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Capturing food-elicited emotions: Facial decoding of children's implicit and explicit responses to tasted samples

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ABSTRACT

Sensory and consumer research increasingly aims to gain direct input from children to study their eating behaviour. However, answering self-administered questionnaires can be challenging for children. In this sense, the prediction of basic emotions via facial decoding, generating quantitative observational data, could offer an alternative to questionnaires.

The present study aimed to measure children's implicit and explicit basic emotions elicited by tasting, through the use of facial decoding and compare them to children's liking ratings in a case study with flavoured chocolate milk samples. Children aged 9–10 participated in the study (n = 48). Six samples based on two design of experiment factors *Added sugar* (yes / no) and *Surprise flavour* (peppermint / liquorice/ no added flavour) were tested. The software iMotions with the AFFDEX algorithm was used for facial decoding. For each sample, facial expression was measured immediately after tasting (implicit basic emotions). Then, children were asked to show a facial expression related to their feelings when they tasted the chocolate milk (explicit basic emotions) and rate their liking on a 7-point-scale.

Implicit and explicit basic emotion likelihoods from facial decoding were correlated to liking ratings regarding the factor *Surprise flavour*. As in previous studies, the measurement of implicit basic emotions discriminated samples according to negative emotions (anger and disgust) which had higher likelihoods in disliked samples with *Surprise flavour* (peppermint and liquorice). Facial decoding of explicit basic emotions was the only measurement discriminating samples also according to the factor *Added sugar,* an advantage over liking ratings. The positive emotion joy, as well as negative emotions (sadness, fear, anger, disgust and contempt), were significant in the explicit evaluation. The results add to previous literature suggesting that the measurement of implicit emotions via facial decoding can be useful to study negative emotions. Further, explicit basic emotions enhanced the discrimination of liked samples with the involved age group.

1. Introduction

Sensory and consumer research increasingly aims to gain direct input from children to study their eating behaviour (Laureati et al., 2015). The measurement of emotions is thought to add additional dimensions to liking ratings and, therefore, it has been reported to improve the predictability of food choices in adults (Gutjar, de Graaf, et al., 2015) as well as children (Schouteten et al., 2018). For tests with children, non-verbal questionnaire-based emotion measurements such as emojis have come into application, being an easy and engaging way to study food experiences (Schouteten et al., 2019; Sick et al., 2020). However, depending on the age group involved, self-administered questionnaires can be cognitively challenging for children (Guinard, 2001). Further, social desirability effects can potentially bias self-reported results (Klesges et al., 2004). Therefore, indirect tests that do not rely on self-reporting have been suggested as less biased measurements (Köster, 2009; Laureati et al., 2015).

Ekman and Heider (1988) defined seven basic emotions, joy, anger, fear, sadness, surprise, disgust, and contempt as universally recognizable based on facial expressions. Traditionally, basic emotions have been classified via the facial action coding system (FACS) performed by highly trained coders. In recent years, advances in image processing and

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machine learning have brought forward opportunities to predict basic emotions via algorithms from video recordings, which could make such measurements more efficient. A broad range of consumer studies has used FACS to measure consumers' affective experiences with products (Clark et al., 2020). facial decoding is also gaining popularity in sensory and consumer science (Savela-Huovinen et al., 2021). This methodological approach could be particularly interesting in applications with children. Several observation studies with infants could associate specific facial expressions to different basic tastes and odours (Forestell & Mennella, 2017; Rosenstein & Oster, 1988; Soussignan et al., 1997; Steiner et al., 2001). Similar patterns were also found in adults (Weiland et al., 2010). However, they also found some deviations, such as a "social" smile in response to unpleasant tastes and negative facial expressions with high sweetness concentrations which the authors linked to socialization rather than innate behaviour observed in infants (Weiland et al., 2010).

The interpretation of facial expressions as emotions are challenged by constructed emotion theorists (Barrett, 2004, 2006a, 2006b; Barrett, 2016; Barrett et al., 2011) that do not consider emotions to be nature-given but rather shaped by culture. Facial expressions differ between individuals: their interpretation is highly dependent on context as well as on the interpreter (Barrett, 2006b; Barrett et al., 2011). Facial decoding via algorithms reflects the uncertainty by providing a prediction of the likelihood for each basic emotion to be present rather than a classification. To account for individual differences, machine learning algorithms are trained on a wide variety of faces.

If participants are not aware of the time point when their facial expression is measured during an experiment or video recording, the study of these images can be considered a measurement of implicit automatic responses. Previous food -related studies with adults in laboratory settings indicated that implicit facial decoding mainly detected negative emotions linked to disliked samples, while liked samples provoked rather neutral faces (Danner et al., 2014; Kostyra et al., 2016; Pedersen et al., 2021). This was also observed in a small sample of school-aged children via human decoders (Zeinstra et al., 2009). Danner et al. (2014) used explicit facial decoding "make a face" as an additional measurement with adults, which yielded a higher food sample discrimination also for the positive emotion "joy". Danner et al. (2014) further noted that some people were generally more expressive than others, the "poker faces", which showed no emotions which might hamper product testing via facial decoding.

The present study aimed to measure children's (9–10 y. o.) implicit and explicit basic emotions elicited by food tasting, through the use of facial decoding, and to compare them to children's liking ratings in a case study with flavoured chocolate milk samples.

2. Materials and methods

The study was conducted at Vitenparken Campus Ås within a science outreach program, which is offered to school classes in the Akershus region. Children visited the science centre with their school classes and teachers. They had different science lectures, activities, and exhibitions throughout the day and among those, the current study. The test was performed by one child at a time and a researcher was present for initial instruction and assistance. Participants also completed a packaging evaluation where their eyes were tracked and filled in an attitude questionnaire (results not reported) resulting in a test length of approximately 20 min.

2.1. Participants

A total of 48 children between 9 and 10 years old with a balanced gender ratio (47 % girls) participated in the study. The protocol was presented to the Norwegian Centre for Research Data (NSD), reference 476380. Prior to the test, parents were informed about the experiment via the school communication app, filled in a short questionnaire about food intolerances or allergies and gave consent through an electronic form. All children provided oral assent. They were informed that they could leave the test at any time without consequences. As a token of appreciation for their participation children received a chocolate milk pack after the test.

Table 1
Chocolate milk sample design with design of experiment factors.

