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Does portion size matter? Dynamic changes in hedonic and emotional responses to foods varying in portion size

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ABSTRACT

One way to promote healthier eating behaviors is to reduce food portion sizes and thereby decrease the average daily energy consumed. Positive emotion is a crucial factor in consumers affective responses to food and add to liking ratings in predicting food preferences and choices. Despite this, we know little about the emotional experiences in response to variations in portion size. This study investigated dynamic changes in hedonic and emotional responses to high energy-dense foods varying in portion size. In a within-subjects design, 58 participants (aged 24.1 ± 2.9 years) randomly consumed three different food portions (i.e., small, regular and large) of two food products (i.e., ice cream and pizza) across six experimental sessions. Explicit measures included liking scores and scores on hunger, arousal, overall satisfaction and Temporal Dominance of Emotions (TDE). Implicit measures included facial (emotional) expressions using FaceReader™. Results showed that the small and regular portions scored higher on liking than the large portions, for both the ice cream and pizza. In addition, the small portions had similar emotional (TDE) profiles as the regular portions (*happy, relaxed and peace*), whereas the large portions evoked more negative emotional (TDE) profiles compared to the small and regular portions (*bored, guilty, disgusted*). The implicit measure facial expressions resulted in a less clear picture, except for the dimensions *valence* and *arousal* for ice cream. Participants showed more negative facial expressions and were more aroused during consumption of the regular and large (too much) portion as compared to the small portion during consumption of ice cream. These findings contribute to a better understanding of the role of emotions in the consumption experience of food products varying in portion size and will help to identify the ideal size of a food product for inducing a positive emotional response.

1. Introduction

Many new food products fail on the market despite previous positive sensory evaluations (Dijksterhuis, 2016). It has been shown repeatedly that liking ratings do not predict food choice behavior accurately (Zandstra & El-Deredy, 2011), and that assessment of consumers' emotional associations with foods and food experiences add predictive power to a food choice prediction model as compared to a model based on food liking ratings alone (Dalenberg et al., 2014; Gutjar et al., 2015). A broader perspective on how people experience a food product is therefore needed that goes beyond sensory liking and considers consumers' behavior in all its facets (Dijksterhuis, 2016) including emotional associations that consumers experience and attach to foods (Gutjar et al., 2015). Such a perspective is relevant from a product development or marketing point of view, but also helps to better explain consumers' preferences and choice behavior, so as to provide new leverage points to change preferred choices towards healthier choices. The Component Process Model (CPM) by Scherer (Scherer, 2005, 2009) defines emotions as dynamic events, with an onset (event, stimulus) followed by a complex process of continuous changes centrally, in the brain, and peripherally in the co-occurring physiological and behavioral expressions, e.g. heart rate, blood pressure, gestures, and facial and vocal expressions, and eventually the subjective, conscious experience, the feeling one becomes aware of (Jager, 2016; Scherer, 2005, 2009). A limitation of commonly used self-report measures is that they only reveal the subjective feeling one becomes aware of, whereas elements of

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the complex emotion process in other subsystems remain hidden (Köster, 2003; Köster & Mojet, 2015; Scherer, 2005, 2009; van Bommel et al., 2020). Kaneko and colleagues (2018) present an overview of measures used in current research on evaluating emotions evoked by food experiences, and categorize these methods along measurement level (physiological, behavioral and cognitive) and emotional processing level (unconscious sensory, perceptual/early cognitive, and conscious/decision making level). The authors conclude that currently most measures used in consumers' emotion research are based on self-reported subjective ratings and questionnaires, and recommend to use a toolbox of measures from different categories, preferably covering all three emotional processing levels (Kaneko et al., 2018). One of the main challenges here is to estimate continuously experienced emotions during a dynamic real-life consumption experience and tasting.

Little is known about emotional responses during consumer-product interactions throughout food consumption in realistic eating contexts (Edwards et al., 2003; Meiselman, 2006). It is common practice in sensory research to provide subjects with small samples, often single bites or sips, for evaluation. However, under naturalistic eating conditions, consumers typically consume a full portion or serving unit of a food or beverage, and valid measures of hedonic and emotional responses to real foods in full portions in realistic eating contexts are lacking (Cardello et al., 2012; Edwards et al., 2003; King et al., 2010; Meiselman, 2006; Nestrud et al., 2016). The use of real stimuli (real foods) in realistic eating contexts will significantly increase our knowledge about emotions in response to food experiences.

There is clear evidence that offering large food portions over longer periods of time results in an increased food intake, while the evidence is less convincing that this necessarily leads to weight gain (Hetherington & Blundell-Birtill, 2018). Previous research has shown that people consume more food when offered larger food portions and that they tend to prefer larger food portions over smaller portions (Brunstrom, 2014; Diliberti et al., 2004; Hetherington et al., 2018). The increased availability and popularity of large food portions in competitive food markets, suggests that consumers are looking of 'value for money', that is, they want filling products at affordable prices (Marteau et al., 2015). There is evidence that adults tend to expect larger portions of palatable foods to increase eating enjoyment (Sørensen et al., 2003). However, these expectations do not always match actual experienced eating enjoyment (Rode et al., 2007). This discrepancy between expected and experienced eating enjoyment was also observed in a series of experiments on multisensory imagery, where people were asked to imagine vividly the taste, smell and texture of particular hedonic foods before choosing a portion size of another hedonic food. Compared to a control condition, this intervention led people to choose smaller food portions, while anticipating greater eating enjoyment and a willingness to pay more for them. The researchers stated this occurred because multisensory imagery prompted participants to evaluate portions on the basis of expected sensory pleasure, with peaks with smaller portions, rather than hunger (Cornil & Chandon, 2016a). Finally, previous research found that the peaks of sensory pleasure at first tastes will decline along consumption due to the "sensory-specific satiety" phenomenon, which might suggest that small food portions can still be enjoyable and rewarding as the large ones, or even more (Hetherington et al., 1989; Rolls et al., 1981).

