1 Associations of Reward Sensitivity with Food Consumption,
2 Activity Pattern, and BMI in Children.

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Associations of Reward Sensitivity with Food Consumption, Activity Pattern, and BMI in Children.

Abstract

In the current study, the associations of reward sensitivity with weight related behaviors and body mass index were investigated in a general population sample of 443 Flemish children (50.3% boys) aged 5.5-12 years. Cross-sectional data on palatable food consumption frequency, screen time, physical activity, parental education level and measured length and weight were collected. The Drive subscale of the 'Behavioral Inhibition Scale/Behavioral Activation Scale' was used as a short method to measure reward sensitivity. A significant positive association of reward sensitivity with the fast food and sweet drink consumption frequency was found. Furthermore, a significant positive association of reward sensitivity with the z-score of body mass index was demonstrated, which explained additional variance to the variance explained by palatable food consumption frequency, screen time, physical activity and parental education level. Hence, the assessment of reward sensitivity may have an added value to the assessment of weight-related behavior indicators when evaluating the determinants of overweight in a child. In sum, children high in reward sensitivity might be more attracted to fast food and sweet drinks, and hence, might be more vulnerable to develop unfavorable food habits and overweight. These findings suggest that considering inter-individual differences in reward sensitivity is of importance in future childhood obesity prevention campaigns.

Keywords: Reward sensitivity; Palatable food; Child; Body mass index; Overweight.

Introduction¹

The prevalence of childhood overweight and obesity has increased dramatically since 1990 (Wang & Lim, 2012). Since childhood overweight and obesity is associated with multiple adverse health outcomes, the current prevalence is identified as a global public health problem (Baker, Olsen, & Sorensen, 2007; Deckelbaum & Williams, 2001; Shrivastava, Shrivastava, & Ramasamy, 2014). Moreover, overweight and obese youth have an increased risk of maintaining their unfavorable weight status into adulthood (Singh, Mulder, Twisk, van, & Chinapaw, 2008).

¹ Abbreviations: RS, reward sensitivity. BMI, body mass index. PA, physical activity. BIS, behavioral inhibition scales. BAS, behavioral activation scales. PAclub, physical activity in sports clubs. CF, weekly consumption frequency. zBMI, age- and sex-adjusted z-score of body mass index. ISCED, International Standard Classification of Education. PEL, highest parental education level of both parents.

53 Therefore, it is of the highest importance to prevent childhood overweight and obesity.
54 Unfortunately, current overweight prevention approaches have no or only small effects (Kamath et
55 al., 2008). A better understanding of the determinants of childhood overweight is needed to improve
56 future prevention approaches.

57 Research has demonstrated positive associations between Body Mass Index (BMI) and the
58 consumption of highly palatable, mostly energy dense foods in children, e.g. fast food (Fraser,
59 Clarke, Cade, & Edwards, 2012), sugar sweetened beverages (Malik, Pan, Willett, & Hu, 2013),
60 and artificially sweetened beverages (Sylvetsky, Rother, & Brown, 2011). For the consumption of
61 sweet food, a significant positive association with BMI was reported in adults, but this association
62 was not demonstrated in children (Te Morenga, Mann, & Mallard, 2013). Furthermore, positive
63 associations between BMI and screen time (Falbe et al., 2013), and negative associations between
64 BMI and physical activity (PA) have been found in children (Chaput et al., 2014). The current
65 western environment facilitates these unfavorable weight-related behaviors, i.e. a high consumption
66 of widely available palatable foods, prolonged engagement in screen time activities, and sedentary
67 lifestyle combined with low levels of PA (Lowe & Butryn, 2007). However, not all children
68 exposed to this obesogenic environment display these unfavorable weight-related behaviors and
69 become overweight (Blundell et al., 2005). It has been shown that some individuals are more
70 reactive to the palatable food environment (Paquet et al., 2010), and noteworthy, Forman et al.
71 reported that this reactivity codetermined the effect of the obesity prevention approaches used in
72 their study (Forman et al., 2007). Furthermore, this reactivity to the food environment depends upon
73 individual differences in reward sensitivity (RS) (Paquet et al., 2010).