Sample code	Sample name	Added sugar	Surprise flavour	Serving block
□	**S**	Yes[1]	–	1
◆	**NS**	No[2]	–	1
★	**L-S**	Yes[1]	Liquorice[3]	2
▭	**L-NS**	No[2]	Liquorice[3]	2
+	**M−S**	Yes[1]	Peppermint[4]	2
△	**M−NS**	No[2]	Peppermint[4]	2

[1] Litago® Original, ingredient list: skim milk, 4% sugar, 1% cocoa, stabilizer (carrageenan), aromas
[2] Skolelyst® Lettmelk Kakao, Uten tilsatt sucker, ingredient list: skim milk, potato starch, cocoa, flavour, stabilizer (carrageenan), vitamin D
[3] 8 drops aroma / liter chocolate milk
[4] 4 drops aroma / liter chocolate milk

2.2. Samples

Six chocolate milk samples, modified with added flavour to be different enough from a sensory perspective, were developed in collaboration with product developers at the Norwegian milk producer Tine SA. As in previous facial decoding studies with adults (Danner et al., 2014) and children (Zeinstra et al., 2009), liquid samples were used to avoid potential distortion of the measurement by chewing motions. Chocolate milk represents a dairy product that is generally highly accepted by children (De Pelsmaeker et al., 2013; Verruma-Bernardi et al., 2015). Further, distinct emotional profiles have been measured for different flavoured milk brands in children previously (De Pelsmaeker et al., 2013).

Samples followed a design of experiment with two factors *Added sugar* and *Surprise flavour* (Table 1). The reduction of sugar-sweetened beverage consumption is a primary aim of public health initiatives for childhood obesity prevention (WHO, 2018) and the dairy producer Tine SA has embraced these goals by developing no-added-sugar dairy products for children. It has been previously shown that sugar reduction in chocolate milk reduced children's acceptance (Li et al., 2015). Therefore, it was of interest to study how sweetness intensity would relate to children's' emotional reactions and whether flavour addition would compensate for the reduced sweetness level or not. Both factors represented sensory properties (flavour intensity and sensory novelty) that have been previously linked to the emotional arousal dimensions in a *meta*-analysis of consumer studies including different product categories (Jaeger et al., 2018).

For the factor *Added sugar*, two commercially available chocolate milk products targeted at children were used (Litago® Original chocolate milk: with added sugar and Skolelyst® Lettmelk Kakao, Uten tilsatt sukker: without added sugar). The no sugar added version was optimized regarding sweetness through lactose hydrolysis as well as regarding bitterness by substitution for a milder cocoa powder which decreased the difference between the two recipes. However, a perceivable difference in sweetness between the two chocolate milk recipes remained, as shown in a previous study with lactose hydrolysis as well (Li et al., 2015). For the second factor, *Surprise flavour*, either liquorice or peppermint aroma were added. The peppermint and liquorice aromas were chosen as these two flavours are usually used in chocolate products, so they would match the sensory profile. However, no chocolate milk with those flavours was available in the Norwegian market at the time of the study. The chocolate milk samples were mixed with the surprise flavours the same day of testing, stored in a refrigerator (4 °C),

Table 2
Mean values of liking ratings (1–7-point scale) and basic implicit and explicit emotions measured by face decoding (maximal likelihood estimation). Values with significant differences according to a Tukey test on a 5% significance level within rows are indicated with superscript letters.

		Mean values of samples							p-values of mixed ANOVAs		Significant design of experiment factors*
		Total	S	NS	L-S	L-NS	M−S	M−NS	Samples	Children	
Liking rating	Liking	3.5	5.8 [a]	5.3 [a]	2.1[b]	2.2[b]	2.7[b]	2.6[b]	**<0.001**	**<0.001**	*Surprise flavour*
Implicit emotions	Joy	37	46	42	37	30	37	27	0.234	**<0.001**	–
	Surprise	22	23	22	21	22	24	22	0.983	**<0.001**	–
	Sadness	18	15	16	21	19	22	17	0.586	**<0.001**	–
	Fear	6	8	6	3	7	5	5	0.673	**<0.001**	–
	Contempt	32	25[b]	34[b]	31 [a]	25 [ab]	39 [ab]	37 [ab]	0.393	**<0.001**	–
	Anger	20	12 [bc]	9[c]	26 [ab]	30 [a]	20 [abc]	24 [abc]	**<0.001**	**<0.001**	*Surprise flavour*
	Disgust	36	23	24	47	41	40	38	**0.001**	**<0.001**	*Surprise flavour*
Explicit emotions	Joy	40	68 [a]	62 [a]	31[b]	27[b]	28[b]	25[b]	**< 0.001**	**<0.001**	*Surprise flavour*
	Surprise	59	62	59	55	54	61	60	0.322	**<0.001**	–
	Sadness	10	3[c]	4 [bc]	16 [ab]	9 [abc]	8 [bc]	21 [a]	**<0.001**	**<0.001**	*Surprise flavour, Added sugar × Surprise flavour*
	Fear	1	0[b]	6 [a]	1[b]	1[b]	0[b]	1[b]	**0.002**	0.648	*Added sugar, Added sugar × Surprise flavour*
	Contempt	8	7 [a]	4 [a]	15 [a]	1 [a]	15 [a]	6 [a]	**0.017**	**0.046**	*Added sugar*
	Anger	16	11 [bc]	5[c]	10 [bc]	23 [ab]	7 [bc]	39 [a]	**<0.001**	**0.020**	*Added sugar, Surprise flavour, Added sugar × Surprise flavour*
	Disgust	32	14[b]	12[b]	31[b]	24[b]	57 [a]	53 [a]	**<0.001**	**<0.001**	*Surprise flavour*

S = Sugar added, **NS** = No sugar added, **L-S** = Liquorice, sugar added, **L-NS** = Liquorice, no sugar added, **M−S** = Peppermint, sugar added, **M−NS** = Peppermint, no sugar added

*Significance of design of experiment factors determined by additional mixed models: detailed results are presented in the Appendix.

and poured just before serving.

As a warm-up sample to the test and to practice and understand test instructions, plain milk was served. Samples were served in black plastic cups that masked slight colour differences between the samples. Cups were coded with angular geometric symbols displayed in Table 2 that facilitated the self-serving of samples by children during the test.

