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Children's sweet tooth: Explicit ratings vs. Implicit bias measured by the Approach avoidance task (AAT)

Martina Galler[a,b,*], Emma Mikkelsen[b], Tormod Næs[a], Kristian Hovde Liland[c], Gastón Ares[d], Paula Varela[a,b]

[a] *Nofima Ås, Department of Innovation, Sensory and Consumer Science, Norway*
[b] *NMBU, Faculty of Chemistry, Biotechnology and Food Science, Norway*
[c] *NMBU, Faculty of Science and Technology, Norway*
[d] *Sensometrics & Consumer Science, Instituto Polo Tecnológico de Pando, Facultad de Química, Universidad de la República, Uruguay*

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ABSTRACT

The study aimed to assess the application of the Approach avoidance task (AAT) with children to measure implicit motivational tendencies towards foods differing in *sweetness* and *calorie* content and to explore the relationship between approach bias and explicit measurements of expected liking, attitudes, and hunger state and their relation to paired-preference tasks. The simplicity and game-like procedure of the AAT, where participants use a joystick to pull or push pictures, seems particularly suitable to measure implicit motivational biases in children. However, to our knowledge, this approach has not been used with children in a food related context.

Children aged 9–11 participated in the study (n = 114). Their implicit bias towards pictures of snacks was measured via AAT. The test instruction was based on pushing or pulling the joystick according to picture category, food vs. non-food: food (18 snack pictures varying in *sweetness* and *calorie*) vs. non-food (18 pictures visually similar to the respective food stimuli). Further, children rated their expected liking of the snack pictures, answered an attitude questionnaire related to health and sugar consumption, and completed two paired preference tests tasting real samples under blind condition and choosing between a sugar and no-sugar added chocolate milk take-home pack.

The percentage of non-valid AAT responses was relatively high, leading to low testing power. There was a significant difference in approach bias between food pictures and non-food pictures; approach bias was positive for food and slightly negative for non-food. Within food pictures, no significant effect of *sweetness* nor *calorie* was found. Nevertheless, children's approach biases were linked to their expected liking ratings, which revealed a clear preference towards high *sweetness* and high *calorie* snacks. Individual differences in children's approach bias to pictures differing in *sweetness* and *calorie* content were related to their hunger state but not to their attitudes or preference towards chocolate milk, indicating relevance for situational food choices. In the present study, questionnaire-based measurements (affective and cognitive attitude towards sugar, sugar craving and using food as reward) were however associated with children's preference towards chocolate milk (blind and/or informed). Higher scores in the measured attitude subscales *craving for sweet food, using food as reward, affective attitude towards sweet food* and *cognitive attitude towards sweet food* were associated with higher odds to choose the sugar added chocolate milk. Methodological considerations and recommendations with regards to the use of approach-avoidance testing with children are critically discussed.

1. Introduction

The rising prevalence of childhood overweight and obesity requires a better understanding of the mechanisms underlying children's self-directed food choices, as they often do not meet nutritional recommendations. As described in a wide body of literature, children tend to prefer sweet food (Cooke & Wardle, 2005; Mennella & Bobowski, 2015; Mennella et al., 2016; Mennella et al., 2012; Venditti et al., 2020) and energy-dense food (Cooke & Wardle, 2005; Gibson & Wardle, 2003). In this sense, previous studies have also indicated a relatively

* Corresponding author.
E-mail address: martina.galler@nofima.no (M. Galler).

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high focus on hedonic over health aspects during childhood (Marty et al., 2018; Marty, Miguet, et al., 2017; Nguyen et al., 2015).

According to dual processing theory, decision-making criteria can be grouped into goal-directed and automatic processes of which the latter are thought to be important drivers of food choices (Jacquier et al., 2012; Rangel, 2013). Automatic decision-making processes are expected to be influenced by implicit attitudes towards foods, i.e. favourable or unfavourable feelings, thoughts, or actions towards different foods that occur without conscious awareness (Greenwald & Banaji, 1995). Implicit attitudes have been shown to have a direct impact on eating behaviour in adults (Dubé & Cantin, 2000; Raghunathan et al., 2006) and have been postulated to be a barrier to healthy food choices (Mai et al., 2011). Köster (2009) highlighted that food habit formation occurs mostly unconsciously in childhood while conscious cognitive learning becomes more important when growing up. While adults might be able to wilfully steer their food choices to a certain degree, linking them to cognitive goals (such as health considerations), children don't reflect too deeply on their food choices. Methods that can capture children's automatic tendencies might therefore offer an advantage over questionnaire-based measurements that according to Köster (2009) assume reasoned action and planned behaviour.

Test protocols to measure automatic processes are called implicit tests and are increasingly used to study eating behaviour (Monnery-Patris & Chambaron, 2020). There are different implicit testing paradigms that address different implicit aspects (Kraus & Piqueras-Fiszman, 2018; Monnery-Patris & Chambaron, 2020). Children's implicit thinking has been investigated via categorization tasks, assessing the usage of hedonic vs. nutrition-based categorization criteria. Results showed that children more frequently used hedonic categorization, especially in their implicit thinking (Marty, Chambaron, et al., 2017) and that their implicit and explicit attitudes had an additive effect on the healthiness of their food choice (Marty, Miguet, et al., 2017; Perugini, 2005). Further, the Implicit association task (IAT) has been used to measure children's implicit bias towards healthy vs. unhealthy foods measuring the relative association of two target concepts, healthy and unhealthy food, with a positive and negative valence category. Surprisingly, studies have repeatedly found that children had an implicit bias towards healthy food while they explicitly liked unhealthy food more (Craeynest et al., 2007; DeJesus et al., 2020; van der Heijden et al., 2020). DeJesus et al. (2020) results indicated that more nutritional knowledge correlated to larger implicit biases for healthy food. None of the IAT studies linked implicit and explicit results to actual food choices.

The application of implicit reaction time tasks with children is not free from limitations; van der Heijden et al. (2020) reported a lower testing power for the IAT performed by children over adults, which indicates that the performance of the task might be challenging for children. Therefore, it is of interest to have other implicit testing procedures to measure implicit food preference patterns in children. The simplicity of the Approach avoidance task (AAT) as well as its game-like procedure, where participants use a joystick to pull or push pictures appearing on a computer screen, might be suitable to study implicit tendencies in children. However, to our knowledge, it has only been applied with children to measure implicit spider phobia, thus avoidance behaviour (Klein et al., 2011).