74 RS is the tendency to engage in motivated approach behavior in the presence of
75 environmental cues associated with reward, such as the sight of palatable foods (Carver & White,
76 1994). Heightened RS has recently been associated with higher intakes of sugar-sweetened
77 beverages and unhealthy snacks in adolescents (De Cock et al., 2015), and with higher fat intake in
78 adults (Tapper, Baker, Jiga-Boy, Haddock, & Maio, 2015). Moreover, in normal to overweight
79 adolescents and adults, a positive association was reported between RS and BMI (Davis & Fox,
80 2008; Davis et al., 2007; Verbeken, Braet, Lammertyn, Goossens, & Moens, 2012). Unfortunately,
81 in children, findings are less consistent. One study did not find associations of RS with unhealthy
82 snack consumption and BMI in children (Scholten, Schrijvers, Nederkoorn, Kremers, & Rodenburg,
83 2014), while another study reported a positive association between RS and BMI in children, which
84 was mediated by overeating (van den Berg et al., 2011). These inconsistencies might be due to the
85 use of a different RS measure.

Besides consumption of palatable foods, also screen time (e.g. computer games) and PA (e.g. endurance running) were reported to have rewarding potential (Buckley, Cohen, Kramer, McAuley, & Mullen, 2014; Garland et al., 2011). This might implicate that RS also plays a role in those weight-related behaviors (Buckley et al., 2014). Nevertheless, literature on the association of RS with PA and screen time is to our knowledge absent in children and adolescents. In adults, one study reported no relation between RS and PA (Finlayson, Cecil, Higgs, Hill, & Hetherington, 2012), whereas another study reported more PA in individuals with higher RS (Voigt et al., 2009).

Since previous research suggested that knowledge on the association of RS with weight-related behaviors and BMI is imperative for the development of effective prevention strategies, the current study aimed to investigate these associations in a large general population sample of children aged 5.5-12 years. Therefore, consumption frequencies of different types of palatable food, screen time, PA, and BMI calculated upon measured weight and height were used. In accordance to the studies in adolescents (De Cock et al., 2015; Verbeken et al., 2012), the current study used the Drive subscale of the 'Behavioral Inhibition/ Behavioral Activation Scales' (BIS/BAS) as a measure of RS, which is conceptualized as the motivation to approach potentially pleasurable activities (Carver & White, 1994). Important advantages of the Drive subscale are that (a) it was validated in neuro-imaging research (Beaver et al., 2006), (b) it is a short 4-item scale, easily and practically applicable in epidemiological research, obesity prevention interventions and clinical practice, and (c) it does not only measures reactivity to food, but to all kinds of reward, such that it has the potential to be associated with food consumption as well as screen time and PA.

A positive association between RS and the consumption of high-fat fast food, sweet food, and sugared and artificially sweetened beverages was hypothesized. Additionally, the relation of RS with screen time and PA was explored. Further, it was hypothesized that RS was positively associated with BMI and explained additional variance of BMI to the assessment of known predictors of BMI (i.e. palatable food consumption, screen time, PA and parental education level).

Method

Study participants

Participants were Dutch-speaking Belgian children aged 5.5-12 years, recruited by random cluster design for the longitudinal Children's Body Composition and Stress (ChiBS) study (Michels et al., 2012) that took place between 2010 and 2012. Children (in most cases accompanied by minimum one parent) attended the survey centre at a prefixed appointment, during which the

120 anthropometric measurements of the child were conducted and questionnaires were filled in by the
121 parent. If the parent could not accompany the child, the parents were asked to fill in the
122 questionnaires at home.

123 The 455 children that participated in the ChiBS study wave of 2011 were included in the
124 current study. Of the 455 children, twelve children were excluded from the analyses (nine had
125 missing RS-data; three children reached the criteria for obesity, see discussion for argumentation on
126 exclusion of children with obesity). As such, the total study sample consisted of 443 children. A
127 post hoc power calculation was performed based on a sample size of 443 children and the mean of
128 the two squared correlation coefficients (i.e. 0.02) reported in the study of van den Berg et al. that
129 demonstrated a significant relation between scores on two RS measures and BMI in children (van
130 den Berg et al., 2011). This revealed a power of 0.79 to detect a true effect between RS and BMI in
131 the current study.

132 The ChiBS study was conducted according to the guidelines laid down in the Declaration of
133 Helsinki and was approved by the Ethics Committee of Ghent University Hospital. Written
134 informed consent was obtained from all parents and the children gave verbal assent.