Samples were randomized across participants in two blocks. First, the two samples without flavour, followed by samples with flavour to prevent carry-over effects of flavoured to non-flavoured samples (Table 1).

2.3. Test procedure

Sample testing was performed in a closed room to avoid distractions. The researcher explained the setting and assisted the tasting of the warm-up sample according to questionnaire instructions (Fig. 1). Then, the researcher sat behind a partition wall to not distract the child during the test to avoid influencing their facial expressions.

The test flow is shown in Fig. 1 as screenshots of the instructions the children received : 1) instruction screen: find sample and show it to the camera; 2) a short instruction film instructing children to taste the samples with the same speed as the person in the film; 3) a fixation point was shown in the middle of the screen, where the implicit facial reaction to the tasted sample was measured (children were instructed by the researcher during the warm-up tasting to look at the fixation point) - after 13 s it automatically forwarded to the next screen; 4) instruction screen: “Show with your face how you feel about the tasted sample” for the explicit facial decoding, 5) liking rating via 7-point hedonic scale, 6) instruction screen: mouth rinsing with water. The time interval of 13 s to measure the implicit facial reaction was defined in a pilot study with a small group of children of the same age.

2.3.1. Facial decoding

Participants’ faces were recorded using a Logitech C920 Hd Pro webcam that was placed on top of the PC screen. The AFFDEX SDK 4.0 (Affectiva Inc., Waltham, USA) system implemented in the iMotions 8.1 platform was used to classify video recorded movements of key face features (i.e., facial landmarks such as brows, eyes, and lips) of participants into basic emotions. The coding system allows the classification of seven basic emotions, joy, surprise, anger, fear, disgust, contempt and sadness. Each basic emotion was quantified as likelihood ranging from 0 (not expressed) to 100 (certainly expressed).

The time frame of measurement after sample ingestion for implicit and explicit facial expression measurements was annotated manually by the researcher that collected the data. For the implicit measurement, the time interval varied between 6 and 13 s, starting at the time point when the child moved down the cup from the face after drinking and ending 13 s after the tasting instruction video had ended (see Fig. 1). Explicit facial expressions (“Show with your face how you feel about the tasted sample”) were stereotypical and limited to a short time frame. Therefore, a constant time interval of 1 s could be annotated by the researcher starting at the onset of the explicit facial expression. Within the annotated time frames of the implicit and explicit measurement, the maximal probability of each basic emotion was extracted and used for subsequent data analysis.

2.3.2. Liking rating

Children rated their expected liking on a 7-point hedonic scale with smiley faces as well as text at 1 = did not like at all, 4 = neither liked nor disliked, 7 = liked very much) as anchor points (Fig. 1, screen 5).

2.4. Data analysis

All analyses were performed in R, version 4.0.4. Significance was determined based on a significance level of $\alpha = 5\%$. The R package “mixlm” (Hovde Liland, 2019) was used for linear mixed ANOVAs and posthoc tests of significant fixed effects. Further, the R package “FactoMineR” (Lê et al., 2008) was used to perform a multiple factor analysis (MFA) as well as a principal component analysis (PCA). One child was excluded from the data analysis as it did not understand the test instruction, resulting in 47 answers considered for the data analysis.

2.4.1. Sample discrimination by different measurements

Children’s liking ratings, implicit and explicit basic emotion likelihoods were analysed as dependent variables via mixed ANOVAs with sample as fixed and child as random independent variable. Further, measurements were analysed regarding the design of experiment factors of the samples, *Added sugar* and *Surprise flavour,* via mixed ANOVAs with *Added sugar* and *Surprise flavour* as well as their interaction as fixed main independent factors and child as random independent factor. Tukey tests were performed as post hoc analyses of significant fixed effects to determine the significance levels.