Approach and avoidance are thought to be more closely linked to wanting than liking, thus to actual behaviour (Kraus & Piqueras-Fiszman, 2016; Tibboel et al., 2015). While Tibboel et al. (2015) doubted that the AAT can measure wanting, there are AAT studies that would support this theory: people high in the trait food craving displayed larger approach biases to food (Brockmeyer et al., 2015). Booth et al. (2018) used a closely related but cognitively more challenging protocol (the Manikin task) to measure approach tendencies to sweet snacks in adolescents placing approach bias as moderator between impulsivity trait and uncontrolled eating behaviour. Further, the AAT has been successfully applied as an intervention for overweight children to learn to resist visual food cues (Warschburger et al., 2018) indicating a tight link to actual behaviour.

In this context, the aim of the study was threefold: i) to assess the application of the Approach avoidance task with children to measure implicit motivational tendencies towards food, ii) to evaluate approach bias towards foods differing in *sweetness* and *calorie* content, and iii) to explore the relationship between approach bias and explicit measurements of expected liking, attitudes, and hunger state and relate results to paired-preference tasks (representing food choice). It was hypothesized that children would display more positive approach biases towards high *sweetness* and high *calorie* foods. Further, it was assumed that implicit approach bias would be related to children's preferences of a sugar and no-sugar added chocolate milk (blind and informed choice).

2. Materials & methods

The study consisted of several tasks including the implicit Approach avoidance task (AAT), explicit questionnaires of attitudes, hunger state and expected liking as well as blind and informed paired preference task of chocolate milk as displayed in Fig. 1. Two workstations were set up. Children (9–11 years old) in groups of a maximum of 12 performed the tests and switched workstations once both groups were finished. Approximately half of the children performed the test before and half after lunch. All results were collected electronically. In each workstation children logged in with a three-digit code distributed as stickers at the beginning of the study. This allowed us to connect the results of the two workstations while ensuring that participants were not identifiable in the data.

2.1. Participants

The study was conducted at Vitenparken Campus Ås within a science outreach program that is offered to school classes in the Akershus region. A total of 114 children between 9 and 11 years old participated (52% girls; 9 years old n = 68, 10 years old n = 36, 11 years old n = 10). Children visited the science centre with their school classes and teachers. They had different science lectures, activities and exhibitions throughout the day, among those the current study.

A protocol of the presented study was approved by the Norwegian Centre for Research Data, reference 476380. Before the test, parents were informed about the experiment via the school communication app, along with an electronic consent form. Some parents forgot to sign the form. In discussion with the teachers who accompanied the school classes, children with a missing consent form were allowed to participate as the tests belonged to their class activity. Passive consent by the parents through the information via school app was regarded sufficient for the presented study, due to the anonymized setup where participating children were not identifiable directly or indirectly which is the best-case scenario regarding data protection (General Data Protection Regulation (GDPR), EU regulation n° 2016/679) and the low risk of experiencing harm during the test. All children were orally asked for their assent to participate in the study and food allergies or intolerances that would not allow the tasting of the chocolate milk samples. They were also informed that they could leave the test at any time without consequences.

2.2. Implicit reaction time measurement – Approach avoidance task (AAT)

The Approach avoidance task (AAT) was implemented with the software Inquisit Millisecond 5.0 using joysticks (Logitech G Extreme 3D Pro). Seats were adjusted according to children's height and joysticks were placed on the side of children's writing hands. Prior to the task, a researcher gave a detailed introduction and encouraged children to test the movement of the joystick.

Children were required to react to a single picture (stimuli) displayed in the centre of the screen of a laptop computer, by pulling or pushing

Work station 1	Hunger state rating (scale)	Implicit Approach Avoidance task (AAT)	Rating of sweetness intensity and expected liking of food pictures used in AAT
Work station 2	Paired preference test (take-home chocolate milk packs)	Demographics (age and gender), self-reported attitudes	Paired preference test (blind tasting of chocolate milk samples)

Fig. 1. Test setup.

the joystick, depending on the picture category and instruction of the test part. The task consisted of two test parts with opposite test instructions that required pulling or pushing according to the picture category (food vs. non-food). This setup corresponds to a feature-relevant task instruction where the reaction criterion is based on picture content which had been found to have a larger testing power regarding discrimination between picture groups (Lender et al., 2018). Other AAT studies (e.g. Brockmeyer et al., 2015; Piqueras-Fiszman et al., 2014) have used a feature-irrelevant setup where reaction criteria were, e.g. based on picture orientation (portrait vs. landscape). In such settings, image processing might be less conscious which can result in lower testing power.

Pictures were enlarged when pulled and shrunk when pushed creating the illusion of coming closer/going farther away. Further, error messages were included for wrong answers so participants could correct the classification criterion in case they forgot it. The order of test instruction ("pull food and push non-food" or "push food and pull non-food") in test part was balanced across participants.

All picture stimuli were retrieved from the image database "Food-pics" (Blechert et al., 2014). The stimuli set consisted of 18 snacks (food category), commonly eaten by Norwegian children, representing approximately one portion. The snacks were selected based on their sweetness level (low, medium, high) and their calorie content (low, high, as per "Food-pics"' database). Sweetness categories were assumed a priori by the experimenters and checked a posteriori by collecting sweetness ratings from participants (Spearman correlation, rs = 0.41). Each food picture was matched to a non-food picture (non-food stimuli) regarding shape and colour (examples in Supplementary material, Fig. 1). In total there were 36 test stimuli, 18 food and 18 non-food pictures. Snacks are listed in Table 1 according to sweetness and calorie category including snack picture number and matching non-food picture number in the "Food-pics" database (Blechert et al., 2019).

Each test instruction block consisted of 16 practice trials to train the response criterion with different pictures than the ones used in the test (#0372, #0865 for food; #1265, #1113 non-food) and 72 measurement trials consisting of two repetitions of the 36 stimuli pictures. In each repetition, pictures were presented in a randomized order. For the measurement, reaction time, at a 30-degree tilt of the joystick, as well as the correctness of the responses were registered. The whole test lasted approximately 15 min, varying according to children's reaction speed.

Table 1
Design of Experiment of pictures used for the Approach avoidance task (AAT) (picture numbers in the "Food-pics" database (Blechert et al., 2019)).

	Food pictures (food picture/matching non-food picture)	
	High calorie (160–621 Kcal/100 g)	Low calorie (16–93 Kcal/100 g)
High sweetness	Gummi candy (#153, #1139) Ice cream (#25, #1314) Chocolate bar (#287, #1004)	Banana (#789, #1256) Grapes (#284, #1072) Watermelon (#829, #1276)
Medium sweetness	Muesli bowl (#181,#1136) Waffle (#9, #1060) Jam toast (#347,#1080)	Pear (#402,#1308) Blueberries (#202,#1137) Orange juice (#358,#1094)
Low sweetness	Cheese toast (#593,#1147) Chips (#26,#1208) Cashew nuts (#110,#1129)	Milk (#573,#1017) Carrot and cucumber (#215, #1311) Cherry tomatoes (#275,1132)

2.3. Explicit questionnaire-based measurements

Electronic questionnaires were implemented in the software EyeQuestion.