135

136 *Measures*

137

138 RS. The BAS scale of the BIS/BAS scale consists of three subscales, namely the Drive,
139 Reward Responsiveness, and Fun Seeking subscale (Carver & White, 1994). The Drive subscale
140 was designed to reflect strong pursuit of appetitive goals and consists of four items which all need
141 to be scored on a 4-point Likert scale (1=not true, 2=somewhat true, 3=true, 4=very true; items are
142 (a) when your child wants something, he/she usually goes all the way to get it, (b) your child does
143 everything to get the things that he/she wants, (c) when your child sees an opportunity to get
144 something that he/she wants, he/she goes for it right away, (d) nobody can stop your child when
145 he/she wants something). Of the three BAS subscales, it has the highest internal consistency (De
146 Cock et al., 2015; Jorm et al., 1999) and the strongest relations with palatable food intake in
147 adolescents (De Cock et al., 2015). Furthermore, the Drive subscale is strongly associated with
148 neural responses to appetizing food-reward cues in the brain reward circuitry, and this association is
149 stronger than the associations between these neural responses and the other BAS subscales (Beaver
150 et al., 2006). Therefore, the term RS refers to the sum of the four items of the Drive subscale.
151 Because the youngest children of the cohort were too young to answer the questionnaire
152 themselves, parents answered a Dutch parent version of the BIS/BAS scale (Vervoort et al., 2015).
153 The Cronbach alpha coefficient of RS in the current study (0.85) was comparable to the alpha

154 reported by Vervoort et al. (i.e. 0.85) in children and adolescents aged 2-18 years (Vervoort et al.,
155 2015).

156 Food indices. Parents completed the Children's Eating Habits Questionnaire - Food
157 Frequency Questionnaire to report the child's usual weekly consumption frequency (CF), thereby
158 considering the preceding 4 weeks. The questionnaire consists of 43 food items/categories and was
159 developed and validated within the EU FP6 IDEFICS project (Huybrechts et al., 2011; Lanfer et al.,
160 2011). For each item, the following response options were used (the assigned score is indicated in
161 brackets): 'never/less than once a week' (value 0), 'one to three times a week' (value 2), 'four to six
162 times a week' (value 5), 'one time a day' (value 7), 'two times a day' (value 14), 'three times a day'
163 (value 21), 'four or more times a day' (value 30), or 'I have no idea' (missing). Based on this
164 questionnaire, three food indices were calculated by summing up the weekly CF's of related food
165 items/categories: (a) Fast food CF, contains all fast food and combined sauces categories; (b) Sweet
166 food CF, contains all sweet food categories; (c) Sweet drink CF, contains all sweet tasting drink
167 categories (Table 1).

168 Screen time and PA. Parents reported on the number of hours of TV/DVD/video viewing
169 and computer/games-console use both for typical weekdays and weekend days. Response categories
170 included: 'not at all' (value zero), '<0.5 hours a day' (value 0.25), '<1 hours a day' (value 0.75),
171 'between 1 and <2 hours a day' (value 1.5), 'between 2 and <3 hours a day' (value 2.5), '>3 hours a
172 day' (value 4). Children's weekly TV/DVD/video viewing (5 times week and 2 times weekend
173 viewing) and computer/games-console use (5 times week and 2 times weekend use) were summed
174 to obtain the hours of screen time per week (Olafsdottir et al., 2014).

175 Parental report on "*How much hours and minutes does he/she spend doing sport in a sports*
176 *club per week*" (no response categories) was used as a proxy measure for moderate to vigorous PA,
177 further referred to as PA at sports clubs (PAclub).

178 BMI. Height (m) and body mass (kg) were measured. Children were not allowed to eat or
179 drink during 2 hours preceding the weighing. Upon weight and length data, BMI (kg/m^2) was
180 calculated, and the standard deviation score of BMI (zBMI) was computed to adjust for age- and
181 sex using xILMS (i.e. an excel add-in for using growth reference data in the LMS format;
182 abbreviation LMS refers to smooth curve-L, mean-M and coefficient of variation-S) with Flemish
183 growth reference data of 2004 (Cole, Freeman, & Preece, 1998; Roelants, Hauspie, &
184 Hoppenbrouwers, 2009). According to the cut-offs of the International Obesity Task Force (Cole &
185 Lobstein, 2012), children with BMI z-scores of ≥ 2.29 for boys and ≥ 2.19 for girls (equivalent of
186 BMI 30 at age 18) were classified as obese, and excluded from further analyses.

187 Parental education level. The highest parental education level of both parents (PEL) was

188 categorized according to the International Standard Classification of Education (ISCED)

189 (UNESCO, 1997). Because of low numbers of participants in category zero to four, the ISCED-

190 categories were aggregated into two levels (ISCED level 0 – 4 = low PEL, value zero; ISCED level

191 5-6 = high PEL, value one).