Two recent studies investigated how consumers, both children and adults, anticipate the effects of portion size reductions on hunger change and eating enjoyment (Haynes et al., 2020; Schwartz et al., 2020). Schwartz and colleagues (2020) found that children anticipate the effects of smaller versus larger portion sizes on residual hunger accurately, but overestimate the effects of portion size on eating enjoyment, in the sense that larger portions increased anticipated but not experienced eating enjoyment. In adults, a reduction in served portion size resulted in a small but significant intake of other foods within the same meal, but only if the reduced portion size was no longer visually perceived as 'normal' (Haynes et al., 2020). However, none of these studies looked at emotions in response to portion sizes, and how emotional responses related to food experiences and measured in a dynamic manner, i.e. throughout consumption, may help to define by how much large food portion sizes can be reduced and still be accepted by consumers.

The present study aimed to: 1) evaluate food-evoked emotions measured at two complementary levels, cognitive and behavioral, using two methods to measure food-evoked emotions in a dynamic manner; Temporal Dominance of Emotions (TDE; (Jager et al., 2014) and facial expressions (De Wijk et al., 2012; De Wijk & Noldus, 2021; van Bommel et al., 2020), and 2) examine the effect of portion size by comparing small versus regular to large portions, on hedonic responses to indulgent foods, i.e. ice cream and pizza. For this purpose, a group of participants was invited for a mid-afternoon snack session, where they consumed these three different food portions (small, regular and large) of the two food products, while they performed a TDE task and where simultaneously video-recorded to monitor facial expressions during consumption. In addition, state of hunger, arousal, liking and overall satisfaction were assessed before and after consumption

In line with the observation that food portion size and pleasure are not always correlated (Cornil & Chandon, 2016a), we expected to find more positive emotional responses during consumption of regular food portions compared to either small or large food portions. It was also expected that liking and overall satisfaction would be highest for regular portions as compared to small and large portions. With regard to feelings of hunger, we hypothesized that the decrease in hunger would be largest for the large portions, followed by the regular portions, and smallest for the small portions.

2. Materials and methods

The study used a within-subjects design, in which participants randomly consumed three different food portions (small, regular and large) of two food products (chocolate-coated vanilla ice cream and pizza) across six experimental sessions. Products were served as a mid-afternoon snack, with test sessions taking place between 2 and 5 pm. Arousal and subjective feelings of hunger were measured before and after eating each product. During consumption, we measured dynamic changes in emotional responses in implicit (FaceReader^{TM} 8.0) and explicit (TDE) ways during consumption of the first and last section of the products (see section 2.2.2 on Product section for rationale). Liking and satisfaction were measured explicitly at the end of consumption of each product. Fig. 1 shows a timeline of the session procedure.

2.1. Participants

In total, 58 healthy and normal weight (self-reported) participants were recruited from a student population at Wageningen University and Research (aged 24.1 (±SD 2.9) years; 43 women and 15 men; with a mean BMI of 21.5 (±SD 1.9) kg/m^2). Exclusion criteria were: following an energy-restricted diet or change in body weight $>$ 5 kg during the last year, lack of appetite, diabetes, an eating disorder (self-reported), being lactose intolerant or hypersensitive to food products used in the experiment and a high and above score on the restrained eating subscale of the Dutch Eating Behavior Questionnaire (score: men $>$ 2.90; women $>$ 3.32). All participants liked chocolate-coated vanilla ice cream and pizza (scoring $\geq$ 4 on a 7-point hedonic scale) and had a normal ability to taste and smell (self-reported). Participants received a monetary incentive for their participation and gave written informed consent before the start of the study. The experimental protocol was submitted to and exempted from ethical approval by the medical ethics committee of Wageningen University (METC-WU).

2.2. Products

Two commercially available food products were used in this study: chocolate-coated vanilla ice cream (brand: Magnum®) and margherita

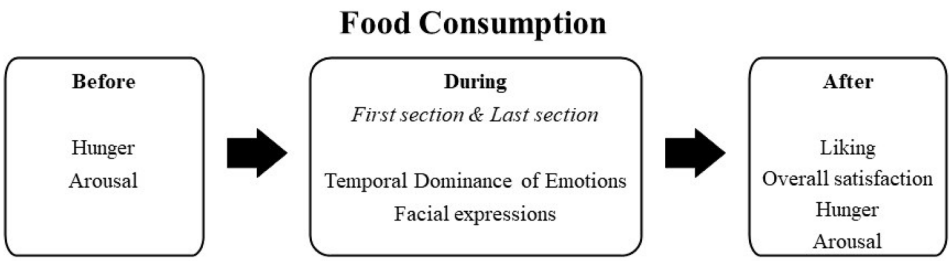

Fig. 1. Timeline of session procedure.

pizza (brand: Dr. Oetker Ristorante®). We used margherita pizza so that vegetarians could also participate in the study. Both products (ice cream and pizza) were purchased from local supermarkets in Wageningen, The Netherlands, and stored in the freezer at −18 °C. Pizzas were cut in eight slices and baked on each test day prior to the testing session using the instructions on the packaging. During test sessions, we kept pizza warm au Bain-Marie at 65 °C until serving. Pizza and ice cream were served at recommended consumption temperature: ice cream at a temperature ranging between −10° and −12 °C and pizza at 65 °C approximately.

