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Comparison of sensory-specific satiety between normal weight and overweight children

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ABSTRACT

Sensory properties of some foods may be of importance to energy consumption and thus the development and maintenance of childhood obesity. This study compares selected food related qualities in overweight and normal weight children. Ninety-two participants were included; 55 were overweight with a mean age of 11.6 years (range 6–18 years) and a mean BMI z-score of 2.71 (range 1.29–4.60). The 37 normal weight children had a mean age of 13.0 years (range 6–19 years) and a mean BMI z-score of 0.16 (range −1.71 to 1.24). All children completed a half-hour long meal test consisting of alternation between consumption of foods and answering of questionnaires. Compared to the normal weight, the overweight children displayed lower self-reported intake paces ($\chi^2(2) = 6.3$, $p = 0.04$), higher changes in liking for mozzarella ($F(1,63) = 9.55$, $p = 0.003$) and pretzels ($F(1,87) = 5.27$, $p = 0.024$), and declines in wanting for something fat, of which the normal weight children displayed an increase ($F(1,83) = 4,10$, $p = 0.046$). No differences were found for sensory-specific satiety, wanting for the main food yoghurt, hunger, or satiety. In conclusion, overweight children did not differ from normal weight children in terms of sensory-specific satiety, hunger, or satiety. However, overweight children had lower intake paces and appeared to differ from normal weight children regarding foods with a fatty taste.

1. Introduction

During the last decade, the prevalence of overweight and obese children and adolescents generally appear to have reached a plateau in Western countries; however, increases in the degree of obesity has recently been documented in the US, and taken together a large number of children are affected with obesity (Ogden, Carroll, Kit, & Flegal, 2014; Olds et al., 2011; Schmidt Morgen et al., 2013; Skinner, Perrin, & Skelton, 2016). Apart from the enormous health economic consequences related to obesity on a societal level, the consequences on an individual level are severe as well (Anis et al., 2010; Colagiuri et al., 2008). In children, obesity may induce the development of metabolic complications such as hypertension, dyslipidemia, prediabetes, and hepatic steatosis, as well as severe psychosocial complications, which e.g. are primarily due to stigmatization and body dissatisfaction (Neef, Weise, & Adler, 2013).

The etiology of childhood obesity constitutes a highly complex interplay between several factors and may to some extent involve an unfavorable diet and or eating patterns. Multiple factors influence food consumption where an important factor is external eating, which describes how easily one is tempted to eat due to external stimuli such as the smell and sight of foods (van Strien, Frijters, Bergers, & Defares, 1986). In the experiment reported in this paper, we investigated whether external eating, intake pace, sensory specific satiety, wanting, transfer effects and induced food desires differ between obese and normal weight children. Sensory specific satiety (SSS) is defined as a decline in pleasantness of a food during its consumption (E. T. Rolls & Rolls, 1997). Therefore, SSS is a mechanism that guides people to eat a varied diet, and imbalances in SSS could lead to inappropriate eating behavior. Furthermore, the decline in pleasantness simultaneously occurs for other foods,

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which share sensory properties with the eaten food. For example, stimulation with a sweet and crunchy biscuit will not only give rise to SSS for the biscuit, but also to other related food items, which either taste sweet and/or are crunchy (Guinard & Brun, 1998). This phenomenon is called a *transfer effect* (Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; B. J. Rolls, Van Duijvenvoorde, & Rolls, 1984). However, this has not been tested in children and in general, only very few studies have approached an investigation of SSS and transfer effects and their possible contribution to obesity in children (Brondel et al., 2007; Olsen, Ritz, Hartvig, & Møller, 2011). Concurrently with SSS, a decline in wanting for a food is often observed during consumption (Berridge & Robinson, 2003; Berridge, 1996; Finlayson & Dalton, 2012; Havermans, 2011, 2012; Møller, 2015). High(er) wanting (and induced desires) will produce larger food intake, increasing the risk of becoming obese. Wanting is often quantified by measuring how much effort participants are willing to apply to obtain a certain food, but since it was not possible to use such a procedure in the present experiment, we used the same method as (Olsen et al., 2011), who asked participants to report wanting by means of a visual analog scale.

Previous studies have shown associations between weight changes and intake pace in adults (Andrade, Greene, & Melanson, 2008; Otsuka et al., 2006; Tanihara et al., 2011). For an example, Otsuka et al. concluded that their results "*among middle-aged men and women suggest that eating fast would lead to obesity*", while Andrade et al. concluded that their "*data suggest that eating slowly may help to maximize satiation and reduce energy intake within meals*"(Otsuka et al., 2006; Tanihara et al., 2011). Thus, as intake pace may act as a contributing factor to or against obesity, this variable was examined as well.

The objective of the present study was to examine sensory specific satiety, wanting, external eating, intake pace, hunger, satiety, and transfer effects comparing normal weight and overweight children. We hypothesized that overweight children display reduced SSS compared to normal weight children, and that overweight children express higher wanting for foods, less decrease in hunger, and less increase in satiety while eating, as well as a higher intake pace. Furthermore, we hypothesized that overweight children score higher on an external eating questionnaire and thereby display a higher degree of temptation towards foods.