Hunger level:

Children rated their hunger level (7-point scale with three anchors "I am hungry", "I am neither hungry nor full" and "I am full") prior to the Approach avoidance task (AAT).

Sweetness intensity and expected liking of food pictures used in AAT:

After the implicit test, children rated their expected liking on a 7-point hedonic scale and their expected sweetness intensity (category scale: "Not sweet", "A bit sweet", "Pretty sweet", "Very sweet") of each of the food pictures (Table 1), to check the sweetness levels defined by researchers. The food pictures were presented in a sequential monadic balanced order.

Attitudes to healthy eating and sweet food:

Children answered an attitude questionnaire with three subscales extracted from the Health and Taste questionnaire by Roininen et al. (1999) (General health interest, Craving for sweet food and Using food as reward) with slight adjustments to fit the age group based on a pilot study (see Supplementary material 1, Table 1). Further, two scales, affective and cognitive attitudes towards sweet food, from a study with children of the same age group (Takemi & Woo, 2017) were included. Questionnaires were translated from English to Norwegian and pilot-tested with a small group of children. For all attitude-based measurements, 7-point agreement-to-statement scales were used.

2.4. Chocolate milk preferences

To link children's implicit and explicit attitudes to their actual preferences, a chocolate milk case study was used, where children chose between two commercially available chocolate milks with added and no-added sugar in two instances, a blind tasting, and a take-home paired preference test.

2.4.1. Take-home paired preference test:

Children chose between two chocolate milk packs (Work station 2, Fig. 1). Children made their choice upon entering the room without knowing about the test scope. They were informed that they could choose one of the chocolate milks as a token for their participation. The main difference between the packs was the presence/absence of the claim "No added sugar". There were slight variations in the pack design but they were generally similar, with a comic figure of a cow. However, the "No added sugar" version had the claim "New" in a yellow flash. Children recorded their take-home preference at the start of the test, clicking on their choice on a screen that displayed the photos of both packs next to each other.

2.4.2. Blind paired preference test

After the attitude and demographics questions, children tasted the two chocolate milks and chose the one they preferred. Samples were served in black plastic cups that masked slight colour differences and were coded with two symbols similar in shape, a cloud and a flower. Chocolate milk recipes differed more than regarding sugar content, as they are optimized products in the market. The "No added sugar" version had been sweetened by lactose hydrolysis. A pre-tasting by the researchers confirmed a perceivable difference in sweetness intensity.

2.5. Data analysis

All analyses were performed in R, version 4.0.4. Significance was determined based on an alpha of 5%. The R package "mixlm" (Hovde Liland, 2019) was used for linear mixed ANOVAs, "lmerTest" (Kuznetsova et al., 2017) for mixed linear regression and logistic regression models and "FactoMineR" (Lê et al., 2008) to perform a Multiple factor analysis (MFA).

2.5.1. Data pre-processing

Children with insufficient data quality in the Approach avoidance task (AAT) (n = 15) and missing data due to software problems in the expected liking (n = 1) were deleted from all analysis resulting in 98 children included in the analyses. For chocolate milk paired-preference tests three additional answers were missing (due to lactose intolerance or milk disliking) resulting in 95 answers for paired-preference tests.

2.5.2. Assessment of AAT data structure

AAT data was pre-processed according to Klein et al. (2011), excluding data points with errors or reaction times that exceeded test cut off values (<200 ms and >5000 ms) and individual cut off values (±2*standard deviation), (=outliers) and excluding children with a very high amount (>25%) of missing data. The remaining dataset contained 11% errors, 5% outliers exceeding individual cut-offs and 1% outliers exceeding test cut-offs, resulting in 15% responses that were deleted for the analysis.

Error and outlier structures were assessed by a mixed logistic regression including *test part, movement* with the joystick*, picture category, gender*, *age* and the interaction *gender* × *age* as fixed and *child* nested in *age* × *gender* as random variables. In the same way, reaction time was tested by a mixed regression model. Results are presented in Supplementary material 2.

2.5.3. Approach bias according to picture category (food vs. non-food)

The approach bias was calculated by subtracting the reaction time for pulling from the reaction time for pushing, per picture. The mean of the two repetitions was used. Approach bias according to picture category (food and non-food) was tested with a mixed ANOVA with *picture category* as fixed, *child* as well as the interaction *picture category* × *child* as random factors.

2.5.4. Approach bias and expected liking of food pictures

For comparison, the same mixed ANOVA models were calculated with approach bias and expected liking ratings as dependent variables. Using the design of experiment factors (sweetness: low, medium, high and calorie content: low, high), pictures were tested for *sweetness*, *calorie*, the interaction *sweetness* × *calorie* as fixed factors and child and the two- and three-fold interactions as random factors.

Supplementary material 3 presents additional analyses. To check the results generated by design of experiment, children's *individual sweetness ratings* as well as *calorie* estimates from the "Food-pics" database were tested by a mixed regression model. A second model also included visual parameters of snack pictures which could have confounded the estimation of *sweetness* and *calorie* content.

The correlation between approach bias and expected liking was estimated by a mixed regression model with expected liking as fixed and child as a random variable. Further, the two measurements were compared visually by multiple factor analysis (MFA). The Multiple factor analysis overlayed the two measurements, each matrix had snack pictures as rows and children's responses as columns. Columns were centred and standardized for the Multiple factor analysis.

2.5.5. Individual differences in approach bias and expected liking

To compare children's approach bias and expected liking to other measurements, differences between the design of experiment levels were calculated. The associations with continuous variables (*attitude* subscales and *hunger state*) were tested by Pearson correlations, categorical variables by unpaired (two-sample) two-sided t-tests in the case of binary variable (*gender*) and ANOVA (*age*).

2.5.6. Implicit and explicit measurements to predict food choice

The association of implicit and explicit (continuous) measurements with chocolate milk paired-preference (=food choice) was tested by unpaired (two-sample) two-sided t-tests.

3. Results

3.1. Approach bias according to picture category (food vs. non-food)

Children's approach bias differed significantly between food and non-food pictures (p-value = 0.005). Their approach bias was positive for food (M = 40.0 SD = 346.4) and slightly negative for non-food (M = −17.8, SD = 361.0). Positive approach biases indicate that the pulling movement when looking at the stimulus was faster than the pushing, indicating approach tendencies, while negative values indicate the opposite: avoidance tendencies.

3.2. Approach bias and expected liking of food pictures

The effects of *sweetness*, *calorie* and their interaction within food pictures did not have a significant effect on children's approach bias (Table 2). There were no significant individual differences regarding *sweetness* (*sweetness* × *child*) indicating that children did not systematically differ in how this factor influenced their reaction times. The interaction *calorie* × *child* was significant, indicating that children differed systematically in their approach biases towards high and low *calorie* snacks.

