposity in this sample, given Tamotharan et al.'s (2013) conclusion that behavioural measures are more likely to yield significant relationships with weight outcomes. Neither did we find support for the hypothesis that inhibitory control abilities would be related to measures of adiposity, despite prior work that has demonstrated such a relationship. For example, Batterink et al. (2010) showed that the number of commission errors on a food-specific GNG task was positively associated with BMI in a sample of female adolescents, suggesting that the inhibitory control facet of impulsivity may be particularly relevant to impulsivity-related weight gain (Batterink et al.; Bennett & Blissett, 2017). In this study however, this particular measure of inhibitory control was not related to adiposity. It is possible that this difference may stem from the younger age range of the children in our sample; perhaps inhibitory control ability has a longer-term effect on adiposity that is not yet evident until children gain greater autonomy over food choices. Indeed, that GNG reaction time was negatively correlated with snack intake supports this idea. Similarly, many of the studies linking inhibitory control and adiposity have focussed on differences between healthy weight and obese samples, so the lack of a relationship in our relatively healthy weight sample is perhaps indicative that this relationship is more prominent at the more extreme end of the child adiposity scale (e.g. Nederkoorn et al., 2006).

Whilst previous research has highlighted that food approach behaviours, measured by the CEBQ, mediates the impulsivity-weight link in children aged 6 to 13 years (Van den Berg et al., 2011), we did not find any relationship between these behaviours and any measure of impulsivity in this sample. In addition to parent-perceived eating behaviour, child self-reported eating behaviours such as emotional, external and restrained eating have previously been associated with impulsivity. Farrow (2012) found that more impulsive 10-13-year-olds self-reported more emotional and external eating tendencies. Findings for dietary restraint have been mixed; some studies have highlighted links between better inhibitory control and greater dietary restraint (Leitch, Morgan, & Yeomans, 2013), while other studies have found that increased impulsivity was linked with greater intention to diet and dietary restraint (Jasinska, et al., 2012; Nederkoorn et al., 2004). In the current study, ability to inhibit a pre-potent response to a non-food stimulus, measured by the GNG task (go trial RT), and child reports of their dietary restraint were positively related, suggesting that children who had better inhibitory control were also more restrictive of their food intake. Previous research has indicated that low levels of impulsivity in combination with dietary restraint appear to lead to more successful dieting outcomes and less disinhibited eating (Jansen et al., 2009; Meule, Lukito, Vögele, & Kübler, 2011; Nederkoorn, Jansen, Mulkens, & Jansen, 2007; Van Koningsbruggen, Stroebe, & Aarts, 2013). This study suggests that the origins of this relationship may be evident in middle childhood.

In support of the hypothesized link between impulsivity and overeating, children who performed more impulsively on the GNG task (go trial RT) also consumed more calories from a snack. Similar findings have previously been reported by Guerrieri and colleagues (Guerrieri, Nederkoorn, & Jansen, 2007; Guerrieri, Nederkoorn, Stankiewicz et al., 2007), especially in the context of a varied food environment (Guerrieri et al., 2008). Similarly, children who showed greater delay discounting were also more likely to consume more snacks, which is consistent with other studies of the relationship between delay discounting, poorer ability to delay gratification and greater risk of overweight and obesity in childhood (Caleza et al., 2016; Epstein et al., 2010). The findings are correlational and do not allow an inference of causality, nevertheless, they do lend further support to the notion that poorer ability to make decisions in favour of future outcomes rather than immediate gratification may lead to overeating (Guerrieri et al., 2007). These data highlight that this relationship is not just evident in overweight or clinical samples, but in healthy samples of 7-11 year olds, and, importantly, that the general ability to make decisions in favour of larger, longer term reward in a non-food context was related to eating behaviour. The finding that both poorer inhibitory control as well as greater delay discounting were both significantly related to more snack intake demonstrates the importance of examining multiple aspects of impulsivity in studies of this kind. Longitudinal work should examine the utility of these measures as indicators of risk for excess energy intake and weight gain in longitudinal studies.

Together, these findings lend further support to the literature emphasising the multifaceted nature of both impulsivity and eating behaviour. Whilst impulsive behaviours or eating behaviour traits may cluster in individuals, it may be prudent in studies interested in examining the relationship between impulsivity and eating behaviour, to specify and delineate the constructs under measurement and/or to take multiple measures of impulsivity and eating behaviour using both parent/child report and direct measurement. In terms of questionnaire measurement, the TMCQ was the only parent report measure to show relationships with measures of adiposity, and therefore may be a useful tool to use in studies interested in adiposity outcomes using larger scale data collection where direct measurement of child impulsivity is not feasible. In terms of behavioural measures of impulsivity, the GNG task and the delay discounting task were the only measures to show reliable relationships with children's eating behaviour, so should be targets for inclusion in further studies. Thus, the findings of this paper point to the importance of the careful selection of measures and use of multiple measures of impulsivity in the developing literature investigating the psychology and neurobiology of the relationships between impulsivity, appetite and eating behaviour.

This study has several limitations. Sample sizes were small and confidence intervals were generally wide and a replication of the findings in larger subsamples is necessary to validate the findings. We carried out multiple correlations within the analysis without correction, because of the exploratory nature of the study, small sample size and to reduce the chance of a type II error, but nevertheless, there is a resulting risk of greater family-wise error. We recruited families to a study of 'School stress and eating behaviour', which ensured that parents were unaware of the focus on impulsivity at recruitment, but nonetheless, were aware of the study's focus on eating. This may have resulted in a bias in recruitment of more families with concerns about children's eating behaviour or adiposity. Furthermore, previous research has indicated that tasks using food stimuli as targets (e.g. GNG task; Batterink et al.,

2010) or as rewards (Delay of Gratification task; Bonato & Boland, 1983) may be more suited to detect associations between impulsivity and BMI-z in children and adults. As the current study only used non-food stimuli, to ensure we did not have confounding effects of tasks on snack intake, the lack of further associations between impulsivity task performance and child BMI-z may be due to this approach. However, that we did find relationships between performance on tasks using non-food stimuli and snack intake also implies that models of the effects of impulsivity on children's eating behaviour need not be domain specific; in other words, greater impulsivity in non-food domains is a risk factor for poorer eating behaviour in non-clinical samples of children. Indeed, this is consistent with previous work which has demonstrated that children low in self-regulation in both food and non-food domains had most rapid BMI-z score gains between 3 and 12 years (Francis & Susman, 2009). There is a need for models to be more fine grained in describing the facets of impulsivity that are at play in these relationships.

Overall, this study lends support for the hypothesis that impulsivity is related to eating behaviour in a healthy weight, non-clinical group of 7-11 year olds. In turn there was some evidence of relationships between impulsivity, restraint and adiposity, indicating that there is potential for a longer-term association between impulsivity and children's adiposity despite their current weight being within the healthy range. The results suggest that parent perception of impulsivity is related to measures of child adiposity, and that inability to inhibit a pre-potent response and greater delay discounting are risk factors for greater snack intake in children aged 7 to 11 years.

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