2. Materials and methods

2.1. Participants

The study was based on 93 participants from the Danish Childhood Obesity Biobank. Forty seven of the participants were overweight/obese and recruited at enrolment at The Children's Obesity Clinic, which offers a multidisciplinary pediatric obesity treatment program (Holm et al., 2011). The other half was recruited as normal weight controls from elementary schools in the same region in Denmark. For both overweight and control participants, anthropometric measurements including height measured to the nearest 1 mm using a wall mounted stadiometer, and weight measured to the nearest 0.1 kg using a Tanita Digital Medical Scale (WB-100 MA, Tanita Corp., Tokyo, Japan) were obtained by clinical and research staff respectively, and body mass index (BMI) adjusted for age and gender, BMI z-scores, were calculated in order to determine the degree of obesity (Nysom, Mølgaard, Hutchings, & Michaelsen, 2001). Furthermore, self-reported data on all participants' ethnicity were collected from the Danish Childhood Obesity Biobank. Pubertal stages, i.e. Tanner Stages, were determined by a trained pediatrician in the overweight participants whereas it was picture pattern recognized and thus self-reported by the control participants in accordance with the Tanner Stage developmental illustrations (Marshall & Tanner, 1969, 1970). The social class was defined according to the parents' occupation where social class 1 represents the highest social class, in which people are self-employed or possesses a high education degree, and social class 5 represents the lowest social class, in which people are unemployed.

Inclusion criteria were that participants should be aged between 6 and 21 years and have a record of anthropometric measurements. Exclusion criteria were pregnancy, having a severe cold, or reduced sense of smell.

Informed oral and written consent was obtained from all participants and their parents, and the study was carried out in accordance with The Code of Ethics of the World Medical Association (The Declaration of Helsinki), approved by the Ethics Committee of Region Zealand, Denmark (protocol no. SJ-104), and by the Danish Data Protection Agency.

2.2. Design and questionnaires

The test was conducted in groups of two to four, and participants who were not able to read or write were allowed to be accompanied by a parent. Multiple participants completed the experiment though not simultaneously thereby preventing comparisons of ratings. At first, the participants were introduced to the study and told that the aim of the study was not to be revealed until after the test, but that it concerned foods and their taste properties. Afterwards, participants filled out the first questionnaire concerning background variables, that is gender, age, height, weight, pregnancy status, smoking, severe cold, or reduced sense of smell. Furthermore, in the same questionnaire, they reported their presumed general intake pace on a scale from 1 to 3 where 1 was fast, 2 was normal, and 3 was slow. Since only a few studies have been performed in children, there is no valid approach concerning the intake pace variable. Therefore, we aimed at the second best i.e. an approach validated in adults. Thereafter, participants filled out the second questionnaire: The External Eating questionnaire, which consisted of ten questions translated concisely into Danish (by a native speaker of Danish) (van Strien et al., 1986). The third questionnaire (two pages) evaluated participants' *baseline values* for hunger, satiety, and wanting for something sweet, salty, spicy, bitter, fat, and sour on 150 mm Visual Analog Scales (VAS) from "not at all"(0) to "extremely"(150) (Flint, Raben, Blundell, & Astrup, 2000; Olsen, Ritz, Kramer, & Møller, 2012; Olsen et al., 2011). The questions were: "*How hungry do you feel right now*?", "*How full do you feel right now*?", and "*How much do you want something [sweet/salty/spicy/bitter/fat/sour] right now?*".

Following the completion of the baseline questionnaire, participants were asked to consume six transfer effect foods and one target stimulus, one at a time, in a completely random order, and score liking and wanting for each food on 150 mm VAS in a fourth questionnaire. The questions were: "*How much do you like the food, you have just eaten?*" and "*How much do you want to eat a portion more of the food?*". Therefore, fourteen questions were asked in total concerning transfer effect foods and the target stimulus. The amount of each transfer effect food, approximately half a tablespoon, was large enough for a full taste experience, though not large enough to influence satiation considerably. Typically, approximately 30 s went by in between the test foods in order to clear both the food and the mouth. The seven foods were yoghurt (target stimulus), tonic water, mozzarella, apple with lemon, grapes, pretzels, and dark chocolate (please refer to the section, "*Test foods*", for more specific details on amounts and energy content). In case of a participant refusing to consume a transfer effect food or being allergic, the food was skipped. Participants were then asked to consume 60 g of the test stimulus, the yoghurt, and evaluate their hunger, satiety, liking, and wanting for the yoghurt

on 150 mm VAS in the fifth questionnaire. Hereafter, participants were offered a second voluntary portion of 60 g of yoghurt followed by completion of an additional fifth questionnaire. Since the overweight participants were restricted to act according to the dietary advices practiced within the Children's Obesity Clinic's Treatment protocol, the maximum amount of yoghurt was set at 120 g (Holm et al., 2011). The controls were offered a maximum of 300 g (5 portions). When participants were feeling full, did not want more of the yoghurt, or were not allowed to eat more yoghurt (in consideration to caloric intake), they filled out a sixth questionnaire quantifying their wanting for foods, either sweet, salty, spicy, bitter, fat, and sour, on 150 mm VASs thereby providing the *end values*. Lastly, participants repeated the consumption of the six transfer effect foods and the target stimulus and completed a seventh questionnaire regarding liking and wanting similar to questionnaire four. The experimental design is shown in Fig. 1.