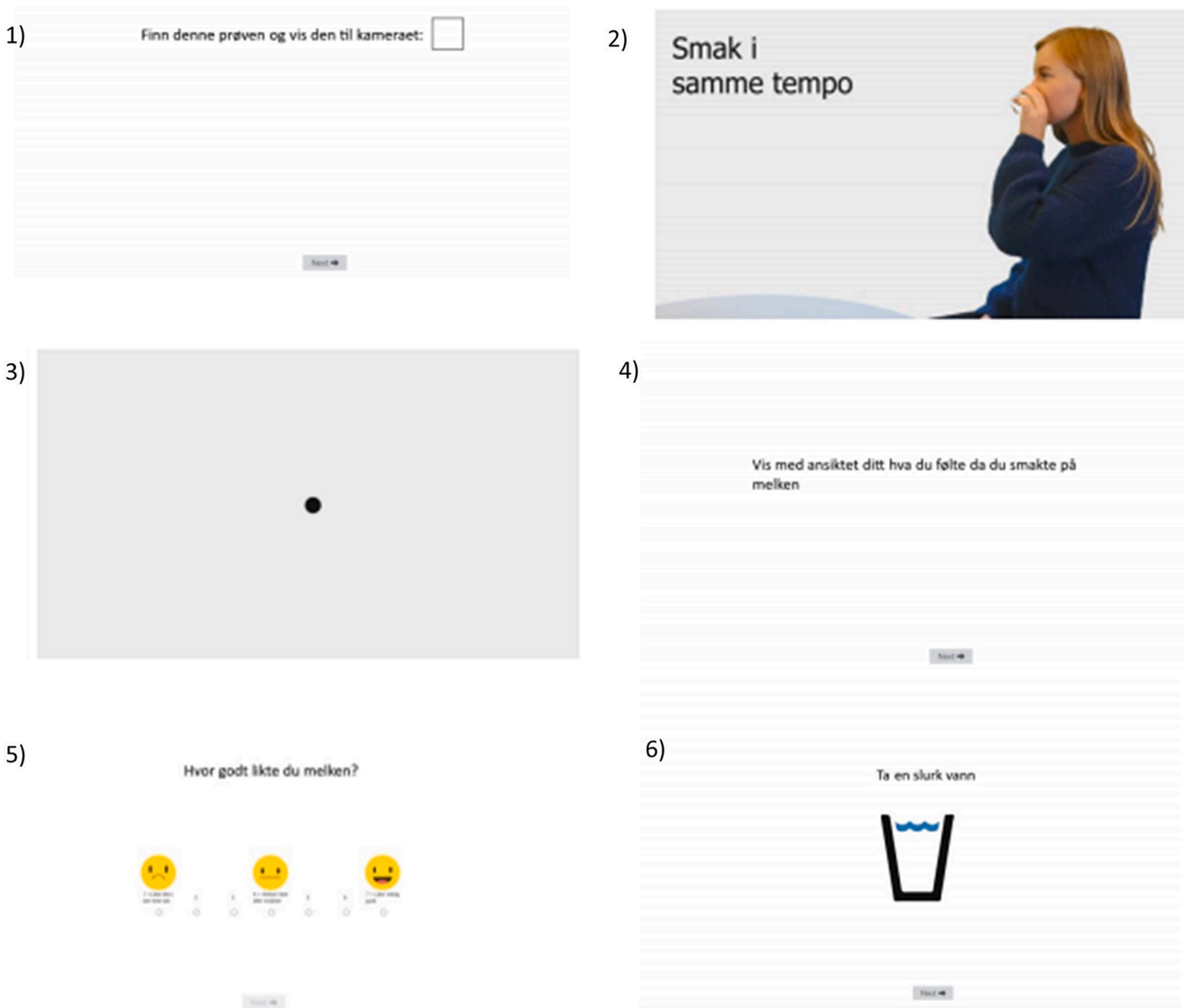

Fig. 1. Screenshots of the sample evaluation procedure: 1) Find sample and show it to the camera, 2) Watch instruction film and taste sample at the same tempo, 3) Fixation point where the implicit facial reaction to tasted sample was measured (children were instructed by the researcher during the warm-up tasting to look at the fixation point), 4) Instruction to show with the face how the sample tasted, 5) Liking rating, 6) Neutralizing taste with water.

2.4.2. Comparison of liking ratings with implicit and explicit basic emotion likelihoods

To investigate the correlation of the three measurements (liking, implicit and explicit basic emotions) a multiple factor analysis (MFA) overlayed the measurements that significantly discriminated samples, averaged over participants. Each measurement represented a block with samples as rows and measurement variables as standardized columns.

2.4.3. Comparison of children's basic emotion likelihoods

To investigate children regarding expressed emotions in response to the tasted samples, a PCA with basic emotions that discriminated children significantly was performed. Basic emotions were averaged over the six tasted samples. Basic emotions were used as unstandardized variables and children as rows in a PCA. A separate PCA was performed for implicit and explicit emotions.

To check, whether children's implicit and explicit facial expressions in reaction to the tasted samples were related or not, variables were classified according to their location on the first two components. For each component, the division was drawn at 0. For each component, the classification based on implicit and explicit emotions were compared per cross-tabulation. Further, a Chi-squared test was used to assess the association between implicit and explicit facial expressions.

3. Results

3.1. Explicit liking rating

Significant differences in children's liking ratings of the samples were found (Table 2). Children's ratings indicated a higher liking of the samples without *Surprise flavour* as compared to those with *Surprise flavour*. As shown in Fig. 2, children expressed dislike for samples with the surprise flavour, which was stronger for liquorice compared to peppermint. No significant difference in liking was found for the factor *Added sugar*.

3.2. Implicit facial decoding

Joy, disgust, and contempt were the implicit basic emotions with the highest average likelihood (32–37 %), whereas fear had the lowest likelihood (6 %) (Table 2 and Fig. 3). Implicit facial decoding discriminated samples regarding two out of seven basic emotions: anger and disgust. Both emotions discriminated samples based on the factor *Surprise flavour*. The addition of the *Surprise flavour*, both peppermint and liquorice, increased the likelihood of children expressing the basic emotions anger and disgust (Fig. 4).

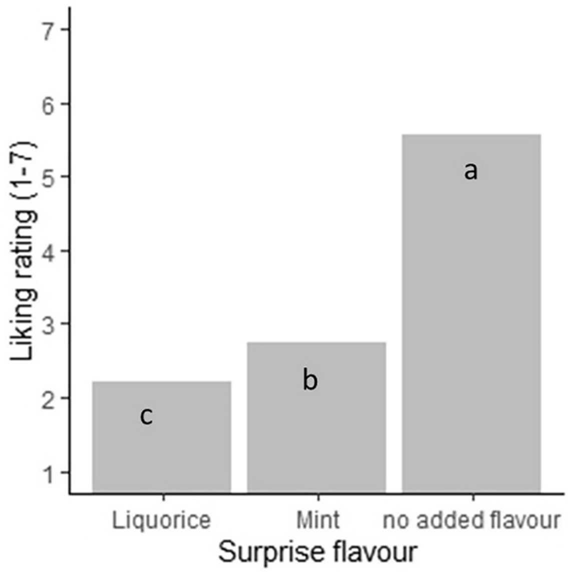

Fig. 2. Liking rating for the significant design of experiment factor Surprise flavour. Values with significant diferences according to a Tukey test on a 5% significane level are marked with letters.

3.3. Explicit facial decoding

Surprise, joy and disgust were the explicit basic emotions with the highest likelihood (32–59 %), fear and contempt the lowest (1–8%) (Table 2 and Fig. 3). Explicit facial decoding discriminated the samples regarding six out of seven basic emotions. Only the emotion surprise did not significantly discriminate the chocolate milk samples. The emotions joy, sadness, anger, and disgust discriminated samples regarding *Surprise flavour* (Fig. 5). The likelihood for the explicit basic emotion joy was higher for the samples without *Surprise flavour*. Sadness, anger, and disgust were higher in the samples with *Surprise flavour*, peppermint in particular. Fear, contempt, and anger discriminated samples regarding *Added sugar*. The likelihood of fear and anger was higher for samples without *Added sugar*, the likelihood of contempt was higher in the samples with *Added sugar*. Sadness, fear and anger were also significant for the interaction between the two factors *Added sugar* and *Surprise flavour* (average likelihoods and significance levels are displayed in Fig. 5).