There were significant differences in children's expected liking according to *sweetness*, *calorie* content, and their interaction (Table 2). Children expected to like the foods in the high *sweetness* level more than those in the low and medium *sweetness* level. Also, foods in the high *calorie* group were expected to be liked more, but only in the low and high *sweetness* group (Fig. 2). There were no significant individual differences regarding the effect of *sweetness* (*sweetness* × *child*) on explicit liking, indicating that most of the participants liked a high *sweetness* level most. The interaction between *calorie* and *child* was significant, indicating individual differences in the effect of *calorie* on expected liking.

A mixed regression analysis confirmed that children's expected liking was significantly associated with children's approach bias (Estimate = 9.9 ms, 95% CI 1.2–18.7 ms). Fig. 3 displays children's approach bias and expected liking configurations of the food pictures overlayed by a multiple factor analysis which explained only 21% of the variance, indicating that the two measurements differed despite the significant association. The configuration of the factors *sweetness* and *calorie* that were projected on the multiple factor analysis plot based on the location of the respective snack pictures is shown in Fig. 3b. High *sweetness* was separated from low and medium *sweetness* in the first dimension. Further, a separation according to *calorie* in a diagonal was apparent,

Table 2
Sweetness, *calorie* and their interaction of the food pictures was analysed with a mixed ANOVA with child as random factor and the interaction between factors and child. Approach bias was the continuous response for implicit responses and expected liking for explicit responses.

Dependent variable	Factors	DF	SS	MS	F-value	P-value
Implicit: approach bias to food pictures	Sweetness	2	245,238	122,619	1.2	0.308
	Calorie	1	120,190	120,190	1.0	0.323
	Child	97	25,632,992	264,258	2.0	**0.002**
	Sweetness × calorie	2	67,771	33,886	0.4	0.687
	Sweetness × child	194	20,099,648	103,606	1.2	0.167
	Calorie × child	97	11,821,755	121,874	1.4	**0.040**
	Sweetness × calorie × child	194	17,495,298	90,182	0.8	0.980
	Error	1078	245,238	122,619		
Explicit: expected liking of food pictures	Sweetness	2	251	125	49.29	**<0.001**
	Calorie	1	111	111	22.33	**<0.001**
	Child	97	872	9	2.07	**0.002**
	Sweetness × calorie	2	85	43	13.47	**<0.001**
	Sweetness × child	194	494	3	0.8	0.937
	Calorie × child	97	481	5	1.57	**0.004**
	Sweetness × calorie × child	194	615	3	1.09	0.199
	Error	1176	3410	3	–	–

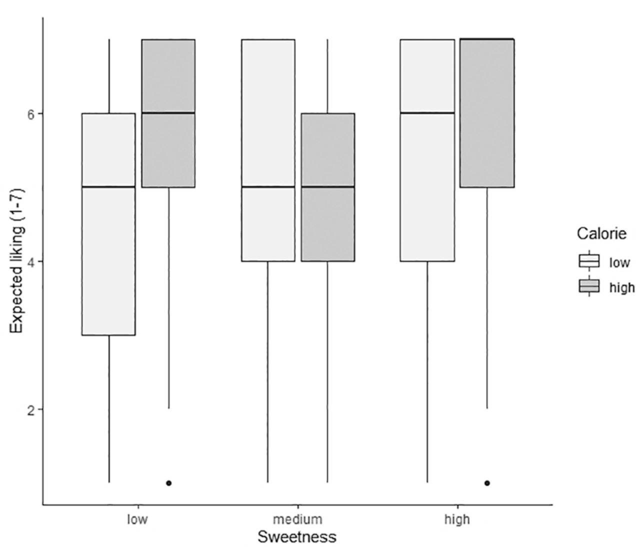

Fig. 2. The factors *sweetness*, *calorie* as well as their interaction had a significant effect on children's expected liking ratings.

high towards the lower right corner and low towards the upper left corner. In the score plot based on implicit and explicit responses "Chips" was placed in the high *sweetness* cluster and "Banana" was not in the high *sweetness* cluster (Fig. 3a). For 54% of the children, the implicit and explicit responses displayed in the loading plot (Fig. 3c) were directed towards the right-hand side of the first dimension (high *sweetness*). Almost all (91%) children's expected liking vectors were directed towards the right hand side of the first dimension (high *sweetness*) while children's approach bias did not show a defined pattern; the vectors pointed in all directions.

3.3. Individual differences in approach bias and expected liking

In order to compare approach bias and expected liking tendencies to different snack groups, differences between factor levels were built. As the Multiple factor analysis (Fig. 3b) separated the high *sweetness* level from medium and low, the difference high – low & medium *sweetness* was correlated to other measurements (demographics, attitude, hunger state). The difference high – low *calorie* was included, as the mixed ANOVAs for approach bias as well as expected liking (Table 2), indicated a systematic difference between children for the factor *calorie* (significant interaction *child* × *calorie*).

Age and gender were unrelated to individual differences regarding approach biases and expected liking to the studied snack groups (Table 3). Some attitude subscales correlated to individual differences in children's expected liking according to *calorie* content but not to *sweetness* nor implicit approach bias (Table 3). Children who were hungry showed larger approach biases and expected liking ratings for high caloric compared to low caloric snacks as well as lower approach biases towards the high sweetness vs. medium and low levels (Fig. 4). As children participated either before or after lunch, their hunger levels differed systematically. There were similar proportions of hungry, neither hungry nor full and full participants (N = 39, N = 31, N = 28).

3.4. Implicit and explicit measurements and chocolate milk preference

Neither individual differences in children's approach bias nor expected liking for *sweetness* or *calorie* were associated with their chocolate milk preferences (Table 4). The attitude subscales, *affective* and *cognitive attitude towards sugar*, *sugar craving* and *using food as reward*, were associated with children's chocolate milk preference (blind and/or informed). Higher scores in the measured attitude subscales were associated with higher odds to choose the sugar added chocolate milk.

4. Discussion

The present research work aimed to apply the Approach avoidance task (AAT) to investigate children's automatic approach tendencies for the first time in a food-related context. The objective was to study if implicit testing would offer additional insights to explicit measurements of attitudes and liking towards foods of different sweetness and calorie content and if implicit biases could explain children's actual food choice.

4.1. Approach bias to food vs. non-food stimuli

Children displayed a positive approach bias towards food (snack) pictures in general and a slightly negative approach bias to non-food pictures. The fact that non-food pictures had slightly negative approach biases confirmed that approach biases to food were not just the result of different movement speeds in general (pushing the joystick faster away than pulling towards) but linked to picture content. Thus, it can be concluded that snack pictures caused an approach behaviour in children. Similar results have been reported in previous AAT of comparable setups in adults (Kahveci et al., 2020; Lender et al., 2018).