2.2.1. Portion sizes

Portion sizes were defined based on the results of an online survey on the maximum amount of ice cream or pizza that one would eat as a mid-afternoon snack, while feeling comfortably full (n = 40 participants), and based on a pilot test with eight participants who actually ate ice cream and pizza in three portions sizes (data not presented). Portion sizes were labelled as small, regular and large. For ice cream, commercially available pre-packaged serving sizes were used: the small portion was a Magnum® Mini Classic ice cream of 44 g; the regular portion was a Magnum® Classic ice cream of 79 g; and the large portion was a combination of a Magnum® Mini Classic and a Magnum® Classic with a combined portion size of 123 g. For pizza, a Dr. Oetker Ristorante® pizza margherita was cut into eight slices of approx. 37 g each. The small portion contained two slices (approx. 74 g); the regular portion contained three slices (approx. 111 g); and the large portion contained eight slices (approx. 296 g). See Fig. 2 for the three portion sizes used per product, and Table 1 for nutritional information.

Table 1
Nutritional information.

Ice cream			
Portion	Small	Regular	Large
Size *(grams)*	44	79	123
Energy *(kcal)*	144	239	383
Fat *(grams)*	9	14	23
Saturated fat *(grams)*	6.1	10	16.1
Carbohydrates *(grams)*	14	24	38
Sugars *(grams)*	12	20	32
Protein *(grams)*	1.5	2.6	4.1
Salt *(grams)*	0.05	0.1	0.15
Pizza			
Portion	Small	Regular	Large
Size *(grams)*	74	111	296
Energy *(kcal)*	191	286	764
Fat *(grams)*	8.9	13.3	35.5
Saturated fat *(grams)*	3.3	5.0	13.3
Carbohydrates *(grams)*	20	30	80
Sugars *(grams)*	2.3	3.5	9.2
Protein *(grams)*	7.4	11.1	29.6
Salt *(grams)*	0.74	1.1	3.0

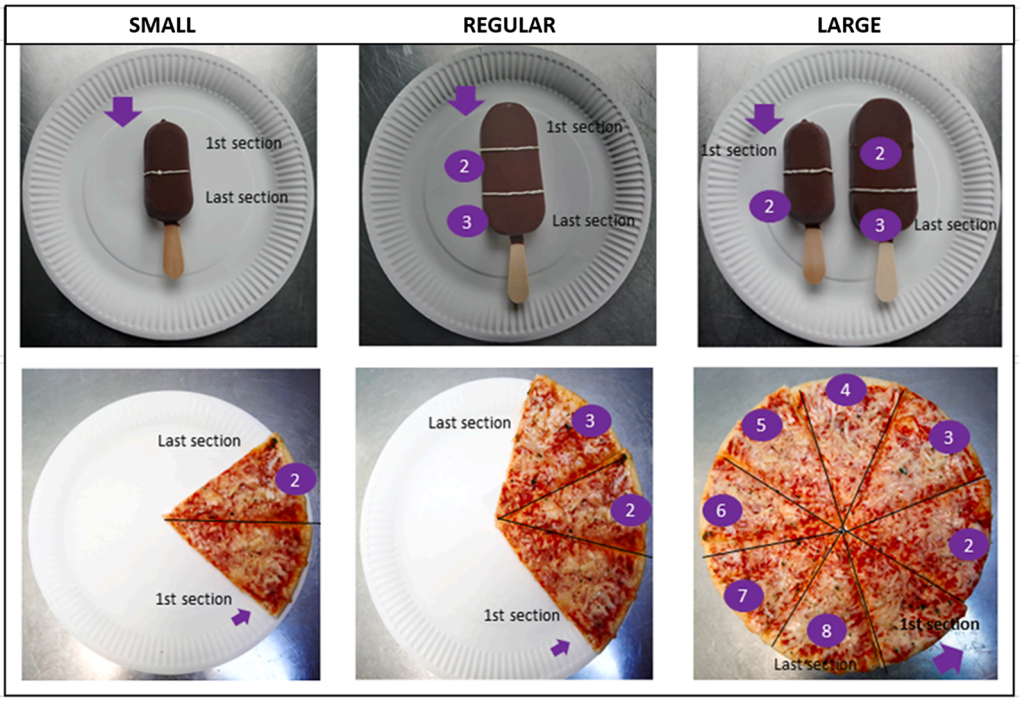

Fig. 2. Portion sizes of pizza and ice cream, including instructions for eating the samples.