3.4. Comparison of liking ratings with implicit and explicit basic emotion likelihoods

Implicit and explicit basic emotions and liking averages per sample were overlayed by a multiple factor analysis (Fig. 6). Implicit and explicit basic emotions were correlated to explicit liking ratings in the

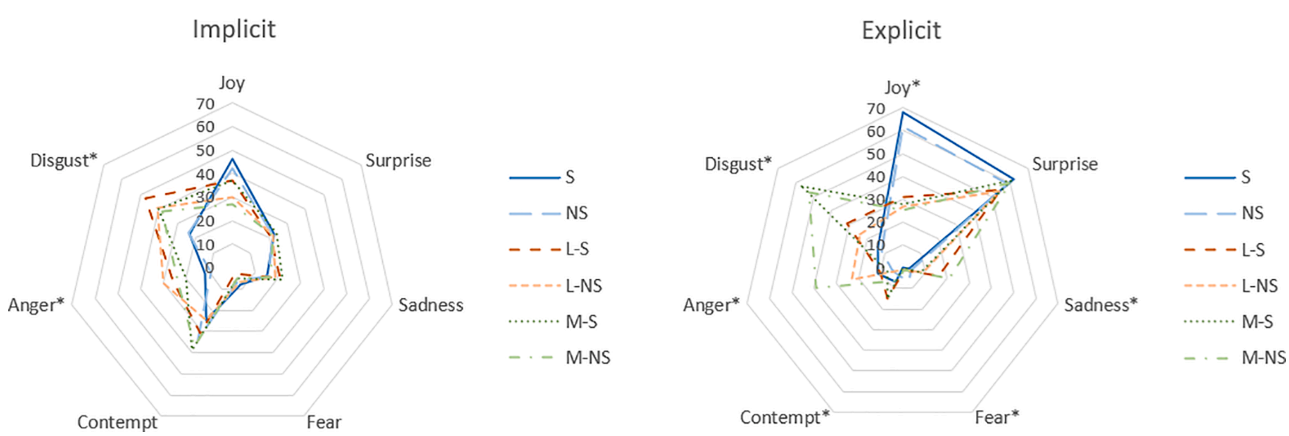

Fig. 3. Implicit and explicit facial decoding predicting basic emotional responses (average likelihoods (%)) to the six tasted samples (**S** = Sugar added, **NS** = No sugar added, **L-S** = Liquorice, sugar added, **L-NS** = Liquorice, no sugar added, **M−S** = Peppermint, sugar added, **M−NS** = Peppermint, no sugar added). * marks basic emotions that discriminated samples significantly via Mixed ANOVA on a 5% significance level.

Fig. 4. Implicit basic emotions as measured by facial decoding for the significant design of experiment factor Surprise flavour. Significance levels from a Tukey test on a 5% level are marked with letters.

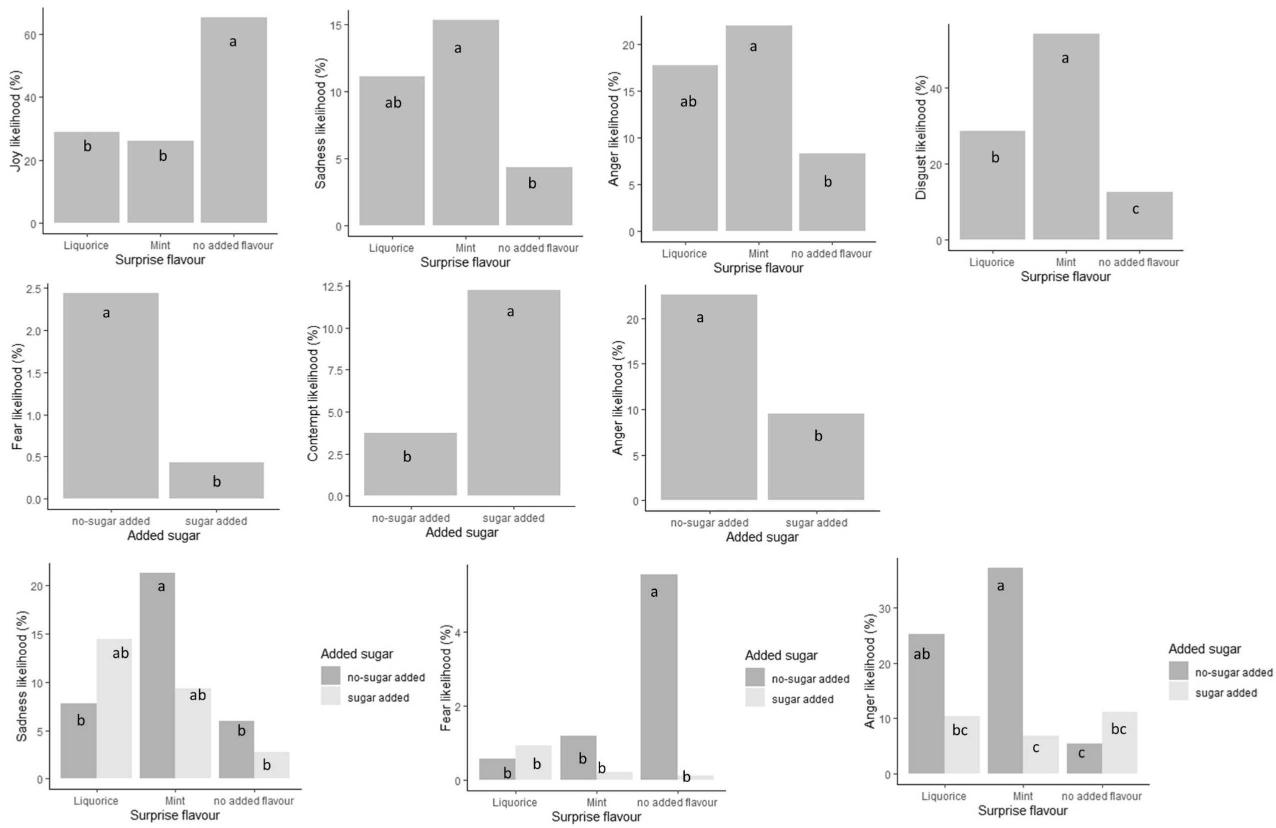

Fig. 5. Explicit basic emotions, as measured by face decoding, for the significant factors of the design of experiment (surprise flavour and added sugar). Values with significant diferences according to a Tukey test on a 5% significane level are marked with letters.

first dimension, explaining 71% of variance. This dimension discriminated samples based on *Surprise flavour* (no added flavour vs. Peppermint or Liquorice flavour). For implicit, as well as explicit facial decoding, the basic emotions anger and disgust were negatively correlated to liking and associated with the added flavours Peppermint and Liquorice. For the explicit emotions by facial decoding, joy was positively correlated to liking and associated with the *no added* flavour samples. Explicit emotions further discriminated samples regarding *Added sugar* in the second dimension explaining 13% of variance. *Added sugar* was associated with the emotion contempt. *Added flavour without added sugar* was associated with anger. No *Surprise flavour* and no *Added sugar* were associated with fear. It has to be noted that due to the standardization of the variables for the MFA, fear seems correlated to liking but its likelihood was low (0–6%) for all samples.