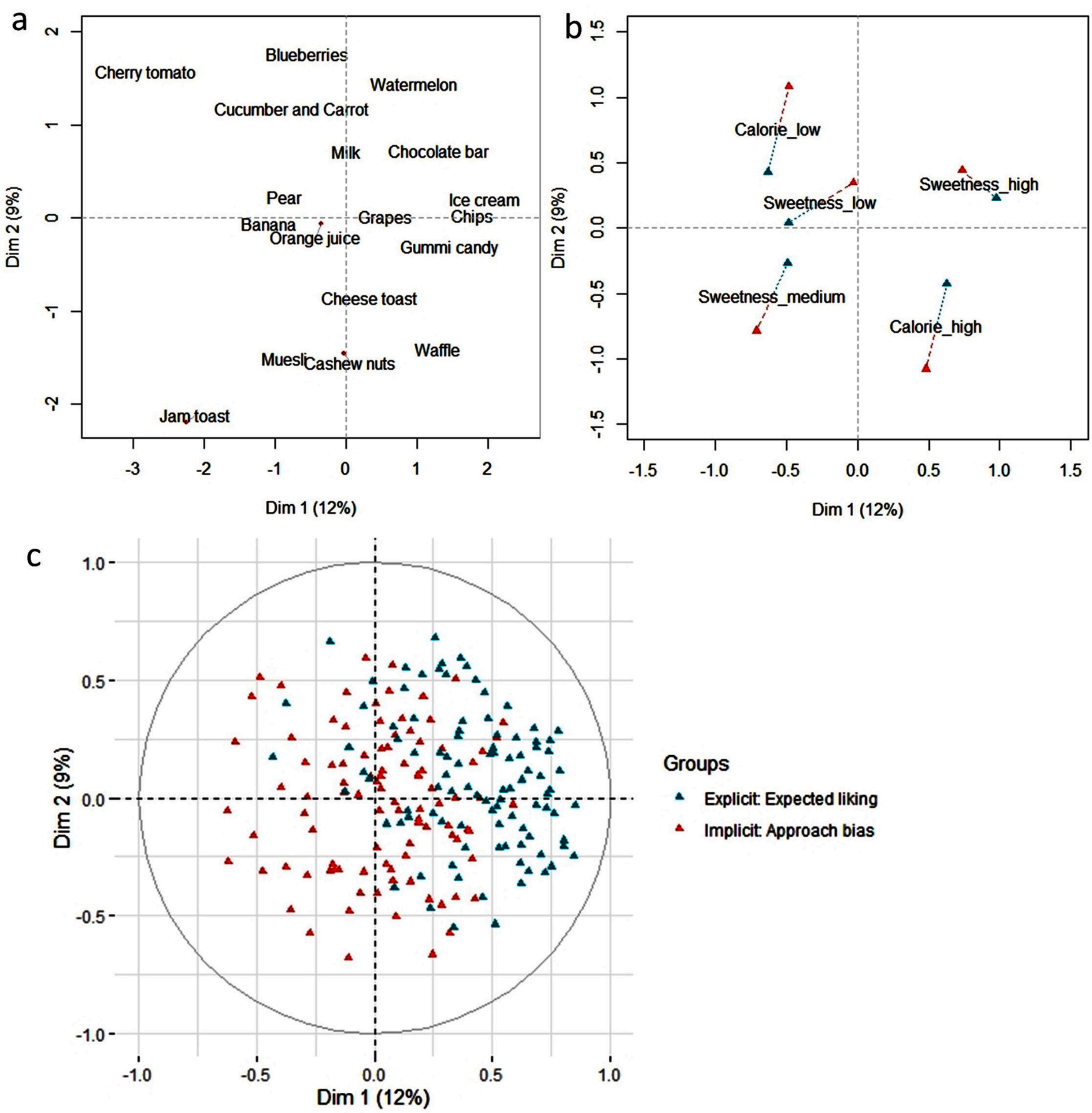

Fig. 3. Multiple factor analysis of implicit (Approach bias) and explicit (Expected iking) responses to snack pictures differing in sweetness level and calorie content. Both matrices were centred and standaridzed with snack picture as row and child as column. a: score plot showing snack pictures (exact location in centre of text unless marked with red dot), b: projection of design of experiment factor levels with lines showing implicit and explicit location, c: loading plot representing children regarding their explicit and implicit response. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.2. Approach bias and expected liking of food pictures

The present study did not find significant differences in approach bias according to sweetness and calorie levels in the selected snack pictures. This was also not the case in a study with adults where calorie content, individual food preferences and food deprivation were investigated in relation to approach bias through a touchscreen-based AAT, with a wide range of food items (Kahveci et al., 2020). The lack of discrimination among food pictures in the present study could be linked to the low test power of the AAT due to high error and outlier rates which did not allow to measure relatively small differences between appealing snack pictures (further discussed in 4.5 Methodological considerations and recommendations).

Expected liking ratings discriminated the food stimuli according to sweetness, calorie content, and their interaction. As in previous studies (Cooke & Wardle, 2005; DeJesus et al., 2020; Ervina et al., 2020; van der Heijden et al., 2020) children expected to like snacks high in sweetness and high in calorie more.

We were able to see some common and some distinct patterns between the implicit and explicit responses. On one side, the regression analysis confirmed that children's expected liking ratings were significantly correlated with children's approach bias, in line with that described by Kahveci et al. (2020) in adults. However, it is interesting to note, that expected liking and implicit bias were not representing similar tendencies for all children, as suggested by the Multiple factor analysis loading plot. While half of the children showed expected liking

Table 3
Individual differences in explicit and implicit responses to snack pictures linked to other measurements: Demographics, health and taste questionnaire subscales, behavioural intention subscales, hunger state and chocolate milk preference. Continuous variables (health and taste subscales, behavioural intention subscales, hunger state) were tested by Pearson correlation (correlation coefficient and p-value reported), categorical variables by unpaired t-tests (chocolate milk preference, gender) and ANOVAs (age).