193 *Statistical analyses*

195 Analyses were performed using PASW Statistical Program version 20.0 (SPSS, IBM, IL,
196 USA). The two-sided level of significance was set at $p < 0.05$. Missing values were not estimated
197 since most missing values were the consequence of questionnaires that were not filled in due to time
198 constraints. Histograms and boxplots were drawn to identify outliers and non-normal distributions.
199 Based on visual inspection, it was decided to exclude five extreme outliers of the sweet drink CF
200 and two of the sweet food CF from further analyses. The fast food, sweet food, and sweet drink CF,
201 and PAclub were found to be non-normally distributed. To use the food indices as dependent
202 variables in regressions, correlations, and t-tests, value one was added to the scores on the single
203 food items of the fast food, sweet food, and sweet drink CF, resulting in a food frequency range of
204 [1;31] instead of [0;30]. Then, the fast food CF, sweet food CF and sweet drink CF sum scores were
205 calculated again, and the natural logarithms (ln) of all food indices were computed, which
206 approached the normal distribution. For PAclub, transformations did not change the distribution
207 towards normality. To use PAclub as dependent variable in regressions, it was dichotomized (zero
208 to two hours per week = low PAclub, value zero; more than two hours per week = high PAclub,
209 value one).

210 Explorative unadjusted Pearson correlations (exception: Spearman correlation for PAclub)
211 and unpaired t-tests (exception: Mann-Whitney U test for PAclub) were conducted to find out if
212 age, sex and PEL had to be included as covariates when regressing weight-related behaviors on RS.
213 They were only included as covariates in regression models if (trend) significant associations were
214 present between age, sex or PEL and (a) the predictor, and (b) the dependent variable.

215 To investigate the research hypothesis that RS was positively associated with the three food
216 indices, three linear regression models were conducted with RS as predictor and fast food CF, sweet
217 food CF and sweet drink CF as dependent variables. To explore if RS was associated with screen
218 time and PAclub, a linear and a logistic regression were conducted respectively with RS as
219 predictor and screen time and PA club as dependent variables.

220 To investigate if RS was positively associated with zBMI and if it explained additional
221 variance to the assessment of known predictors, a hierarchical linear regression model with zBMI as
222 dependent variable was conducted. This analysis was conducted on a subsample of the total study
223 sample, for which all predictors included in the model were reported. In step 1 of the hierarchical
224 linear regression model, the three food indices, screen time, PAclub and PEL were added as
225 predictors. In step 2, also RS was added as predictor to the regression model. Since zBMI scores are
226 adjusted for age and sex, and inclusion of age and sex as covariate did not change the results, age
227 and sex were not included in the regression model.

228 For the linear regression models, semi-partial correlations were computed to measure the
229 effect size of RS (Aloe, 2014). Effects of 0.10 were interpreted as small, of 0.30 as medium and of
230 0.50 as large (Cohen, 1992).

231

232 **Results**

233

234 *Descriptive statistics and comparisons between the total sample and subsample*

235

236 Table 2 shows the descriptive statistics on age, RS, zBMI, and weight-related behaviors. Of
237 the total study sample of 443 children (50.3% boys), 22.6% had low PEL, 70.7% high PEL, and
238 6.8% missing PEL-data. Further, 46.7% children were categorized as low and 40.6% as high
239 PAclub; 12.7% had missing PAclub data.

240 The subsample of children for which all variables included in this study were reported
241 consisted of 344 children (50.6% boys; 21.8% low PEL; 51.7% low PAclub). Using unpaired t-
242 tests, the mean RS and zBMI score did not significantly differ between the 344 participants with all
243 data and the 99 participants with missing data on one or more variables (RS: $t(441)=0.52$, $p=0.60$;
244 zBMI: $t(441)=-0.11$, $p=0.91$).

245

246 *Association of RS with food indices, screen time and PAclub*

247

248 Explorative analyses. Correlations and comparisons were performed to find out which
249 variables should be included as covariates in the regression models with RS as predictor and
250 weight-related behaviors as dependent variables (Table 3). Based on these results, age was included
251 as covariate in all five regression models with RS as predictor and the weight-related behaviors as
252 dependent variables because (a) a trend significant correlation between RS and age was present, and
253 (b) age was significantly related to screen time and PAclub, and trend significant to the fast food

254 and sweet food CF. Sex was only included as covariate in the regression model with screen time as
255 dependent variable, since trend significant sex differences were only present on RS and screen time.
256 PEL was not included as covariate in the regression models: although the CF of fast food and sweet
257 drink were significantly higher in low PEL (mean fast food CF low PEL=7.61, high PEL=5.57
258 times a week; mean sweet drink CF low PEL=11.39, high PEL=8.69 times a week), no association
259 was found between PEL and RS.