3.5. Segmentation of children according to their basic emotion likelihoods

Individual variations in taste-elicited basic emotion likelihoods were investigated to assess the main differences between participants. The first two components of a PCA on children's unstandardized basic emotion likelihoods summed up over the six samples revealed similar patterns for the implicit and explicit facial decoding (Fig. 7). Emotion likelihoods were correlated in the first component, explaining 26% of variance in the implicit and 65% of variance in the explicit facial decoding. The results suggest that there were children whose predicted basic emotion likelihoods were generally lower (on the left side of PCA plot), previously classified as "poker faces" by Danner et al. (2014). The second component of the PCA separated children who had higher likelihoods of basic emotions with a negative and children that had higher likelihoods of basic emotions with a positive or neutral valence. For the implicit facial decoding the negative basic emotion contempt correlated with the positive and neutral emotion joy and surprise, however.

To check, whether implicit and explicit facial expressions in reaction to the tasted samples were related, children were classified into expressive vs. poker faces (PC1) and positive vs. negative facial expressions (PC2) regarding their implicit and explicit basic emotions (Table 3). However, the dependency between implicit and explicit basic emotion level per child was not significant for expressive vs. poker faces (PC1): X2 $(1, N = 47) = 0.07$, $p = .796$ nor positive vs. negative facial expression (PC2): X2 $(1, N = 47) = 0.00$, $p = 1$. For example, taking child number 29 in the plots (Fig. 7), in the implicit facial decoding it was classified as "poker face" and in the explicit as "expressive" face.

4. Discussion

4.1. Emotions measured by facial decoding vs. liking ratings

Results showed that facial decoding of implicit emotions discriminated disliked samples based on children's increased likelihood of expressing anger and disgust. These results add to previous studies in laboratory settings which measured negative basic emotions for disliked samples, but not positive emotions linked to liked samples (Danner et al., 2014; Kostyra et al., 2016; Pedersen et al., 2021; Zeinstra et al., 2009). The four disliked samples in the study were not further discriminated by implicit facial decoding while liking ratings discriminated the samples further. Thus, in the present case study, liking ratings were also more sensitive regarding the discrimination of disliked samples than implicit emotions.

Facial decoding of explicit emotions showed higher discrimination regarding the design of experiment factors than liking ratings, discriminating samples based on *Surprise flavour,* as well as on *Added sugar*. Explicit emotions discriminated liked and disliked samples. However, opposite patterns regarding *Surprise flavour* of the disliked samples occurred: children's liking ratings were lowest for the *Surprise flavour*

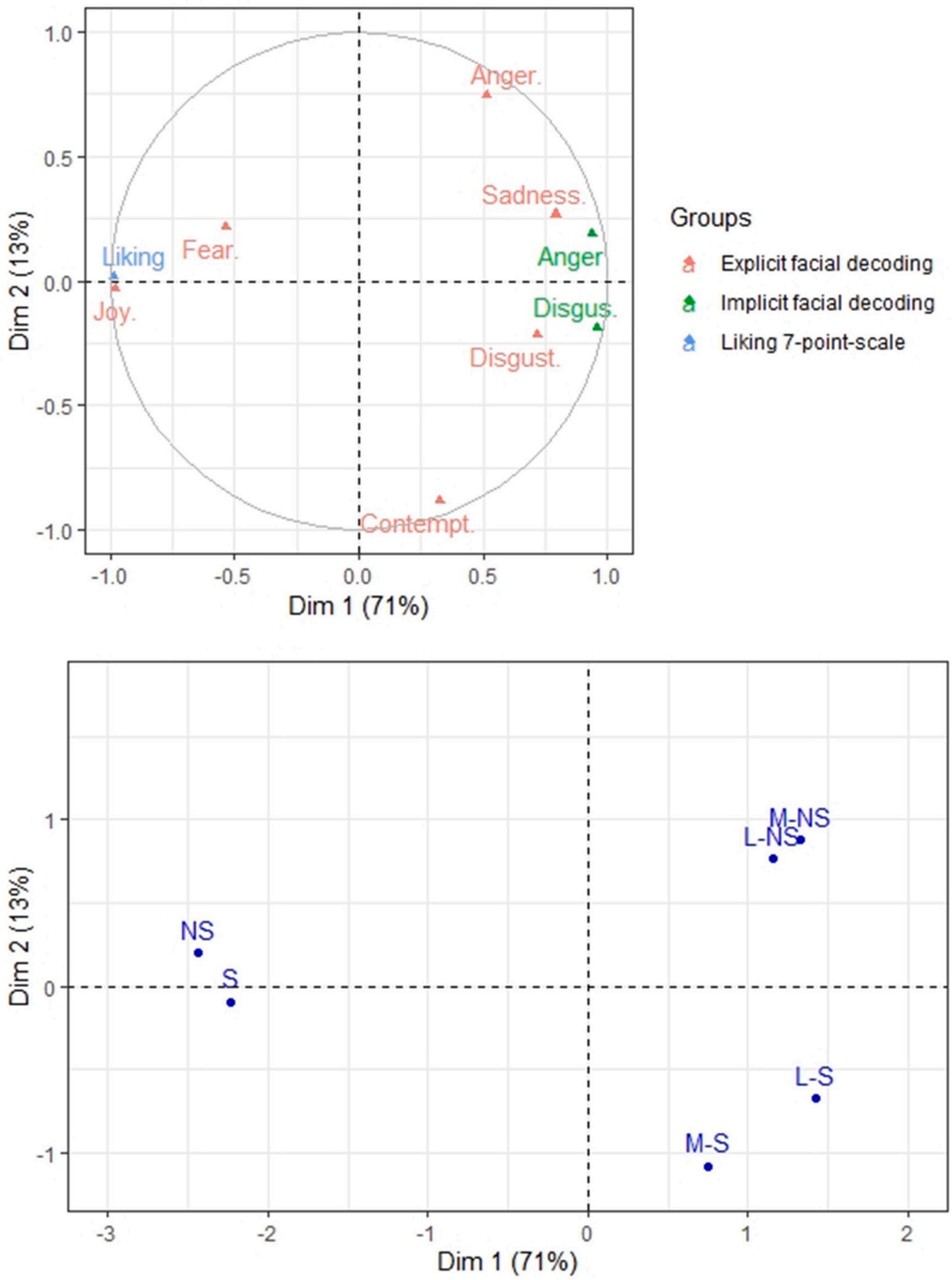

Fig. 6. Multiple factor analysis overlaying implicit and explicit basic emotions that discriminated samples significantly on a 5% significance level as well as liking ratings. All variables were standardized. Top: Variable plot, bottom: product plot.