2.3. Test foods

The study tested seven different foods, chosen by their sensory properties. The main food, the yoghurt ("Yoggi®", Arla Foods, Denmark, a pear and banana tasting yoghurt), was chosen as test stimulus, since it has been used to examine SSS in children (and adults) previously (Olsen et al., 2011). Each food's sensory properties were determined as mean values of five young adults' evaluations of the food's saltiness, sourness, sweetness, fattiness, fruitiness, bitterness, and spiciness on a 150 mm VAS. Mean values below 30 were discarded, because we were interested in determining the main sensory properties of the foods. This selection of values gave the test food to have similar sensory properties as found in Olsen et al. in 2011 (Olsen et al., 2011). Since the test was conducted in the morning, and the foods should be perceived as relevant at breakfast, no test foods were spicy. The transfer effect foods were chosen in order to secure different taste properties compared to the main test stimuli, the yoghurt. Information concerning the foods are given in Table 1.

All statistical analyses were conducted in SAS version 9.3, and the significance level was set at 0.05. All tests were two-sided. Changes in all examined variables were calculated by subtracting *baseline values* from *end values*. Both paired and unpaired *t*-tests were used.

T-tests were conducted for normal weight and overweight participants separately examining changes in hunger and satiety taking into account the different maximum number of offered portions; the analyses were performed on the changes from baseline to after second portion. Furthermore, intake pace was examined using a χ^2-test whereas external eating was examined using a *t*-test.

Finally, changes in liking, changes in wanting, changes in liking and wanting for the six transfer effect foods and the target stimulus, and changes in wanting for the six different taste properties were examined using ANOVA with time(before/after), overweight status (yes/no) and the interaction between time and overweight. If the interaction was non-significant the significant main effects were reported. Values for changes in liking and wanting were based on all participants who voluntarily stopped eating. Normality was only assumed when a visual inspection of probability plots did not reveal clear deviation from the normal distribution.

3. Results

3.1. The participants

Of the 93 tested participants, 92 met the inclusion criteria. The 93th participant was excluded due to missing data. Since the control participants included overweight children ($N = 9$) and had a larger variation in BMI z-scores, participants with a BMI above the 90th percentile (BMI z-score $\geq$ 1.28) were allocated to the

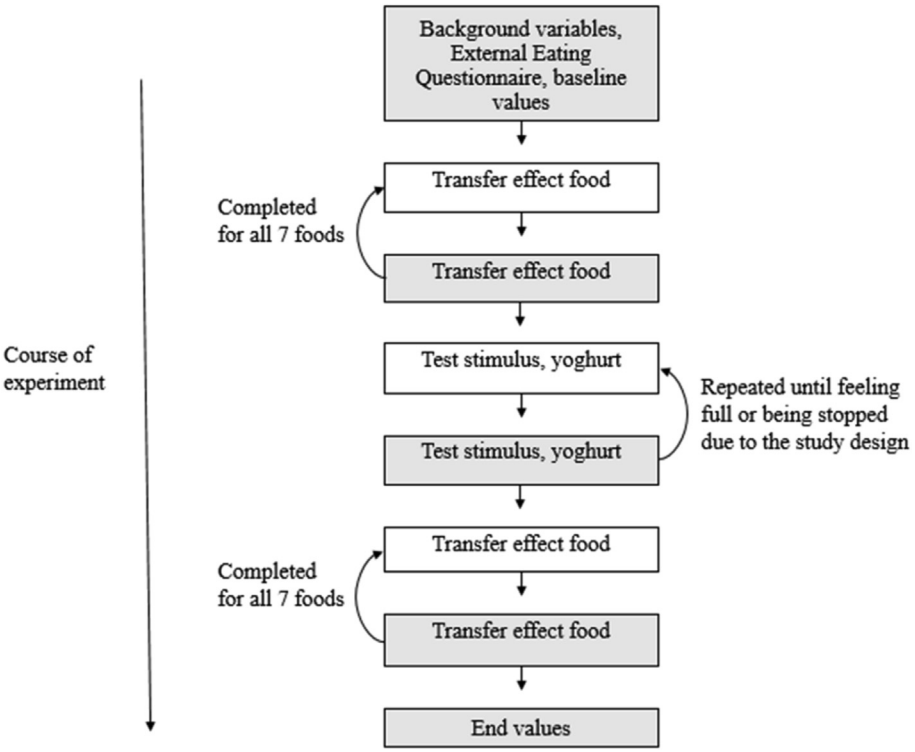

Fig. 1. The experimental design. Steps consisting of questionnaires are grey. White steps represent steps of food consumption. Arrows state that a step was repeated.

Table 1
The consumed amount and energy content of the six transfer effect foods and the target stimulus.

Food	Information	Amount	Energy content
Yoghurt (test stimulus)	"Yoggi®", Arla Foods, Denmark	One teaspoon	340 KJ per 100 g
Tonic water	"Indian Tonic Water", Schweppes	One sip	159 KJ per 100 mL
Mozzarella	"Mozzarella", Spezialitäten-Käserei Saputo, Germany	One piece (6 g)[a]	1038 KJ per 100 g
Apple with lemon	Sort: Golden Delicious	One piece (3 g)[a]	
Grapes	Sort: Superior S	One (5 g)	
Pretzels	"Snack Sticks (Blister)", Pauly, Germany	One (<1 g)	1590 KJ per 100 g
Dark chocolate (70%)	"Ecuador dark 70%", Björnsted, Germany	One piece 2.5 g[b]	2375 KJ per 100 g

[a] At approximately the size of one cubic centimeter.
[b] (100 g were divided into 40 pieces)Data analyses.

overweight group whereas participants with BMI z-score below 1.28 were allocated to the normal weight group. For specific details on the two groups, please refer to Table 2. The total number of participants corresponding to the individual variable may vary due to missing data.