2.2.2. Product section

Both products were divided into a first section and last section of consumption. For ice cream, two lines of white chocolate were drawn on the surface of each product to indicate these sections (first and last; see Fig. 2). For pizza, we cut each portion into slices of 37 ± 1 g and we displayed on the screen the direction of eating (counterclockwise) as well as the first and last section of the sample (Fig. 2). The reason for focusing on a first and last section of consumption was three-fold: 1) performing the TDE task during consumption of larger portions can become tedious, and participants may lose focus; 2), it was expected that the first and last parts of consumption would be the parts where dynamics within the emotional processing are most explicit; and 3) recording facial expressions over prolonged consumption durations, results in large datafiles. When appending all FaceReader™ output for all participants, all products and portion sizes into one large file, which is required for specific statistical models, the maximum number of rows allowed in datasheets for Microsoft Excel, SPSS and RStudio would be exceeded.

2.3. Attribute selection

To select representative emotions, a list of 29 food related emotions was preselected based on the 25 food related emotion terms from the EsSense25® (Cardello et al., 2012; King & Meiselman, 2010; Nestrud et al., 2016) and four additional emotions recognized by FaceReader™ 8.0. This list was presented to 20 regular consumers of ice cream and pizza (not participating in the main experiment), who were asked to taste the products and perform a Check-All-That-Apply (CATA) test (data not presented). The 10 most frequently cited emotion terms that also matched with the emotions recognized by the FaceReader™ 8.0 Software were included in the present study. Table 2 shows the emotion attributes (*angry, bored, disgusted, guilty, happy, peace, relaxed, sad, surprised, worried*) with descriptions as provided to the participants during TDE instructions.

2.4. Procedure

Each participant completed six test sessions of about 15 to 20 min each. Test sessions were scheduled on separate days at a fixed time between 2 and 5 pm with at least 48 h in between. One day before the start of the study participants received the attribute list with definitions by e-mail to familiarize themselves with the terminology (see Table 2). Before the start of the first session, participants were instructed on the study procedures. The order of presentation for portion size and product was randomly determined across the test sessions. The products were served on white paper plates and no cutlery was used. Participants were asked to drink only water and refrain from eating for at least 2 h prior to each test session. Upon arrival to the facility, we welcomed participants and took them to the sensory booths. In the sensory booths, participants followed instructions on the screen (described below). Before consumption of the portions, participants rated arousal and subjective feelings of hunger. Then, participants received the foods and were asked to consume the whole portion. Participants performed TDE during consumption of the first and last product section. During the middle section subjects ate the product without performing TDE. Video recording of facial expressions was time-locked to the TDE task, meaning that when participants clicked the start button for TDE, video recording started automatically and lasted until perception ended and participants had to click the stop button. Finally, directly after consumption of the whole portion, participants rated arousal and feelings of hunger again, and rated liking and overall satisfaction.

Table 2
Emotion attributes and descriptions with examples.

Emotion	Description	Example
Angry	Strong feeling when something unfair or bad happens.	If someone intentionally crashes my phone I might feel angry.
Bored	Finding something uninteresting or when you have nothing to do.	Doing the same thing every day makes me feel bored.
Disgusted	A strong aversion to something or someone	Smelling an unpleasant odor makes me feel disgusted.
Guilty	The feeling you have when you do something wrong.	Forgetting my mother's birthday makes me feel guilty.
Happy	Feeling full of enjoyment and pleasure.	Achieving my goals makes me feel happy.
Peace	Freedom from disturbance; tranquility.	Doing breathing exercises makes me feel at peace.
Relaxed	Feeling comfortable because nothing is worrying you.	When I talk to my friends, I feel relaxed.
Sad	Feeling unhappy because something not satisfactory or unpleasant happened.	Failing in my final exam makes me feel sad.
Surprised	The feeling you have when something that you did not expect has happened.	When I see someone that I do not expect I feel surprised.
Worried	The feeling you have when thinking about problems or other unpleasant things that are happening or may happen.	When I am late in class, I feel worried.

2.5. Measures

2.5.1. Arousal, feelings of hunger, liking and overall satisfaction

Participants rated levels of arousal by use of the 9-point Self-Assessment Manikin (SAM) (Bradley & Lang, 1994). This scale has end anchors "excited" and "calm" and involves the question: "How are you feeling right now from excited to calm?". Subjective feelings of hunger were assessed with a 100-mm visual analogue scale anchored from "Not hungry at all" to "Extremely hungry". Liking and overall satisfaction was assessed with a 100-mm visual analogue scale anchored from "Not liked at all" to "Extremely liked", and "Not satisfied at all" to "Extremely Satisfied", respectively.

2.5.1.1. Temporal dominance of emotions (TDE). This study assessed Temporal Dominance of Emotions (TDE) using TimeSens® software (version 1.1.601.0, ChemoSens, Dijon, France). Ten emotion attributes were presented on the screen; the order of the attributes was randomized across participants, but kept constant for each participant across TDE for all six samples. When participants put the first bite into their mouth, they clicked on the "start" ($t = 0$) button on their screens, which activated the video and time recording for consumption of the first section of the product. Participants were asked to select the emotion that they perceived as dominant, i.e. the attribute that catches most of their attention (Jager et al., 2014). The recording of dominance of that attribute started from then and remained selected until a new dominant attribute was selected. Participants could select as many attributes as they wanted, including the same emotion several times, or never select a certain emotion if they found it irrelevant. When the first section mark on the product was reached (first line on ice cream or first cut line on pizza (see Fig. 2), participants clicked on "stop" (this action stopped video and time recording) and continued eating the product freely until they reached the last line (ice cream) or the last cut line (pizza). At this moment, participants had to click the "start" button again to activate video and time recording for the last section of the product, and again selected the dominant emotions in the same way as during consumption of the first section. After finishing eating and when perception of any emotion as dominant ended, participants had to click the "stop" button , allowing time recording and video recording to stop (Pineau et al., 2009).