260 Regression analyses adjusted for covariates. Table 4 shows the results of the five
261 regressions. RS was significantly and positively related to the fast food CF and sweet drink CF, but
262 not to the sweet food CF, screen time, and PAclub. The models predict that children aged 8.86 years
263 (i.e. mean age) at percentile 10 versus 90 of RS consume fast food on average 4.89 versus 5.85
264 times a week respectively, and consume sweet drinks on average 6.95 versus 8.42 times a week,
265 respectively.

266

267 *Association of RS with zBMI*

268

269 RS was significantly and positively associated with zBMI (Table 5). RS significantly
270 explained an extra 2% of the variance in zBMI to the variance explained by the weight-related
271 behaviors and PEL. Tolerance values to check multicollinearity were all above 0.8 in both steps of
272 the model. The model predicts that children at percentile 90 of RS have on average a 0.34 units
273 higher zBMI than children at percentile 10 of RS.

274

275 **Discussion**

276

277 The present study investigated the associations of the scores on a short RS questionnaire,
278 namely the Drive subscale of the BIS/BAS scale (Carver & White, 1994), with weight related
279 behaviors and zBMI in a general population sample of children aged 5.5-12 years.

280 The results confirmed that children with higher RS may consume more frequently fast food
281 and sweet drinks. Similar findings were recently found in adolescents aged 14-16 years (De Cock et
282 al., 2015). The current study findings suggest that even in children, whose access to food is strongly
283 determined by others (e.g. parents, teachers), the individual characteristic RS may play a role in
284 palatable food consumption. Children high in RS might be more easily tempted by palatable fast
285 food and sweet drink cues, and more motivated to consume them. This might shape unfavorable
286 food habits that continue during life.

287 The research hypothesis that RS was positively associated with the sweet food CF could not
288 be confirmed. Nevertheless, in line with other studies, the sweet food CF was not related to PEL,
289 whereas the fast food and sweet drink CF were related to PEL (Elinder, Heinemans, Zeebari, &
290 Patterson, 2014). Possibly, the fast food and sweet drink CF might be determined by different
291 parameters (PEL, RS) than the sweet food CF, which might be determined by habits in Flemish
292 primary schools (eating biscuits and/or chocolate bars as snacks during school breaks is common).

293 The present study found no associations between RS and the potentially rewarding
294 behaviors “screen time” and “physical activity in sports clubs”. Previous research on this
295 associations in primary school children is to our knowledge absent. Possibly, RS does not influence
296 these weight-related behaviors. Nonetheless, the lack of a relation between RS and screen time
297 might also be due to high parental control or restriction over screen time in this age group.
298 Additionally, screen time was measured in the current study by the sum of ‘hours of television
299 viewing’ and ‘hours in front of a computer/game console’, but only the hours of engagement in
300 rewarding computer games might be related to RS. Future research is therefore needed to replicate
301 these findings with refined measures of screen time, thereby differentiating between television and
302 gaming. The lack of a relation between RS and PAclub was in line with results of a systematic
303 review on children and adolescents, which concluded that PAclub was more consistently related to
304 environmental characteristics than to interpersonal factors (de Vet, de Ridder, & de Wit, 2011).
305 Indeed, whether children like sporting in a sports club or not, the hours of PAclub of primary school
306 children is dependent on the permission and logistic support of their parents and on nearby sports
307 club facilities. Further, future research in children might explore the relationship between RS and
308 objectively measured physical activity (e.g. with accelerometers), assessing the overall level of PA
309 during daytime.

310 In the current study, only a trend significant positive association between the fast food CF
311 and zBMI was present. No associations of the sweet drink CF, screen time, and PAclub with zBMI
312 were found. Recent reviews indicated that only some studies reported significant relations between
313 these parameters and BMI (Malik et al., 2013; Must, Barish, & Bandini, 2009). Probably,
314 differences in methodology can explain the different findings. Further, a negative relation between
315 sweet food CF and zBMI was found, which is in conflict with a meta-analysis that reported no
316 significant relationship between sweet food and BMI in children (Te Morenga et al., 2013). This
317 negative association might be due to the assessment of consumption frequencies without inquiring
318 portion sizes. Portion sizes of sweet food CF might vary substantially across children (e.g. one
319 versus three cookies per consumption). Hence, future research should include more detailed
320 assessment of dietary habits, identifying not only frequency but also portion size.