In terms of the exclusion criteria, one participant was a smoker, and 14 reported to have a minor cold, which did not prevent them from smelling or tasting properly. This is why none were excluded for these reasons. Furthermore, the normal weight participants were significantly older and in higher pubertal stages than the overweight participants, while the overweight participants came from lower social classes (Table 2).

3.2. The meal test

Six foods were chosen based on their taste properties and used to examine transfer effects. The mean values of the taste properties of the six foods and the target stimulus are given in Table 3.

3.3. Hunger, satiety, intake pace, and external eating

The paired *t*-tests revealed declines in hunger for both overweight from on average 93 mm–7 mm ($p \leq 0.001$, $T(54) = -7.3$) and normal weight children from 87 mm to 17 mm ($p \leq 0.001$, $T(35) = -6.3$, data not shown), but no significant effect was found for satiety (overweight from 33 mm to 29 mm and normal weight 36 mm–43 mm). Furthermore, analyses adjusted for ethnicity, social class, gender, age, having a minor cold, and Tanner Stage showed that participants reporting having a minor cold displayed larger decreases in hunger, and boys had smaller increases in satiety (data now shown).

The χ^2-and unpaired *t*-test revealed significantly lower self-reported intake paces in the overweight group, 48% reported slow eating compared to 22% in the normal weight group ($\chi^2(2) = 6.3$, $p = 0.04$, $N = 90$) and an on average 0.34 higher external eating scores (confidence interval (0.10; 0.59) $t(90) = -2.8$, $p = 0.007$, $N = 92$) among overweight participants. However, in an analysis adjusted for ethnicity, social class, gender, age, having a minor cold, and Tanner Stage, this tendency became insignificant for the external eating scores (data not shown).

3.4. The ANOVA tests

The ANOVA tests revealed a decline in liking ($F(1,90) = 12.52$, $p < 0.001$, $N = 92$), but the SSS was independent of the degree of overweight ($F(1,90) = 0.02$, $p = 0.90$, $N = 92$). In analyses adjusted for ethnicity, social class, gender, age, having a minor cold, and Tanner Stage, participants of Danish origin revealed a reduced SSS compared to participants of another origin than Danish (data not shown). As with SSS, declines in wanting were observed ($F(1,90) = 52.05$, $p \leq 0.001$, $N = 92$), and these were independent of degree of overweight ($F(1,90) = 3.16$, $p = 0.08$, $N = 92$). These results are depicted in Fig. 2 and Fig. 3 respectively.

Footnote: ANOVA analyses with overweight and start/end and the interaction was performed on the six transfer effect foods or the target stimulus. For the yoghurt, mozzarella, apple, tonic, and chocolate, no significant interaction was found, but for the grapes and the pretzels, the change over time was significantly different in the normal weight and the overweight groups. However, for the yoghurt, the liking declined significantly. Furthermore, liking for the mozzarella increased significantly. For the apple, tonic, and chocolate no significant effects where found.

Footnote: ANOVA analyses with overweight and start/end and the interaction was performed on the six transfer effect foods or the target stimulus. For all seven foods, no significant interactions were found. However, concerning the yoghurt and the grapes, wanting declined significantly. In addition, wanting for the mozzarella increased significantly. For the apple, tonic, chocolate, and pretzels, no significant effects were found.

In terms of the six transfer effect foods and the target stimulus, significant declines were observed in liking ($F(1,83) = 20.86$, $p \leq 0.001$, $N = 86$) and wanting ($F(1,85) = 47.55$, $p \leq 0.001$, $N = 86$) for the yoghurt for both normal weight and overweight participants. For the mozzarella, both groups displayed an increase in

Table 2
Baseline characteristics of normal weight and overweight participants.

	Normal weight	Overweight	All	*P*-value	Test statistic
N	37	55	92		
N girls	25	31	56		
Mean ages (y)	12.97	11.55	12.12	<0.05	$t(90) = 2.0$ (unpaired)
Range	6–19	6–18	6–19		
Mean BMI z-score	0.16	2.71	1.68		
Range	−1.71–1.24	1.29–4.60	−1.71–4.60		
N Caucasian Danish	32	44	76		
N other ethnic origin	5	11	16		
N social class	35	50	85		
Median social class	1	3	3	<0.0001	$\chi^2(4) = 32$
Median Tanner Stage	4	2	2	0.01	$\chi^2(4) = 13$

Table 3
The taste properties of the six transfer effect foods and the target stimulus. Values above 30 are marked with grey as these properties characterize the foods.