2.5.1.2. Facial expressions. Participants were video recorded using a Logitech C270 webcam mounted on top of the computer screen. Per session two video files per participant were generated, one for

consumption of the first section, and another for the last section of each sample. FaceReader™ 8.0 (Noldus Information Technology, Wageningen, The Netherlands) was used to automatically classify facial expressions from the video recordings at a time frame of 0.2 s (5 Hz). Upon facial recognition, an artificial 3D face model is obtained based on the Active Appearance Method (AAM) (Cootes et al., 2001) using 500 key points in the face. For each data frame, facial expressions are classified based on a database of 10.000 facial expression images that were manually classified by trained experts. Detailed information on how facial expressions are identified with FaceReader™ is described in the FaceReader™ Methodology Note by Loijens and Krips (https://info.noldus.com/free-white-paper-on-FaceReader-methodology) (Loijens & Krips, 2019). FaceReader™ 8.0 detects 6 basic emotions (*angry, disgusted, happy, sad, scared,* and *surprised*), a neutral state, and it can analyse *contempt*. Depending on the facial expression, the intensity of the emotions is scored between 0 and 1 (from absence to fully present). Furthermore, FaceReader™ calculates *valence* (i.e. positive or negative emotion state) scored between −1 for negative emotions and 1 for positive emotions; and *arousal* (i.e. level of activation) scored between 0 (not active) and 1 (active) (van Bommel et al., 2020).

2.6. Data analysis

Statistical analyses were performed with SPSS (version 25, IBM Corp, New York, United States) and RStudio (R version 4.0.2, RStudio Team (2015), Boston, United States). A statistical significance level of $p < 0.05$ was selected for all data analyses.

2.6.1. Arousal, feelings of hunger, liking and overall satisfaction

Scores for arousal were reversed first, so that the scores went from 1 = calm to 9 = excited. Mean scores and standard deviations (SD) were calculated for arousal and feelings of hunger before and after consumption, and for liking and overall satisfaction after consumption, for each portion size per product.

For arousal and subjective feelings of hunger, linear mixed models were used to test for significant differences and interactions between product, portion size and time, with product (pizza or ice cream), portion size (small, regular and large) and time (before and after consumption) as fixed effects, and participants as random effects. Pairwise comparisons were performed upon significance of the ANOVA of the mixed model. For, liking and overall satisfaction, similar linear mixed models were used, with the exception that fixed factor "time" was not included in the model as liking and overall satisfaction were measured only once after consumption.

2.6.2. Temporal dominance of emotions (TDE)

TDE data was analyzed using TimeSens® Software (version 1.1.601.0, ChemoSens, Dijon, France). Band-plots, representing the sequence and duration of significant dominant attributes as time-bands, without taking into account dominance rates at a given time point (Galmarini, Visalli, & Schlich, 2017), were computed per product, portion sizes and sections of consumption. The band-plots were visually inspected to identify differences and similarities in the dominance sequences between products, portion sizes, and section of consumption. Mean values (±*SD*) for dominance duration of the emotions were calculated for each product, portion size and section of consumption. Mixed model ANOVA was performed to test for significant differences in dominance durations per product, portion size and section of consumption. A canonical variance analysis (CVA) was conducted to provide a visual representation of the differences in the "duration of dominance of emotions" between the first and last section of each portion size for ice cream and pizza. This analysis minimizes residual variability and maximizes the distances between samples (Delarue & Sieffermann, 2004).

2.6.3. Facial expressions

Facial expression data was automatically analyzed with FaceReader™ 8.0 at a frequency of 5 Hz (i.e. 5 data frames per second) using the "Active Appearance Modelling (AAM)" (Cootes et al., 2001). First, for each section (first and last section of consumption), we calculated for each facial expression, mean intensity and standard deviations. According to the skewedness and kurtosis of the distribution of each emotion, the following transformations were used to normalize the distribution: logarithmic transformation for *angry*, *surprised*, and *scared*; x'=log10(x + 1) for *sad*, cube root for *disgusted*, reciprocal transform for *arousal*, and $x' = \left(\frac{1}{2}\right)\log\left(\frac{1+x}{1-x}\right)$ for *valence*. After transformation, normality of the data was checked by visual inspection of histograms of each variable and performing a Kolmogorov-Smirnov and Shapiro-Wilk test (data not presented). A linear mixed model analysis was conducted with portion size and section as fixed factors, and participants as random factor to test for main and interaction effects on the intensity of five basic emotions (*angry, disgusted, sad, scared* and *surprised*), and on *valence* and *arousal*. The basic emotion *happy*, as well as *contempt* were excluded from this analysis due to the low intensity scores (all close to zero), resulting in minimal variation. This approach was adopted from authors (Rocha et al., 2019), who also excluded some variables from the analysis based on "low emotional stimulus intensity" and a lack of variation over time, so no change can be detected. Upon significance of the linear mixed model ANOVA, pairwise comparisons with Bonferroni correction were performed to identify the significant pairs of the levels of this model.