liquorice, while negative explicit emotion likelihoods (sadness, anger, and disgust) were highest for the *Surprise flavour* peppermint. Potentially, the difference came from arousal aspects of basic emotions beyond valence previously described for verbal emotion catalogues (Gutjar, Dalenberg, et al., 2015) and emoji scales (Sick et al., 2020).

In another study by the authors (Galler et al., 2022), a paired preference task between the same samples of sugar and non-sugar added chocolate milks (without *Surprise flavour*), showed that the sugar added version was significantly preferred. This suggests that in the wider sensory space of the present work, the measured explicit basic emotions may have helped to predict food choice more accurately than liking ratings. Facial decoding of explicit emotions might be particularly well suited for product testing with children. Measurement of explicit expressions may be part of their games, so they could see it as more natural or they may be less shy than adults when presented with these types of exercises.

4.2. Implicit vs. Explicit emotion measurement

In line with the previous study measuring explicit facial reactions by Danner et al. (2014), the measurement of explicit emotions discriminated samples more than implicit measurements. Stockli et al. (2018), who validated the accuracy of facial decoding by the iMotions software used in the present study, found a low accuracy for natural expressions (corresponding to implicit facial expressions) as compared to prototypical ones (corresponding to explicit facial expressions), which might explain the lower discrimination.

We further compared children regarding their basic emotion likelihoods to investigate individual variations in the applicability of facial decoding measurements as pointed out by (Danner et al., 2014). Implicit

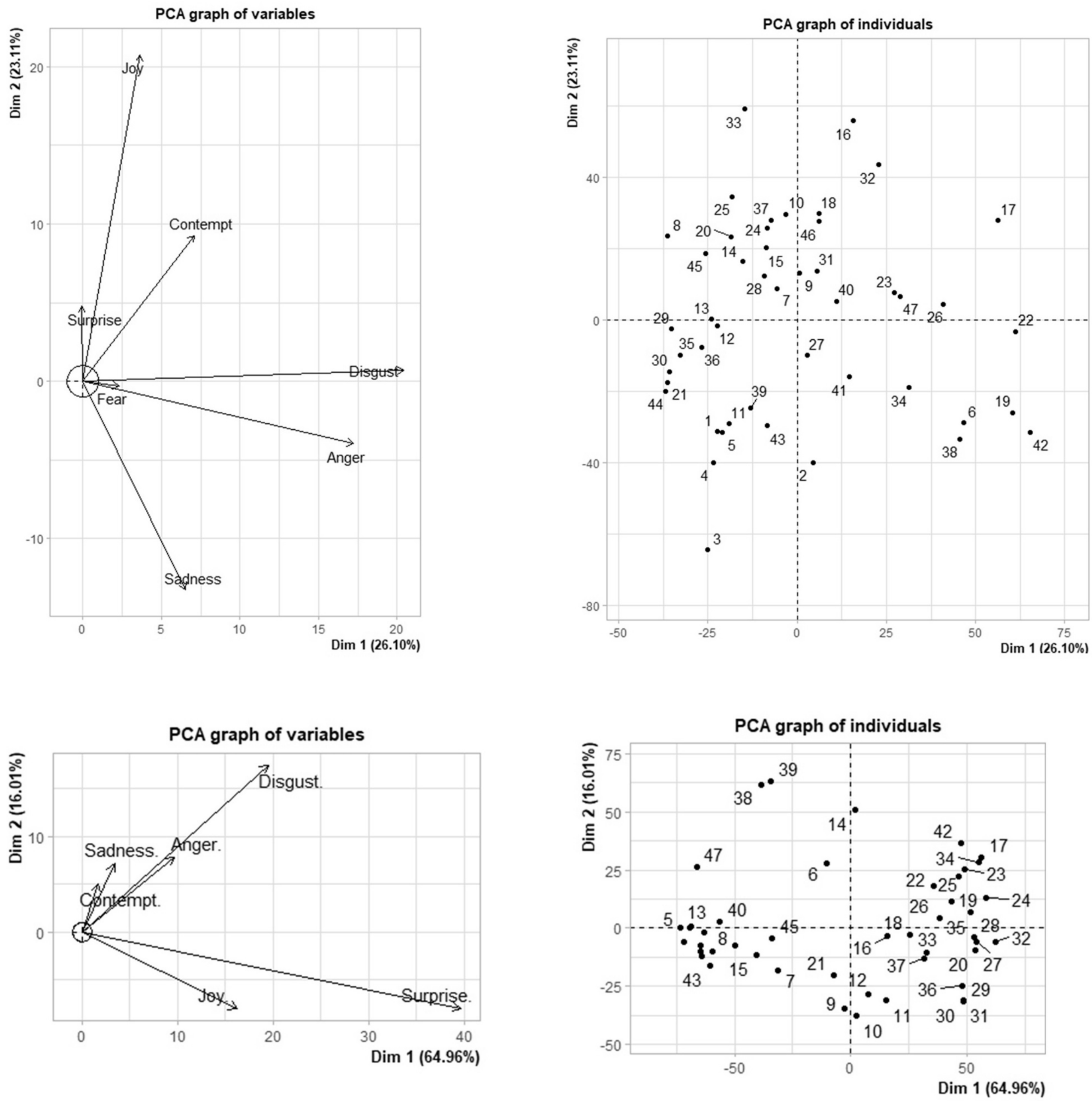

Fig. 7. Principal component analysis of children's likelihood of an emotion summed up over the six samples with emotions as unstandardized variables and children as individuals. Only emotions that discriminated children significantly on a 5% significance level were included. Top: implicit basic emotions, bottom: explicit basic emotions.