	Sweet	Salty	Sour	Bitter	Fat	Fruity
Pretzel	11 mm	104 mm	6 mm	6 mm	40 mm	–
Apple with lemon	56 mm	–	72 mm	15 mm	–	136 mm
Chocolate (70%)	62 mm	6 mm	29 mm	53 mm	48 mm	7 mm
Tonic water	26 mm	5 mm	38 mm	116 mm	–	56 mm
Grapes	98 mm	2 mm	11 mm	9 mm	–	142 mm
Mozzarella	10 mm	14 mm	3 mm	–	83 mm	–
Yoghurt	85 mm	5 mm	≈34 mm	≈3 mm	≈78 mm	≈84 mm

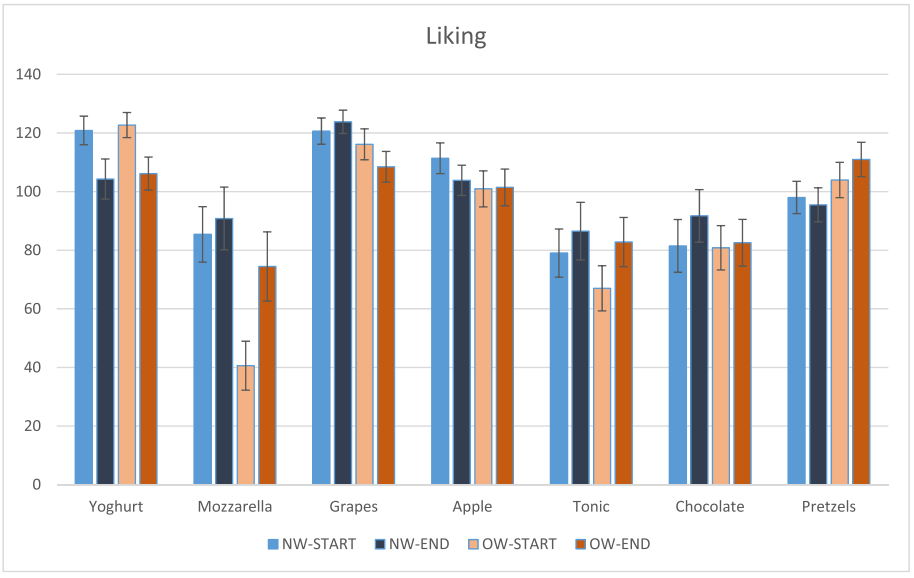

Fig. 2. Baseline and end values including SEMs concerning liking for normalweight and overweight children, respectively.

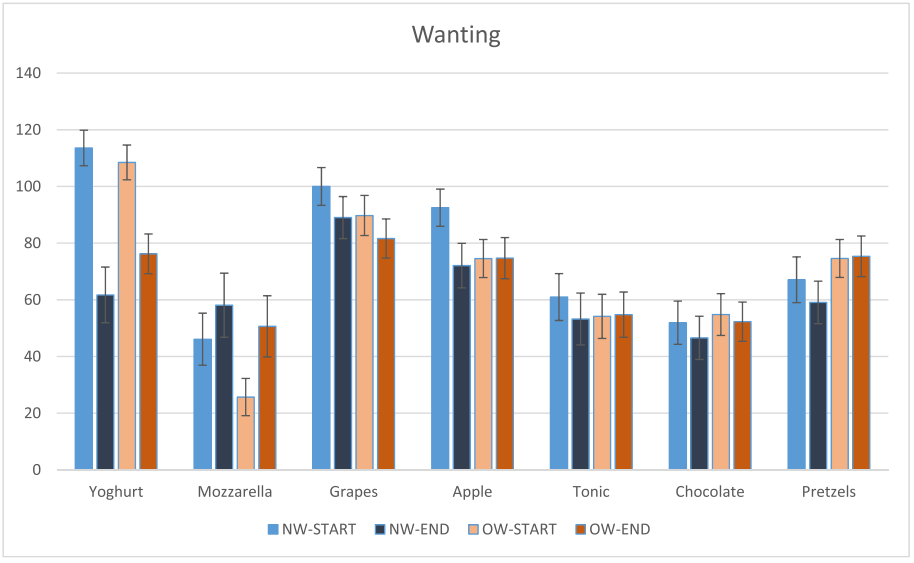

Fig. 3. Baseline and end values including SEMs concerning wanting for normalweight and overweight children, respectively.

liking ($F(1,45) = 5.52$, $p = 0.023$, $N = 55$) and wanting ($F(1,48) = 7.83$, $p = 0.007$, $N = 56$), and the overweight participants had a significantly larger liking ($F(1,63) = 9.55$, $p = 0.003$, $N = 55$). Both groups revealed a decrease in wanting for grapes ($F(1,87) = 4.90$, $p = 0.03$, $N = 89$), which only the overweight participants revealed in terms of liking (test for interaction, $F(1,84) = 4.53$, $p = 0.036$, $N = 89$). The analysis adjusted for ethnicity, social class, gender, age, having a minor cold, and Tanner Stage revealed that this decline in liking for grapes for overweight children increased with age (data not shown). For pretzels, both groups displayed an increase in liking, which was significantly larger for overweight participants (test for interaction,

$F(1,87) = 5.27$, $p = 0.024$, $N = 90$), however nothing significant was found when examining wanting for pretzels. In addition, the ANOVA tests displayed no significant results regarding liking and wanting for apple with lemon, tonic water, and chocolate, neither interactions between time and weight group nor any of these two groupings as main effects.

Lastly, changes in wanting for the six different taste properties were examined (see Fig. 4). Normal weight participants displayed higher wanting for sour foods compared to overweight participants ($F(1,89) = 10.63$, $p = 0.002$, $N = 87$). Furthermore, normal weight participants displayed an increase in wanting for something fat, while overweight children displayed a decrease (test for interaction, $F(1,83) = 4.10$, $p = 0.046$, $N = 87$). Finally, no significant differences were found, neither comparing before/after or OW/NW when examining wanting for something sweet, salty, bitter, or spicy.