3. Results

3.1. Arousal, feelings of hunger, liking and overall satisfaction

Table 3 shows the mean scores (±*SD*) for arousal, feelings of hunger, liking and overall satisfaction. Table 4 shows a summary of the outcomes of the linear mixed model analysis. For arousal, a significant main effect

Table 3
Mean scores (±SD) for arousal, feelings of hunger, liking and overall satisfaction.

	Before consumption			After consumption		
Ice cream	*Small*	*Regular*	*Large*	*Small*	*Regular*	*Large*
Arousal						
9-point scale	3.9	3.8	3.9	3.3	3.2	3.2
(1 – 9)	(2.0)	*(1.5)*	*(1.8)*	*(1.3)*	*(1.3)*	*(1.5)*
Feelings of hunger						
100-mm scale	59.9	51.2	56.7	45.1	30.1	18.9
(1 – 100)	*(18.5)*	*(19.9)*	*(18.3)*	*(17.0)*	*(19.4)*	*(17.9)*
Liking						
100-mm scale				75.5	74.2	67.4
(1 – 100)				*(14.3)*	*(17.7)*	*(21.4)*
Overall satisfaction						
100-mm scale				62.6	67.9	63.3
(1 – 100)				*(18.7)*	*(18.4)*	*(23.3)*
Pizza	*Small*	*Regular*	*Large*	*Small*	*Regular*	*Large*
Arousal						
9-point scale	4.2	4.0	4.0	3.3	3.2	3.7
(1 – 9)	*(1.8)*	*(1.7)*	*(1.7)*	*(1.6)*	*(1.6)*	*(1.8)*
Feelings of hunger						
100-mm scale	58.7	60.6	60.5	43.2	34.3	14.4
(1 – 100)	*(19.9)*	*(19.5)*	*(19.4)*	*(21.7)*	*(200)*	*(16.6)*
Liking						
100-mm scale				68.7	64.4	53.4
(1 – 100)				*(18.0)*	*(18.9)*	*(21.9)*
Overall satisfaction						
100-mm scale				55.7	62.6	62.9
(1 – 100)				*(20.5)*	*(18.6)*	*(22.5)*

Table 4
Summary of fixed effects from Linear Mixed Model analysis.

	Product			Time			Portion size			Portion size * Time			Portion size * Product		
	F	*Sign*	*Pairs*	*F*	*Sign*	*Pairs*	*F*	*Sign*	*Pairs*	*F*	*Sign*	*Pairs*	*F*	*Sign*	*Pairs*
Arousal	2.55	ns		47.36	***	B > A	0.49	ns		0.49	ns		0.25	ns	
Feelings of hunger	1.61	ns		431.85	***	B > A	39.37	***	S > L	37.15	***	$S_B > L_A$	4.04	*	$S_{ice\ cream} > L_{pizza}$
Liking after consumption	76.18	***	ice cream > pizza	na			35.97	***	S > L for ice cream and pizza	na			3.62	*	$S_{ice\ cream} > L_{pizza}$
Satisfaction after consumption	10.34	**	ice cream > pizza	na			8.31	***	S < L < R for ice creamS < R = L for pizza	na			2.26	ns	

ns: not significant.
na: not applicable.
* $0.01 < p < 0.05$.
** $0.001 < p < 0.01$.
*** $p < 0.001$.
B: before consumption; A: after consumption.
S: small; R: regular; L: large.

was found of time ($p < 0.001$), with arousal being higher before consumption than after consumption. Main effects of product, portion size, and interaction effects were not significant.

For feelings of hunger, a significant main effect was found of time ($p < 0.001$), with hunger scores being higher before consumption than after consumption, portion size ($p < 0.001$), and a significant interaction effect of time*portion size ($p = 0.02$), with participants feeling less hungry after eating the large portion size, compared to the regular and small portion size ($p < 0.001$) for both ice cream and pizza.

For liking scores after consumption, a significant main effect was found of product ($p < 0.001$), where ice cream was liked better than pizza, and of portion size ($p < 0.001$), with small portions being liked better than large portions for both products. Furthermore, a significant interaction effect was observed for product*portion size ($p = 0.03$). For ice cream, the small portion was liked better than the regular and the large portion with no difference in liking between the regular and the large portion. For pizza, the small and regular portion was better liked than the large portion. Taken together, on average for both products, the large portion was liked the least.

Regarding overall satisfaction after consumption, a significant main effect was found of product ($p < 0.01$), where ratings were higher for ice cream compared to pizza, and of portion size ($p < 0.001$). Pairwise comparisons showed that after consumption of ice cream, participants were most satisfied with the regular portion: satisfaction scores were significantly higher for the regular portion as compared to the small portion ($p = 0.02$), whereas the difference in overall satisfaction was marginally significant when comparing the regular to the large portion ($p = 0.07$). After consumption of pizza, participants were equally satisfied with the regular and the large portion, but less satisfied with the small portion as compared to the regular ($p = 0.004$) and the large portion ($p = 0.002$), respectively.