321 Finally, the current study demonstrated a positive association between RS, measured by the
322 Drive subscale of the BIS/BAS scale, and zBMI in normal to overweight children. This finding was
323 already reported in adolescents with the same RS questionnaire (Verbeken et al., 2012) and in
324 children with a different RS questionnaire (van den Berg et al., 2011). Another study in children
325 that used a behavioral task as RS measure did not find this association (Scholten et al., 2014).
326 Moreover, RS assessment explained additional variance of zBMI to the variance explained by food
327 consumption, activity pattern, and PEL. Therefore, the assessment of RS with this very short
328 questionnaire might have an added value in public health and pediatrics.

329 The positive association between RS and zBMI was found in a population of children
330 without obesity. Children with obesity were excluded from the analyses because (a) the focus of this
331 study is on obesity prevention, (b) the obesity rate in the current sample was too low to accurately
332 investigate the relation between RS and zBMI in obese children, and (c) most importantly, RS was
333 only positively associated with BMI in adolescents (Verbeken et al., 2012) and adults (Davis &
334 Fox, 2008) without obesity, but negatively associated with BMI in the obese population in both
335 studies. This inverted relation is probably due to changes in brain reward processes over the course
336 of obesity development (Kessler, Zald, Ansari, Li, & Cowan, 2014).

337 The positive associations of RS with fast food CF, sweet drink CF and zBMI reported in this
338 paper are relevant for future prevention strategies, certainly if future longitudinal studies can
339 confirm an increased obesity risk in high RS children. Such associations can offer an explanatory
340 framework for parents and health care workers on why some children are more tempted by
341 palatable food compared to other children. Further, specifically targeting children high in RS, which
342 are assumed to be more vulnerable to the obesogenic environment, may improve the effectiveness
343 of obesity prevention interventions. In fact, there is already some evidence in adults as to which
344 elements to include in prevention interventions tailored to this RS feature. Three such elements are
345 worth briefly describing in the context of this paper. First, messages that are framed in terms of the
346 benefits of adopting the recommendation (i.e. gain-frame) rather than the disadvantages and costs of
347 not adopting a recommendation are more effective in high RS individuals (Covey, 2014). Second,
348 the study of Forman et al. (2007) compared two methods designed to help individuals manage
349 palatable food cravings such that they do not lead to palatable food consumption: (a) ‘control-based
350 strategies’, e.g. removing palatable foods from the direct home or work environment, restructuring
351 thoughts that permit eating palatable food, and refocusing strategies designed to turn attention away
352 from food related stimuli towards non-food related stimuli; (b) acceptance-based strategies, e.g.
353 awareness and acceptance of the feelings of food cravings without trying to suppress or eliminate
354 them and without taking actions in order to consume the desired food. The method with acceptance-

355 based strategies decreased the consumption of palatable foods in participants with high RS specific
356 to food, but increased food cravings in participants with low RS specific to food. Hence,
357 interventions using these acceptance-based strategies are useful only in high RS individuals. Third,
358 self-regulatory skills were found to moderate the relation between RS and BMI in adults (Lawrence,
359 Hinton, Parkinson, & Lawrence, 2012). Therefore, the training of self-regulatory skills (Verbeken,
360 Braet, Goossens, & van der Oord, 2013) might be effective to reduce palatable food consumption in
361 high RS individuals. Future research should clarify if also in children, these three intervention
362 techniques can be successfully applied.

363 The limitations of the current study include its cross-sectional design. Future longitudinal
364 research to confirm causality is needed. Further, although BMI is a frequently used measure of
365 adiposity, better measures exist (e.g. densitometry). Next, children with overweight and obesity, as
366 well as families with lower levels of parental education were relatively underrepresented in the
367 current study. Therefore, future research in a more representative sample is recommended.
368 Additionally, RS and all weight-related behaviors were based on subjective questionnaires. The
369 construct of RS could be confounded by parenting style, and the relation of RS and palatable food
370 consumption in children could be confounded by food provision patterns of parents, which were not
371 taken into account in the current study. Further, the PAclub measure did not include PA of the child
372 outside of sports clubs. The number of missing values on weight-related variables was high due to
373 time constraints of parents. However, no differences were found in RS and zBMI between the total
374 sample and the subsample. Because inclusion of portion size assessment in a cohort study is a high
375 burden for participants and would result in a reduced sample size, the food indices were only based
376 on consumption frequency assessments. Therefore, associations between the three food indices and
377 zBMI should be interpreted with caution. Unless the mentioned limitations, relationships between
378 the weight-related parameters screen time, the fast food CF, sweet food CF, sweet drink CF, and
379 PEL were as expected based on the literature (Fernandez-Alvira et al., 2015; Pearson & Biddle,
380 2011; Tandon et al., 2012). Further, the strengths of the current study include the large general
381 community sample of primary school children, the use of a simple and short RS questionnaire, the
382 consideration of multiple weight-related behaviors, and the objective measurement of weight and
383 length.