4. Discussion

The present study aimed to investigate differences in SSS between normal weight and overweight children. However, no such differences were found. This is in agreement with a few other studies (Brondel et al., 2007; Snoek, Huntjens, Van Gemert, De Graaf, & Weenen, 2004). Brondel et al. included 144 participants (age range 7–62 years), and found that overweight and lean participants have similar hedonic control of food intake. This was also the case in Snoek et al., who examined differences in SSS for high fat foods in 21 obese and 23 normal weight Dutch women (age range 36–58 years).

However, Epstein et al. found that 10 obese women experienced significantly slower declines in salivation when presented with palatable food cues compared to 10 normal weight women, which suggests that it is more difficult for obese women than for normal weight women to resist palatable foods (Epstein, Paluch, & Coleman, 1996). It is important to note that these studies primarily are based on smaller adult populations, which may explain the different results since differences in SSS between normal weight and overweight participants may be small and therefore require larger study samples in order to detect such differences. Similarly, age may influence SSS, which makes the comparisons between children and adults difficult. An effect of age was found by Olsen et al. who demonstrated that children and adults experience different types of SSS (Olsen et al., 2011). Therefore, future studies should examine changes in SSS during different periods of life, e.g. puberty and/or in longitudinal weight change studies. Furthermore, longitudinal tracking of wanting (motivation), external eating scores, and intake pace concurrent with changes in BMI z-score may reveal if any of these are causal determinants of obesity or result from obesity. In addition, it is noticeable that only few transfer effects were observed for both normal weight and overweight children, which is partly in agreement with the results of Olsen et al., who found both similarities and differences between children and adults (Olsen et al., 2011).

We found no differences for satiety and hunger between overweight and normal weight children. This was not anticipated since Mack et al. found that obese children and adults (ages 9–17 years, 60 obese and 27 normal weight) need 20% more volume of water until onset of satiety compared to normal weight participants (Mack et al., 2014). Therefore, we expected overweight children to display less satiation and more hunger when eating the same amounts of food as normal weight children. However, this tendency might have been observed, if we had incorporated larger portions as used in other studies (Olsen et al., 2011). Furthermore, the overweight children had slower intake paces concordant with other studies, but the overweight children did not show significantly larger external eating scores as the literature suggests (Andrade et al., 2008; Braet & Van Strien, 1997; Castellanos et al., 2009; Otsuka et al., 2006; Tanihara et al., 2011).

An interesting finding was that both overweight and normal weight children displayed an increase in liking for pretzels, which are salty and fat, and that this increase was significantly larger for overweight children. Likewise, this was observed for liking for the fat mozzarella. Furthermore, both groups revealed an increase in wanting for the mozzarella. Contrary, normal weight children displayed an increase in wanting for something fat while overweight children displayed a decrease. This suggests that there are differences in the way children respond to fat-tasting foods, which may depend on the degree of overweight.

During the execution of the measurements and interpretation of the results, we identified some limitations of the study design. The idea was that the children should consume the test stimuli (the yoghurt) to satiety though with a maximum consumption of 300 g. In order to avoid being in conflict with the Children's Obesity Clinic's Treatment protocol, the overweight children were only

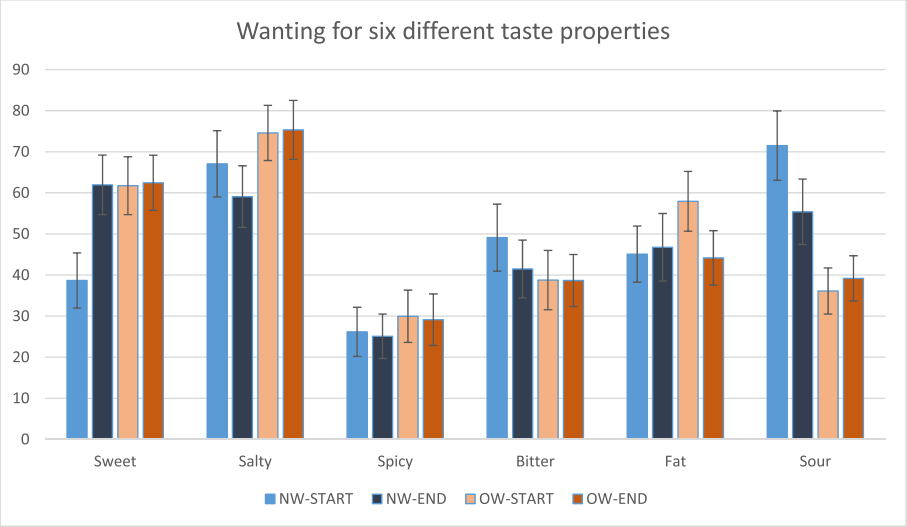

Fig. 4. Baseline and end values including SEMs concerning wanting for something sweet, salty, spicy, bitter, fat, and sour for normalweight and overweight children, respectively.

offered a maximum of 120 g, which is a limitation in the study design. On the other hand, recruiting children at entry to childhood obesity treatment may be advantageous since they have clinically been evaluated as obese individuals, and thus are recruited without a selection bias, which is anticipated to include genuine differences in potentially altered eating patterns.