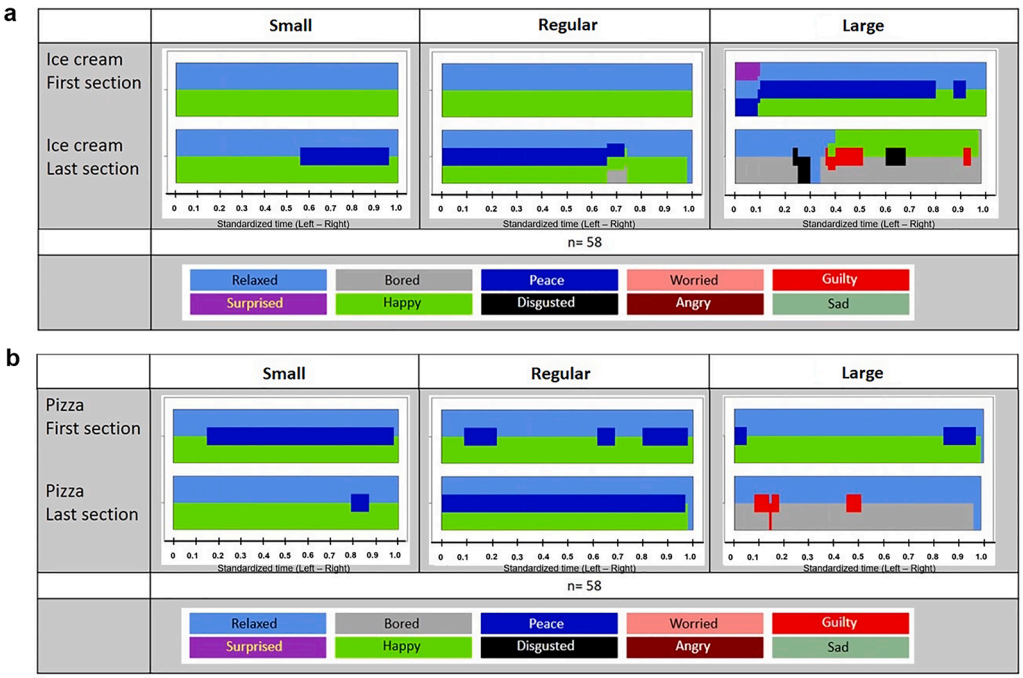

Fig. 3. a + 3b: TDE band-plots of the sequence of dominant emotions for ice cream (3a) and pizza (3b) for the small, regular and large portion sizes. Colored rectangles represent the dominant emotions and are stacked at each moment, displaying multiple dominances (without taking into account dominance rates) at a given time point. Represented emotions are significant at $p < 0.05$.

3.2. Temporal dominance of emotions

3.2.1. Ice cream

Fig. 3a depicts the dominance band-plots for emotions for the first section (upper row) and last section (bottom row) for all three portion sizes. First and last section represent start of consumption of the ice cream up till one third is finished, and consumption of the last third of the ice cream (see Fig. 2), irrespective of the portion size that was offered. On visual inspection of the band-plots, it becomes clear that the dynamics of the emotion responses over consumption differs for the large portion, as compared to the small and the regular portion which are similar. The first sections of consumption for the small and regular portion are characterized by a dominance of *relaxed* and *happy* feelings with hardly any dynamics of change. This is similar for the last sections, however, here *peace* also becomes dominant for the final half of consumption for the small portion, whereas *peace* dominates the first half of consumption of the regular portion, next to *relaxed* and *happy*. For the large portion, the dominance profile of the first section, resembles the dominance profile of the last section of the regular portion, being characterized by *relaxed, happy* and *peace*. The last section of consumption of the large portion is still characterized by *relaxed* and *happy*, but *peace* has disappeared, and less positive feelings become dominant, especially *bored*, but also short time periods show up where *disgusted* and *guilty* are dominant.

3.2.2. Pizza

Fig. 3b displays the dominance band-plots for emotions for pizza for the first section (upper row) and last section (bottom row) for all three portion sizes. Visual inspection of the band-plots shows that similar to ice cream, for pizza the dynamics of emotion responses during consumption of the large portion differs from that of the small and regular portion, predominantly during the last section. During consumption of the first sections the dominance profile is characterized by *happy, relaxed* and *peace* for all three portion sizes. For *happy* and *relaxed*, no dynamics can be observed, whether *peace* is somewhat more dynamic. During consumption of the last sections *happy* and *relaxed* were the dominant emotions for the small portion, with *peace* added for the regular portion. However, during consumption of the last section of the large portion *happy* has disappeared, and less positive feelings become dominant, especially *bored*, but also short time periods show up where *guilty* is dominant.

3.3. Product discrimination

Fig. 4a and 4b show the CVA plots for ice cream and pizza respectively. The CVA plots indicate product differentiation based on the dominance duration of emotions, accounting for 89.81% and 88.55% of explained variance for ice cream and pizza, respectively. The amount of product discrimination explained by the first two canonical variates was 70.99% for ice cream and 76.03% for pizza.

Dimension 1 (horizontal axis) distinguishes between products on portion size (*see* Fig. 3a for ice cream and 3b for pizza). The second dimension (vertical axis) seems to distinguish emotions from positive (*happy*) to negative, with *surprised* being different. Hence, the pattern is not clear. For both products, the means of the final consumption section of the large portion size significantly differed from all other sections and portion sizes. In both cases, ice cream and pizza, the last sections of their large portion sizes were described as *bored, disgusted* and *guilty* (see Fig. 4a and 4b).