384

385 **Conclusion**

386

387 Overall, the results of the current study suggest that children high in RS are more easily
388 tempted by palatable fast food and sweet drink cues, which might lead to unhealthy food habits.

389 Further, children high in RS might be more prone to develop overweight. These findings suggest
390 that considering inter-individual differences in RS can be of importance in future childhood obesity
391 prevention campaigns. Future longitudinal research is warranted to verify that RS is a risk factor of
392 unfavorable food habits and overweight in children.

393

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395

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568

569 **Table 1.** Food indices based on the food categories included in the Children’s Eating Habits Questionnaire – Food
570 Frequency Questionnaire

Fast food consumption frequency
=Weekly consumption frequency of the following food categories
Fried potatoes, potato croquettes
Pizza as main dish
Chips, tortillas, popcorn
Sausage roll, cheese roll, pizza-snack
Hamburger, hotdog, kebab, wrap, pita, durum
Ketchup
Mayonnaise, mayonnaise based products
Sweet food consumption frequency
Candies, marshmallow
Chocolate, candy bars
Biscuits, cakes, pastries
Ice cream
Sweet drink consumption frequency
Fruit juice
Sweet and soft drinks
Light and zero soft drinks
Sugared milk

571

572

573 **Table 2.** Descriptive data of the key variables

	N	Min	P25	P50	P75	Max	M	sd
Age (years)	443	5.65	7.80	8.98	10.07	11.95	8.86	1.48
RS (range 4-16)	443	4.00	6.00	8.00	11.00	16.00	8.66	2.84
Fast food CF (times per week)	427	0.00	2.00	6.00	8.00	20.00	6.09	4.26
Sweet food CF (times per week)	431	0.00	5.00	9.00	13.00	30.00	9.25	5.63
Sweet drink CF (times per week)	427	0.00	4.00	8.00	14.00	37.00	9.32	6.94
Screen time (hours per week)	383	0.50	6.75	9.50	15.25	33.00	11.06	6.07
PAclub (hours per week)	387	0.00	1.00	2.00	3.50	8.00	2.29	1.68
zBMI	443	-2.89	-0.83	-0.22	0.34	2.19	-0.22	0.91

574 N, number. Min, minimum. P25, percentile 25. P50, median. P75, percentile 75. Max, maximum. M, mean. sd, standard
575 deviation. RS, reward sensitivity. CF, weekly consumption frequency. PAclub, physical activity in sports clubs. zBMI,
576 age- and sex-adjusted z-score of Body Mass Index.

Table 3. Correlations between reward sensitivity, age and weight-related behaviors and comparisons of these variables across sex and parental education level

	RS		Age		Fast food CF ^a		Sweet food CF ^a		Sweet drink CF ^a		Screen time		PAclub	
	r	P	r	P	r	P	r	P	r	P	r	P	r	P
Age ^b	-0.09	0.06												
Fast food CF ^{a, b}	0.09	0.06	0.08	0.10										
Sweet food CF ^{a, b}	-0.03	0.51	-0.09	0.07	0.10*	0.05								
Sweet drink CF ^{a, b}	0.09	0.06	0.03	0.57	0.26**	<0.01	0.15**	<0.01						
Screen time ^b	0.03	0.62	0.23**	<0.01	0.29**	<0.01	0.11*	0.04	0.14**	0.01				
PAclub ^c	0.02	0.67	0.16**	<0.01	<-0.01	0.96	<-0.01	0.87	-0.03	0.55	0.03	0.63		
	t (df)	P	t (df)	P	t (df)	P	t (df)	P	t (df)	P	t (df)	P	U (Z)	P
Sex	1.82 (441)	0.07	-0.35 (441)	0.73	0.59 (425)	0.56	0.54 (429)	0.59	0.82 (425)	0.41	1.76 (359.44)	0.08	16604.00 (-1.61)	0.11
PEL	0.47 (411)	0.64	1.66 (411)	0.10	3.99 (396) **	<0.01	-1.24 (400)	0.22	3.60 (395)**	<0.01	3.15 (367)**	<0.01	11294.00 (-1.07)	0.29