Moving children from the normal weight group to the overweight group based on their degree of overweight most likely has an effect on the results and is considered a drawback. The justification for moving the children from the normal to the obese group was that overweight children in the normal weight group would bias the results due to the assumption, that the study examined a biological difference induced by the degree of overweight. However, we do recognize that the amount of food ingested has physiological consequences on satiety through the degree of filling of the stomach. Furthermore, a number of children were accompanied by a parent, which may have influenced the answers. An example of this is the self-report of the intake pace, e.g., a child from a fast-eating family would report a normal intake pace even though being a fast-eater. However, this method has previously been used though not in children (Otsuka et al., 2006; Tanihara et al., 2011).

Furthermore, missing data occurred during the study. This mainly happened because the investigator did not check the quality of the answers during the study due to time limitations.

Though a number of limitations have been identified the general study design and the large number of children completing the study strengthen the results. Prior to the study, all children completed similar tests, and the study was performed at the same time of the day in similar environments. As an example, the investigators wore the same clothes (not white coats), independently of location, in order to prevent an uncomfortable situation for especially the overweight children. Furthermore, all investigators were instructed to use the same phrases during introduction of the study and guided the children in case of misunderstandings. Questions were made easily understandable, and only one questionnaire was presented at a time. Additionally, all procedures have been used in previously published studies and the study included many aspects of eating-related qualities (Andrade et al., 2008; Olsen et al., 2011; van Strien et al., 1986). For example, without the external eating-variable, one might have concluded that wanting alone is one of the most important items contributing to the development of childhood obesity.

5. Conclusions

In conclusion, both normal weight and overweight children displayed SSS and declines in wanting during consumption of the target stimulus (yoghurt), but no differences in these quantities were found between the two groups. Increases in liking for mozzarella and pretzels were observed in both groups, and the overweight children displayed the highest increases. Furthermore, normal weight children displayed an increase in wanting for something fat, while overweight children displayed a decrease. Lastly, overweight children displayed slower self-reported intake paces. To summarize, the findings of the present study suggest that overweight and normal weight children to some extent display perceptual differences during eating, especially in quantities related to fat-tasting foods.

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References

Andrade, A. M., Greene, G. W., & Melanson, K. J. (2008). Eating slowly led to decreases in energy intake within meals in healthy women. *Journal of the American Dietetic Association, 108*(7), 1186–1191. http://dx.doi.org/10.1016/j.jada.2008.04.026.

Anis, A. H., Zhang, W., Bansback, N., Guh, D. P., Amarsi, Z., & Birmingham, C. L. (2010). Obesity and overweight in Canada: An updated cost-of-illness study. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity, 11*(1), 31–40. http://dx.doi.org/10.1111/j.1467-789X.2009.00579.x.

Berridge. (1996). Food reward: Brain substrates of wanting and liking. *Neuroscience and Biobehavioral Reviews, 20*, 1–25. http://dx.doi.org/10.1016/0149-7634(95)00033-B.

Berridge, K. C., & Robinson, T. E. (2003). Parsing reward. *Trends in Neurosciences*. http://dx.doi.org/10.1016/S0166-2236(03)00233-9.

Braet, C., & Van Strien, T. (1997). Assessment of emotional, externally induced and restrained eating behaviour in nine to twelve-year-old obese and non-obese children. *Behaviour Research and Therapy, 35*(9), 863–873.

Brondel, L., Romer, M., Van Wymelbeke, V., Walla, P., Jiang, T., Deecke, L., et al. (2007). Sensory-specific satiety with simple foods in humans: No influence of BMI? *International Journal of Obesity, 31*(6), 987–995. http://dx.doi.org/10.1038/sj.ijo.0803504 (2005).

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., et al. (2009). Obese adults have visual attention bias for food cue images: Evidence for altered reward system function. *International Journal of Obesity, 33*(9), 1063–1073. http://dx.doi.org/10.1038/ijo.2009.138 (2005).

Colagiuri, S., Lee, C. M. Y., Colagiuri, R., Magliano, D., Shaw, J. E., Zimmet, P. Z., et al. (2008). *The cost of overweight and obesity in Australia*.

Epstein, L. H., Paluch, R., & Coleman, K. J. (1996). Differences in salivation to repeated food cues in obese and nonobese women. *Psychosomatic Medicine, 58*(2), 160–164.

Finlayson, G., & Dalton, M. (2012). Current progress in the assessment of "liking" vs. "wanting" food in human appetite. Comment on '"You Say it's Liking, I Say it's Wanting…" on the difficulty of disentangling food reward in man'. *Appetite, 58*, 373–378. http://dx.doi.org/10.1016/j.appet.2011.10.011.

Flint, A., Raben, A., Blundell, J. E., & Astrup, A. (2000). Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *International Journal of Obesity, 24*(1), 38–48. http://dx.doi.org/10.1038/sj.ijo.0801083.

Griffioen-Roose, S., Finlayson, G., Mars, M., Blundell, J. E., & de Graaf, C. (2010). Measuring food reward and the transfer effect of sensory specific satiety. *Appetite, 55*(3), 648–655. http://dx.doi.org/10.1016/j.appet.2010.09.018.

Guinard, J. X., & Brun, P. (1998). Sensory-specific satiety: Comparison of taste and texture effects. *Appetite, 31*(2), 141–157. http://dx.doi.org/10.1006/appe.1998.0159.