	Variables	Frequency for categorical/mean (SD) for continuous variables	High – medium & low sweetness		High – low calorie	
			Implicit: approach bias	Explicit: expected liking	Implicit: approach bias	Explicit: expected liking
Demographics (N = 98)	Gender	Girls:47%, boys:53%	T(96) = 0.1 p = .922	T(96) = 1.7 p = .090	T(96) = 1.7 p = .100	T(96) = 1.0 p = .317
	Age	9: 62%, 10: 29%, 11: 9%	F(2,95) = 0.4 p = .642	F(2,95) = 1.8 p = .175	F(2,95) = 0.1 p = 0.904	F(2,95) = 1.1 p = 0.345
Attitude subscales (N = 98)	General health interest (1–7) (α = 0.41)	4.4 (0.9)	−0.18 p = .080	0.04 p = .697	−0.05 p = .646	−0.06 p = .579
	Craving for sweet food (1–7) (α = 0.69)	4.7 (2.0)	0 0.14 p = .167	0.08 p = .445	0.09 p = .390	**0.32** p = **.001**
	Using food as reward (1–7) (α = 0.64)	4.1 (1.1)	0 0.01 p = .930	−0.02 p = .859	−0.06 p = .536	**0.37** p < **.001**
	Affective attitude towards sweet food (1–7) (α = 0.64)	4.4 (0.8)	0 0.01 p = .911	0.02 p = .866	−0.00 p = .978	**0.41** p < **.001**
	Cognitive attitude towards sweet food (1–7) (α = 0.52)	4.3 (0.6)	0.01 p = .919	0.01 p = .919	−0.04 p = .666	**0.41** p < **.001**
State (N = 98)	Hunger (1–7)	4.2 (1.7)	**−0.24** p = **.017**	0.06 p = .552	**0.25** p = **.014**	**0.26** p = **.010**

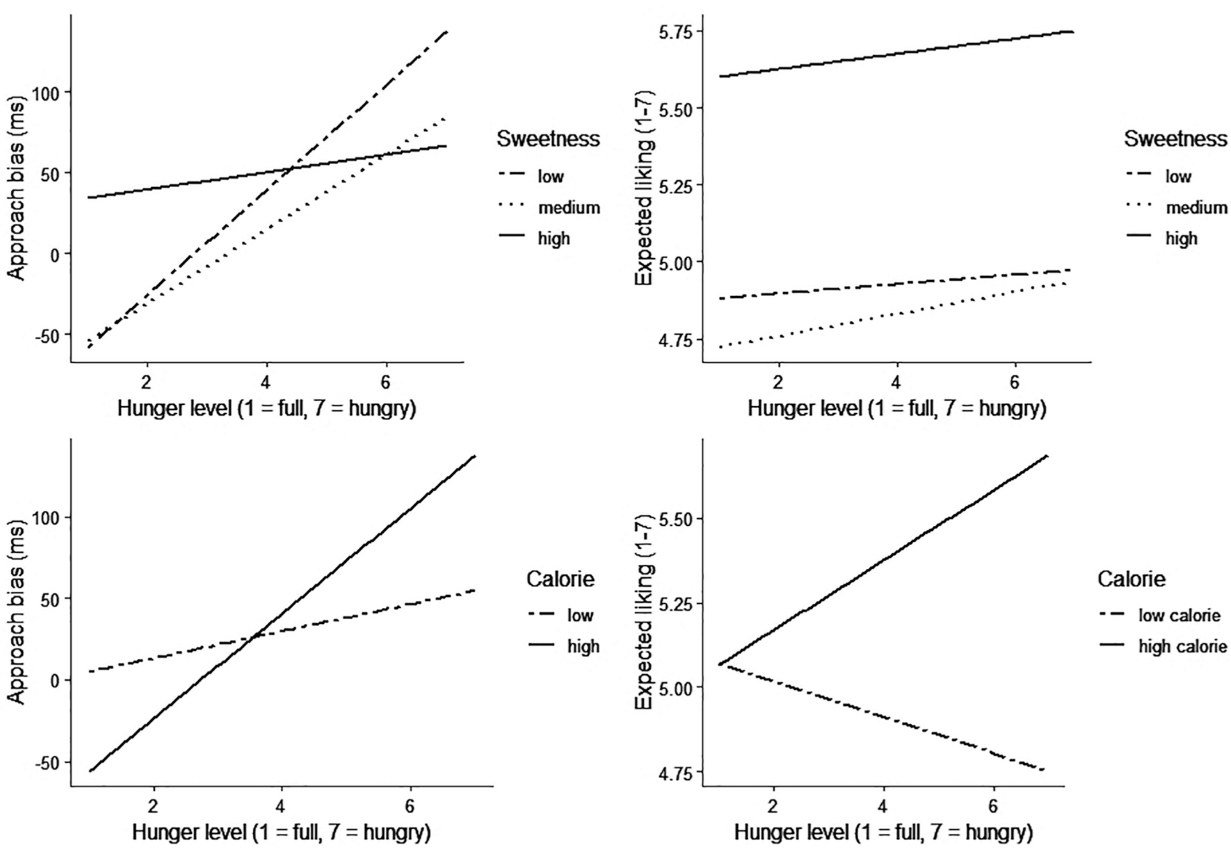

Fig. 4. Implicit (Approach bias) and explicit (Expected liking) according to hunger level. Regression lines were drawn per sweetness level and calorie content. There were similar ratios of hungry, neither hungry nor full and full participants (N = 39, N = 31, N = 28).

responses in line with their implicit bias responses (associated with high sweetness levels), many other children had opposite patterns for both responses. These results link back to what was suggested by Piqueras-Fiszman et al. (2014): implicit test results may be more sensitive for studying individual differences amongst certain groups of consumers and are not necessarily linked to (positive) affective ratings measured via visual analogue scales (VAS) (e.g. liking or wanting).

4.3. Individual differences in approach bias and expected liking

There were no significant individual differences regarding the effect of sweetness on explicit liking, indicating that most of the participants liked the foods with a high sweetness level most. However, we observed individual differences in expected liking as related to calorie level which were related to attitude subscales (*craving for sweet food*, *using food as reward*, *affective* and *cognitive attitude towards sweet food*) and children's

Table 4
Two-sided unpaired t-tests comparing implicit and explicit measurements with paired-preference tasks. N was reduced to 95 in this part because three children did not participate in the chocolate milk preference task due to disliking/lactose intolerance/milk allergy.

			Blind paired preference test (tasted samples)	Take-home paired preference test
			79% preferred added sugar, 21% preferred no added sugar	74% preferred added sugar, 25% preferred no added sugar
Implicit	Approach bias	High – medium & low sweetness	T(93) = 1.2 p = .235	T(93) = 0.4 p = .671
		High – low calorie	T(93) = 0.6 p = .554	T(93) = −0.4 p = .670
Explicit	Expected liking	High – medium & low sweetness	T(93) = 1.4 p = .167	T(93) = 1.1 p = .275
		High – low calorie	T(93) = 1.4 p = .161	T(93) = 0.5 p = .645
	Hunger state	Hunger level	T(93) = 1.2 p = .235	T(93) = -1.2 p = .224
	Health and Taste	General Health interest	T(93) = 0.1 p = .898	T(93) = 0.8 p = .433
		Craving for sweet food	T(93) = 1.8 p = .063	T(93) = 2.2 p = **.027**
		Using food as reward	T(93) = 2.2 p = **.028**	T(93) = 2.5 p = **.015**
	Attitudes towards eating sweets	Affective attitude	T(93) = 2.7 p = **.008**	T(93) = 3.5 p < **.001**
		Cognitive attitude	T(93) = 2.5 p = **.013**	T(93) = 3.0 p = **.003**

hunger level.