RS, reward sensitivity. CF, weekly consumption frequency. PAclub, physical activity in sports clubs. r, correlation coefficient. t(df), t-value and degrees of freedom of unpaired t-test. U(Z), Mann-Whitney U and Z test statistic. PEL, parental education level. ^aThe natural logarithm of the food indices was used. ^bPearson correlation was conducted. ^c Spearman correlation was conducted. * $P < 0.05$, ** $P < 0.01$.

Table 4. Linear and logistic regressions with reward sensitivity as predictor and weight-related behaviors as dependent variables

Dependent variable	Intercept			RS			Age ^b			Sex ^c			r_{sp} (RS)	R^2
	N	b (SE)	P	b (SE)	β	P	b (SE)	β	P	b (SE)	β	P		
Fast food CF ^a	427	2.42 (0.05)	<0.01	0.01 (0.01)	0.10	0.04	0.02 (0.01)	0.09	0.07				0.10	0.02
Sweet food CF ^a	431	2.55 (0.07)	<0.01	-0.01 (0.01)	-0.04	0.42	-0.03 (0.01)	-0.09	0.06				-0.04	0.01
Sweet drink CF ^a	427	2.30 (0.08)	<0.01	0.02 (0.01)	0.10	0.05	0.01 (0.02)	0.04	0.46				0.10	0.01
Screen time	383	10.92 (1.04)	<0.01	0.08 (0.11)	0.04	0.44	0.96 (0.20)	0.24	<0.01	-1.13 (0.61)	-0.09	0.10	0.04	0.06
	N	b_{log} (SE)	P	b_{log} (SE)	OR	P	b_{log} (SE)	OR	P	Nagelkerke R ²				
PAclub	389	-0.57 (0.33)	0.09	0.05 (0.04)	1.05	0.18	0.27 (0.07)	1.32	<0.01	0.05				

RS, reward sensitivity. r_{sp} , semipartial correlation. b, unstandardized regression coefficient. SE, standard error of b. β , standardized regression coefficient. CF, weekly consumption frequency. b_{log} , logistic regression coefficient. OR, odds ratio. PAclub, dichotomized physical activity in sports clubs with value zero for low and value one for high PAclub.

^aThe natural logarithm of the food indices was used. ^bCentralized child age. ^cValue zero for boys, value one for girls.

Table 5. Linear regression with Body Mass Index as dependent variable. Weight-related behaviors and parental education level were included as predictors in step 1, reward sensitivity was added as predictor in step 2.

Dependent variable: zBMI					
	Predictor	b	SE	β	<i>P</i>
Step 1 $R^2=0.08$	Intercept	0.35	0.19		0.06
	Fast food CF	0.02	0.01	0.11	0.06
	Sweet food CF	-0.03	0.01	-0.15	<0.01
	Sweet drink CF	<0.01	0.01	-0.03	0.53
	Screen time	<0.01	0.01	-0.02	0.73
	PAclub	-0.04	0.03	-0.07	0.19
	PEL	-0.39	0.12	-0.18	<0.01
Step 2 $R^2=0.10$ $P(\Delta R^2)<0.01$	Intercept	-0.04	0.23		0.85
	Fast food CF	0.02	0.01	0.09	0.09
	Sweet food CF	-0.02	0.01	-0.15	0.01
	Sweet drink CF	-0.01	0.01	-0.05	0.4
	Screen time	<0.01	0.01	-0.02	0.74
	PAclub	-0.04	0.03	-0.07	0.15
	PEL	-0.39	0.12	-0.18	<0.01
	RS ^a	0.05	0.02	0.15	<0.01

zBMI, age- and sex-adjusted z-score of Body Mass Index. b, unstandardized regression coefficient. SE, standard error of b. β , standardized regression coefficient. CF, weekly consumption frequency. PAclub, physical activity in sports clubs. PEL, parental education level, value zero for low and value one for high PEL. $P(\Delta R^2)$, *P* value of the R^2 change between step 1 and step 2. RS, reward sensitivity. ^aSemi-partial correlation of RS is 0.15.