Havermans, R. C. (2011). "You Say it's Liking, I Say it's Wanting…". On the difficulty of disentangling food reward in man. *Appetite, 57*(1), 286–294.

Havermans, R. C. (2012). How to tell where "liking" ends and "wanting" begins. *Appetite, 58*, 252–255. http://dx.doi.org/10.1016/j.appet.2011.10.013.

Holm, J.-C., Gamborg, M., Bille, D. S., Grønbæk, H. N., Ward, L. C., et al. (2011). Chronic care treatment of obese children and adolescents. *International Journal of Pediatric Obesity: IJPO: An Official Journal of the International Association for the Study of Obesity, 6*(3–4), 188–196. http://dx.doi.org/10.3109/17477166.2011.575157.

Mack, I., Sauer, H., Weimer, K., Dammann, D., Zipfel, S., Enck, P., et al. (2014). Obese children and adolescents need increased gastric volumes in order to perceive satiety. *Obesity (Silver Spring, Md.), 00*(00), 11–13. http://dx.doi.org/10.1002/oby.20850.

Marshall, W. A., & Tanner, J. M. (1969). Variations in pattern of pubertal changes in girls. *Archives of Disease in Childhood, 44*(235), 291–303.

Marshall, W. A., & Tanner, J. M. (1970). Variations in the pattern of pubertal changes in boys. *Archives of Disease in Childhood, 45*(239), 13–23.

Møller, P. (2015). Satisfaction, satiation and food behaviour. *Current Opinion in Food Science, 3*, 59–64. http://dx.doi.org/10.1016/j.cofs.2015.02.008.

Neef, M., Weise, S., & Adler, M. (2013). Best practice & research clinical endocrinology & metabolism health impact in children and adolescents. *Best Practice & Research Clinical Endocrinology & Metabolism, 27*(2), 229–238. http://dx.doi.org/10.1016/j.beem.2013.02.007.

Nysom, K., Mølgaard, C., Hutchings, B., & Michaelsen, K. F. (2001). Body mass index of 0 to 45-y-old Danes: Reference values and comparison with published European reference values. *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 25*(2), 177–184. http://dx.doi.org/10.1038/sj.ijo.0801515.

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *Jama, 311*(8), 806–814. http://dx.doi.org/10.1001/jama.2014.732.

Olds, T., Maher, C., Zumin, S., Péneau, S., Lioret, S., Castetbon, K., et al. (2011). Evidence that the prevalence of childhood overweight is plateauing: Data from nine countries. *International Journal of Pediatric Obesity: IJPO: An Official Journal of the International Association for the Study of Obesity, 6*(5–6), 342–360. http://dx.doi.org/10.3109/17477166.2011.605895.

Olsen, A., Ritz, C., Hartvig, D. L., & Møller, P. (2011). Comparison of sensory specific

satiety and sensory specific desires to eat in children and adults. *Appetite, 57*(1), 6–13. http://dx.doi.org/10.1016/j.appet.2011.03.009.

Olsen, A., Ritz, C., Kramer, L., & Møller, P. (2012). Serving styles of raw snack vegetables. What do children want? *Appetite, 59*(2), 556–562. http://dx.doi.org/10.1016/j.appet.2012.07.002.

Otsuka, R., Tamakoshi, K., Yatsuya, H., Murata, C., Sekiya, A., Wada, K., et al. (2006). Eating fast leads to obesity: Findings based on self-administered questionnaires among middle-aged Japanese men and women. *Journal of Epidemiology/Japan Epidemiological Association, 16*(3), 117–124.

Rolls, E. T., & Rolls, J. H. (1997). Olfactory sensory-specific satiety in humans. *Physiology and Behavior, 61*(3), 461–473. http://dx.doi.org/10.1016/S0031-9384(96)00464-7.

Rolls, B. J., Van Duijvenvoorde, P. M., & Rolls, E. T. (1984). Pleasantness changes and food intake in a varied four-course meal. *Appetite, 5*(4), 337–348.

Schmidt Morgen, C., Rokholm, B., Sjöberg Brixval, C., Schou Andersen, C., Geisler Andersen, L., Rasmussen, M., et al. (2013). Trends in prevalence of overweight and obesity in danish infants, children and adolescents–are we still on a plateau? *PloS One, 8*(7), e69860. http://dx.doi.org/10.1371/journal.pone.0069860.

Skinner, A. C., Perrin, E. M., & Skelton, J. A. (2016). Prevalence of obesity and severe obesity in US children, 1999-2014. *Obesity (Silver Spring, Md.), 24*(5), 1116–1123. http://dx.doi.org/10.1002/oby.21497.

Snoek, H. M., Huntjens, L., Van Gemert, L. J., De Graaf, C., & Weenen, H. (2004). Sensory-specific satiety in obese and normal-weight women. *American Journal of Clinical Nutrition, 80*(4), 823–831. http://dx.doi.org/10.1097/01.BRS.0000083281.48923.BD.

van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*(2), 295–315. http://dx.doi.org/10.1002/1098-108X(198602)5, 2<295::AID-EAT2260050209>3.0.CO;2-T.

Tanihara, S., Imatoh, T., Miyazaki, M., Babazono, A., Momose, Y., Baba, M., et al. (2011). Retrospective longitudinal study on the relationship between 8-year weight change and current eating speed. *Appetite, 57*(1), 179–183. http://dx.doi.org/10.1016/j.appet.2011.04.017.