With regards to approach bias tendencies, individual differences were not correlated with explicit attitudes. Interestingly, there was a significant link to children's hunger state. The children in this study seemed to implicitly regulate their approach bias response to snack pictures according to their appetite level. Children who were hungry (who performed the AAT just before their lunch) had a stronger approach bias to high caloric snacks and snacks with medium and low sweetness level, so they were significantly more attracted to calorie-dense, non-dessert food in the case of being hungry. Kahveci et al. (2020) did not find food deprivation to produce a larger approach bias towards high calorie food in adults. In our study hunger state also influenced children's explicit expected liking rating of snack pictures: children who were hungry showed larger expected liking ratings for high caloric snacks. However, the effect was only seen for calorie content and not for sweetness level. This indicates that the approach tendency patterns may have been more predictive of situational food choices while expected liking was somewhat more static. Kraus and Piqueras-Fiszman (2016) highlighted that approach or avoidance tendencies may be more linked to dynamic, motivational states, associated with the specific state (e.g. hungry vs. full) or a momentaneous desire to eat, while liking represents an evaluative concept, linked to habitual preferences. A previous study investigating the effect of hunger state on liking vs. wanting (measured by forced-choice tasks) of high vs. low fat and sweet vs. savoury foods (Finlayson et al., 2007) found similar diverging patterns. So, results of the present work add to the literature, suggesting that implicit approach bias interpreted as a representation of automatic wanting and explicit liking ratings may be representing different driving forces behind food behaviour.

4.4. Implicit approach bias and explicit measurements as related to chocolate milk preference

In the present study, neither children's approach bias nor expected liking nor their hunger state were associated with their preference for a sugar vs. non-sugar added chocolate milk either in the blind or informed paired-preference task. Despite low internal consistency, attitude measurements (*craving for sweet food, using food as reward, affective* and *cognitive attitude towards sweet food*) were significantly associated with children's preferences of chocolate milk. This suggests that the involved age group (9–11 y. o.) was able to describe their eating behaviour through the attitude questionnaires, attesting them a certain degree of introspection. However, the low internal consistencies (Cronbach's alpha smaller than 0.7) of the attitude subscales indicate that self-administered attitude questionnaires have limitations with the involved age group as well.

The blind and informed chocolate milk paired preference tests were set up to assess if children with an implicit bias towards sweet or high caloric foods would more frequently choose the higher caloric option (added sugar sample in the informed take-home test) and/or the sweeter one (added sugar sample in the blind tasting preference test and take-home test); and if their explicit attitudes were linked to their preferences. The authors acknowledge the prediction power of the performed preference tests is limited and more research is needed to assess the potential link of implicit bias measurements with actual food choice patterns. The paired-preference task was chosen to have ecological validity as Norwegian children might be confronted with the choice scenario in a grocery store (packs were real commercial products) and to ensure familiarity, as the samples are offered as part of the "school milk program" in Norwegian schools. As a downside, the commercial samples (packs and formulations) contained some confounders which could have biased or added noise to the results. The packaging contained information about calorie content (61 kcal/100 g vs. 41 kcal/100 g) and sweetness intensity (no info vs. "No sugar added"), the variables under study in this research. However, the claim "New" on the packaging of the no-sugar added chocolate milk could have shifted the focus of attention when choosing, or prevented neophobic children from choosing this option. The tasted samples in the blind test differed in sugar content and resulted in a perceivable difference in sweetness intensity, having comparable sensory profiles, as evaluated by the research team. However, the non-sugar added recipe had been optimized regarding other ingredients which could have confounded the assessment of preferences towards sweetness intensity. Children might also have been more familiar with the sugar added recipe, that had been for longer in the market. Food memory is particularly good at detecting novelty which could result in rejection (Morin-Audebrand et al., 2012). A more general limitation was the limited focus of testing preferences on only one food category (chocolate milk) as indicator of more general food choice patterns. Marty, Miguet, et al. (2017) used for this purpose a buffet set-up where children could make several choices to measure children's preference patterns, an approach that could have presented a more valid food choice scenario. A choice scenario based on a buffet composed of similar snacks to those assessed via AAT and liking (picture stimuli) might have been more predictive and should be considered for future studies. However, the test procedure in the present study, involving questionnaires, implicit testing and two preference tests was, on one hand, long enough for children, and on the other, entailed numerous methodological complex decisions that made us settle for a simple preference testing approach. Even with their limitations, the obtained results gave us a first indication of how to link implicit motivations and explicit preferences and provided new knowledge that can be utilised in future test designs.

Results suggest that social desirability may not bias explicit measurements in self-administered test settings with children in the same way as it might be the case with adults, as e.g. found by Raghunathan et al. (2006). According to these authors, the majority of adults claimed to like healthy but ultimately chose unhealthy food. In the present work, the majority of participating children rated unhealthy snacks (=high in calorie and sweetness) higher in expected liking than healthy snacks and also chose the unhealthier option (chocolate milk with sugar over no-sugar added). Further, their self-reported attitudes were associated to their chocolate milk preference. Implicit testing might be more relevant in populations where implicit motivation and liking, representing goal-directed intention, stand in opposition, e.g. overweight children who are trying to lose weight but do not manage. The AAT has come into application with overweight adults (Kakoschke et al., 2017; Maas et al., 2016; Paslakis et al., 2016) and as intervention to "retrain" overweight children (Warschburger et al., 2018).

4.5. Methodological considerations and recommendations

When planning and evaluating the study we were confronted with the question, if the AAT is most suitable to compare individuals regarding their approach biases as done in most previous food-related AAT studies (Booth et al., 2018; Brockmeyer et al., 2015; Kahveci et al., 2020; Kakoschke et al., 2017; Lender et al., 2018; Maas et al., 2016; May et al., 2016; Paslakis et al., 2016; Piqueras-Fiszman et al., 2014; Rohr et al., 2015) or if differences between food categories could be investigated as well. We decided to focus on both, as done in a few studies (Kahveci et al., 2020; Maas et al., 2016; Paslakis et al., 2016; Rohr et al., 2015). First, investigating children's general approach bias tendencies and then investigating individual differences in the assessments. However, we did not find significant effects of the design of experiment parameters (*sweetness* and *calorie*) within snack pictures, as discussed above. This question remains open and future studies should include varying levels or relevant product features, based on controlled design of experiment, to better understand the applicability of AAT and other implicit methods to product differentiation.