Table 3
Number of children' facial expressions classified as poker vs. expressive (PC1) and positive vs. negative facial expression (PC2) in the PCA of implicit and explicit facial expressions.

PC1				**PC2**			
		Implicit				**Implicit**	
		Poker face	Expressive face			Positive	Negative
Explicit	Poker face	13	8	**Explicit**	Positive	14	14
	Expressive face	14	12		Negative	10	9

as well as explicit emotions revealed the same pattern: children varied most regarding facial expression degree (poker vs. expressive faces) as well as regarding their tendency to express more positive or more negative emotions. However, children's implicit and explicit facial expression patterns were not aligned in this regard (i.e., expressive children in the implicit were not necessarily so in the explicit face making). The different patterns of implicit and explicit facial expressions could be related to psychological factors (susceptibility to give socially desirable answers and introspection capability) that can bias explicit measurements (Lagast et al., 2017). On the other hand, de Wijk and Noldus (2021) described implicit emotions to be particularly sensitive to eating context. Thus, implicit measurements were potentially more influenced by the participant's tasting experience in the laboratory setting.

4.3. Methodological considerations and future research

As in previous studies conducted under laboratory conditions, the measurement of implicit basic emotions was only useful to discriminate samples according to negative emotions. The usefulness of implicit basic emotion measurement for product optimization testing of generally liked food is of limited application, as only differences between clearly liked and disliked samples could be measured. Other previous facial decoding studies also tended to include samples with low acceptance levels (Lagast et al., 2017). Implicit facial decoding could, however, be particularly useful to investigate food-elicited disgust which is highly relevant to study food rejection linked to picky/fussy eating or food neophobia (e.g. Lafraire et al., 2016) in children. Further, results indicated that explicit facial decoding could offer advantages over liking ratings in terms of sample discrimination, which opens the door for further studies. Explicit facial expressions might, to a certain extent, be relevant in real -life eating situations, where expressions are used to communicate with others. In this sense, Köster and Mojet (2015) highlighted that situational factors, such as eating alone vs. eating with family are closely linked to emotions and that emotion tests in laboratories might fail to measure emotions of ecologic validity. It is therefore of interest to explore more natural eating situations which may call for different test protocols and evaluation methods.

There is limited facial decoding research where food samples are tasted, particularly with children. It is challenging to measure implicit facial expressions when samples are tasted as the hands that move the samples to the mouth can cover part of the face. Further, in the case of solid food samples, chewing motions could distort facial decoding. In the presented study, challenges were addressed by using liquid samples and displaying a video instruction to enable a standardized one sip tasting. The video instruction aimed to ensure that the cup did not cover the face after the tasting. In line with previous studies (Danner et al., 2014; Kostyra et al., 2016) and recommendations of the software provider iMotions, data was extracted from the time point on when the cup was moved down from the face and all facial landmarks were visible. Through this setup, it is possible that some fast emotional responses were missed. Developments in facial decoding software where emotions can be accurately measured based on a partly covered face could increase the applicability for product testing with food samples in the future.

It remains unclear, what the measured basic emotions mean in an eating context and how accurate the predictions are. For example, A sad face while eating could mean profound pleasure (Barrett, 2020). To shed light on the meaning of predicted basic emotions in the eating context, it is of interest to study how basic emotion classifications relate to self-reported emotions, although such measurements are explicit and require introspection from participants. van Bommel et al. (2020) compared facial decoding by the Noldus software to self-reported emotions in a temporal way concluding diverging patterns. For example, the self-reported emotion happy was correlated to neutral, surprised or bored facial expressions. Further, a recent study measured implicit basic emotions via the AFFDEX algorithm and self-reported emotions via the EsSense Profile®, but did not directly compare the two measurements (Mehta et al., 2021).

Last but not least, the focus on individual differences might be highly relevant for the measurement of emotions (Köster & Mojet, 2015). The preliminary analysis performed in the present study suggested differences in expression level (poker vs. expressive faces) as well as valence (more positive or negative basic emotions). Future studies with larger sample sizes should investigate individual differences in basic emotion likelihoods linking them to sample preferences, food -related attitudes such as food neophobia as well as psychological and physiological traits.

5. Conclusions

The present study suggested a procedure to perform facial decoding with children in tasting experiments and offered preliminary insights into the applicability of such measurements for the understanding of hedonic and emotional reactions to foods. Measurement of implicit and explicit emotions by facial decoding was successful with 9 to 10 -year -old children, enabling a non-verbal sample evaluation. results add to previous literature, suggesting that the measurement of implicit emotions via facial decoding can be useful to study negative food-elicited emotions, e.g. disgust, elicited by disliked samples. Measurement of explicit emotions by facial decoding was suitable to study negative as well as positive emotions. Sample discrimination of explicit facial decoding was in fact higher than liking ratings. Further research is needed to assess facial decoding prediction accuracy for food choice, the meaning of food-elicited basic emotions from facial decoding in the eating context as well as individual differences.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A1

Table A1
Mixed ANOVAs with DoE factors as main and interaction as fixed, child as well as child in interaction with DoE factors as random variables.

		Added sugar	Surprise flavour	Added sugar × Surprise flavour	Child
Explicit rating (1–7-point scale)	Liking	0.372	**<0.001**	0.350	**<0.001**
Implicit facial decoding (maximal likelihood estimation)	Joy	0.261	0.051	0.795	**<0.001**
	Surprise	0.883	0.902	0.843	**<0.001**
	Sadness	0.523	0.424	0.544	**<0.001**
	Fear	0.917	0.503	0.508	**<0.001**
	Contempt	0.870	0.052	0.463	**<0.001**
	Anger	0.755	**<0.001**	0.599	**<0.001**
	Disgust	0.394	**<0.001**	0.877	**<0.001**
Explicit facial decoding (maximal likelihood estimation)	Joy	0.380	**<0.001**	0.982	**<0.001**
	Surprise	0.469	0.077	0.935	**<0.001**
	Sadness	0.264	**0.002**	**0.012**	**<0.001**
	Fear	**0.020**	0.072	**0.017**	0.658
	Contempt	**0.002**	0.328	0.288	**0.046**
	Anger	**<0.001**	**0.004**	**<0.001**	**0.024**
	Disgust	0.281	**<0.001**	0.912	**<0.001**

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