Measuring reaction time is likely to contain a high amount of noise (due to distraction), which might be more pronounced in children, as noted by (van der Heijden et al., 2020), who compared the test power of children and adults in the implicit association task. Although the pulling and pushing of a joystick as a reaction tool in the AAT is particularly easy, the task still required children to stay focused over an extended period (appr. 15 min in the presented study). In the present study, 15 children had to be excluded from the data analysis due to large error and outlier rates and the resulting AAT dataset contained 15% missing values which reduces test power which was higher than in previous studies with adults (e.g. Lender et al., 2018).

The multidimensional characteristics of pictures as test stimuli, makes the setup of a suitable test design challenging, as there are many potential confounders. In our test, visual aspects (shape and colour) of food were controlled for by the inclusion of visually similar non-food items. However, within food items, no standardization was easily attainable if the objective was to vary levels of sweetness and calories. Foroni et al. (2016) found that human's arousal is linked to colour, however only in food not visually similar non-food pictures. Therefore, colour imbalances between factor levels of snacks could have biased findings. We explore this aspect when checking data quality (Supplementary material 3) but no visual picture features (such as redness or contrast) had a significant effect on Approach bias. Further, picture meaning can be confounded as well. Coricelli et al. (2019) proposed natural vs. processed food as an additional dimension which was almost 1:1 represented by the factor *calorie* in our study (the high calorie foods were processed to a certain degree, low calorie were not). However, our results may indicate that calorie content rather than processing level was decisive for children's response as implicit and explicit tendencies towards high calorie content correlated to children's hunger level. Further, our results suggest a main separation between the frequently consumed and the more special snacks (more seasonal or usually restricted by parents), as shown by the Multiple factor analysis, an aspect that could be worth investigating further. It could also be of interest to compare two extreme food groups as done by Piqueras-Fiszman et al. (2014). They compared individuals regarding approach and avoidance towards appealing and disgusting foods and also assessed the role of their hunger state. With children, food neophobia topics could potentially be explored this way.

In the feature-relevant task instruction chosen in the presented study, the response criteria are based on the stimulus picture content; in the feature-irrelevant used by other authors, the task focuses on a different aspect (e.g. landscape and portrait format of stimulus picture). Lender et al. (2018) found larger effects comparing food and non-food pictures in a feature-relevant setting. It could be that in feature-irrelevant task instructions, participants are so much focused on the task goal that they do not perceive the picture content. Selective attention has been well demonstrated, e.g. in the Nobel price winning "Gorilla experiment" (Simons & Chabris, 1999). It can be assumed that the discrimination between stimuli could be even weaker in feature-irrelevant AAT tasks where stimulus processing mostly occurs subliminally. However, more than just assuring the processing of picture content, similar as in the Implicit association task, the feature-relevant AAT task instruction brings the classification concepts into participants' consciousness. This could extend participants' response towards the concept of the two groups (food vs. non-food in our study) rather than the presented stimuli in the pictures. Lavender and Hommel (2007) argued that the intention to act upon affect will lead to approach behaviour. In our setup participants were aware of the food vs. non-food group and were instructed to act upon this criterion. But they were not aware and therefore had also no intention to act upon the factor levels within food which could explain weaker discrimination within food pictures. Perhaps, a feature-relevant AAT where the task instruction was based on a food category (e.g. sweet vs. not sweet) would lead to higher discriminability. Although it seems to be standard procedure in the AAT, visually similar object pictures might not be essential and some studies (Paslakis et al., 2016; Rohr et al., 2015) did not include them. Similar to the IAT, two separatable food groups could potentially be compared this way.

A major disadvantage of a feature-relevant task instruction lies in the need of participants to switch task instruction after the first test part which is not necessary for feature-irrelevant task instructions. Our results (presented in supplementary material 2) suggest that it was not easy for children to switch task instruction resulting in more errors and outliers in the second test part with a lower testing power as consequence. Furthermore, children's reaction time decreased over the course of the task probably due to training effects. Because approach bias represents the difference between the first and second test parts in the feature-relevant task setup, a systematic difference between children that started with one and children that started with the opposite task instruction occurred. In order to allow an accurate estimation larger training blocks might be necessary, or otherwise, the decrease in reaction time per test part needs to be corrected as done in the presented study. To our knowledge, this effect has not been investigated before. It could be particularly relevant in the application with children.

5. Conclusions

The present work aimed to apply the Approach avoidance task (AAT) to investigate children's automatic approach tendencies for the first time in a food-related context. We explored children's implicit approach bias to snacks differing in *sweetness* and *calorie* content and the link to explicit questionnaire-based results and preferences for a sugar vs. no-sugar added chocolate milk.

Children displayed a significant positive approach bias towards snack (food) pictures in general and a slightly negative approach bias to non-food pictures; we did not find significant differences in approach bias towards snack pictures with different levels of *sweetness* and *calorie* content.

Explicit expected liking discriminated among snacks varying in *sweetness* and *calorie* content, with most children liking *high sweetness* most, but individual differences regarding *calorie* content, some liked high caloric and others low caloric snacks more.

Individual differences in hunger state influenced children's implicit and explicit assessments; children who were hungry showed larger approach biases and expected liking ratings for high caloric snacks and a lower approach bias towards the high sweetness level, being more attracted to calorie-dense non-dessert food.

There were some common and some distinct patterns between the implicit and explicit results: around half of the children showed expected linking responses in line with their implicit bias responses (associated with high sweetness), while other children had distinct or even opposite patterns for both responses, suggesting that implicit bias measured via AAT and liking ratings may be representing different driving forces behind food behaviour.

Attitude subscales *craving for sweet food, using food as reward, affective attitude towards sweet food* and *cognitive attitude towards sweet food* were positively associated with children's explicit liking for high caloric snacks and were significantly associated with children's blind and informed preferences between a sugar and no-sugar added chocolate milk. Children's implicit approach bias was not significantly associated with their blind or informed preferences in the present study. Nevertheless, the potential link of approach bias to *sweetness* and *calorie* preference patterns cannot be dismissed by our study which focuses on preferences towards chocolate milk only. Future research should explore wider food choice scenarios, where more diverse, real choices are studied in a variety of foods, to assess food preference patterns in relation to implicit motivational tendencies.

CRediT authorship contribution statement

Martina Galler: Conceptualization, Methodology, Investigation, Writing – original draft, Visualization. **Emma Mikkelsen:** Conceptualization, Methodology, Investigation. **Tormod Næs:** Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision. **Kristian Hovde Liland:** Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision. **Gastón Ares:** Conceptualization, Writing – original draft, Supervision. **Paula Varela:** Conceptualization, Methodology, Writing – original draft, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2021.104416.

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