3.4. Facial expressions

3.4.1. Ice cream

Table 5 shows the mean intensities (*±SD*) in facial expressions for five basic emotions *(angry, disgusted, sad, scared, surprised)*, and *valence* and *arousal*, per portion size and per section. Table 6 summarizes the

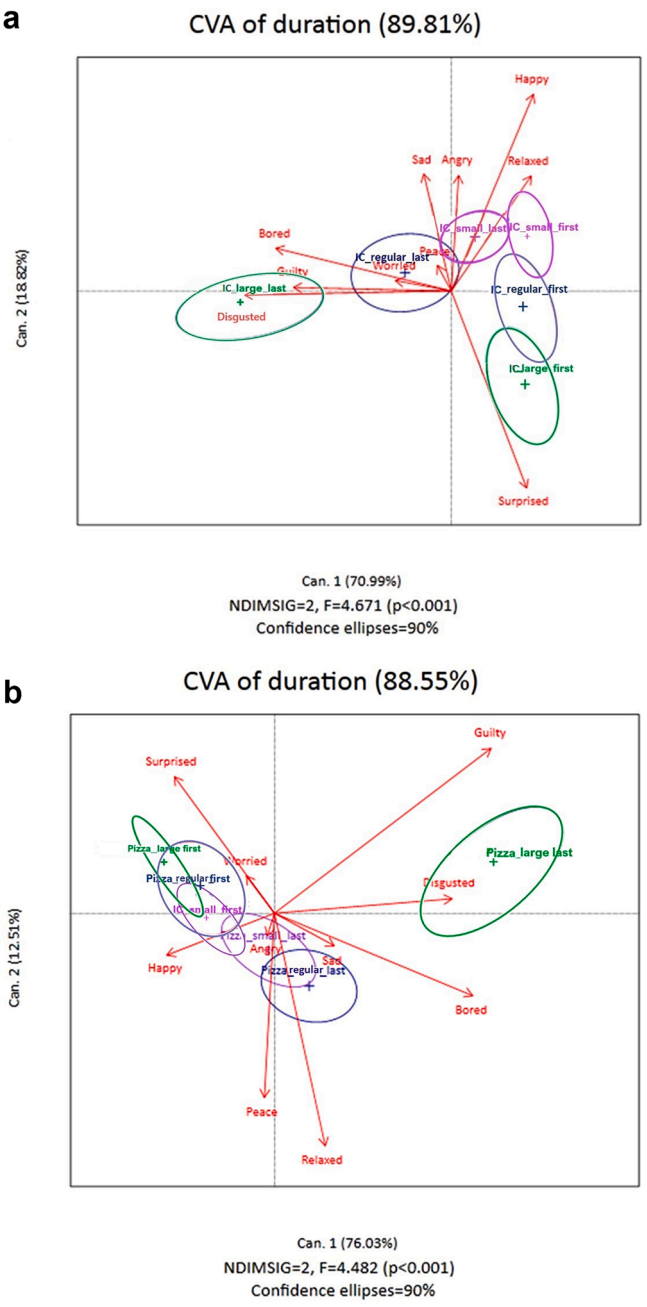

Fig. 4. a + 4b: CVA maps of dominance durations of emotions for ice cream (4a) and pizza (4b). Confidence ellipses at 90% and F-values significant at $p < 0.001$. NDIMSIG represents the number of significant dimensions.

linear mixed model ANOVA results of the mean facial expression intensities by portion size, section and portion size*section (see also Fig. 5a and 5b). Portion sizes of ice cream could be differentiated based on *disgusted* ($F(2, 984) = 4.3$, $p < 0.001$), *sad* ($F(2,982) = 22.2$, $p < 0.001$), *surprised* ($F(2,983) = 9.6$, $p < 0.001$) and *scared* ($F(2,981) = 8.3$, $p < 0.001$) facial expressions, and based on the composite scores for *valence* ($F(2,984) = 1602.2$, $p < 0.001$) and *arousal* ($F(2,992) = 926.9$, $p < 0.001$. Sections (first vs. last) could be differentiated for *angry* ($F(1,979) = 5.7$, $p = 0.02$), *disgusted* ($F(1,980) = 18.4$, $p < 0.001$), *sad* ($F(1,979) = 11.7$, $p = 0.001$) and *surprised* ($F(1,979) = 13.2$, $p < 0.001$) facial expressions, and for *arousal* ($F(1,980) = 4.1$, $p = 0.04$). Portion size*section interactions effects indicated changes in average intensities of facial expressions for *scared* ($F(2,978) = 4.7$, $p = 0.01$) and *surprised* ($F(2,979) = 9.5$, $p < 0.001$), and for *arousal* ($F(2,980) = 7.0$, $p = 0.001$).

Table 5
Mean scores (±SD) of intensity for five basic emotions and the dimensions valence and arousal for different portion sizes of ice cream.

Portion size	Section	Angry	Disgusted	Sad	Scared	Surprised	Valence	Arousal
Small	First	0.06 *(0.07)*	0.06 *(0.06)*	0.17 *(0.12)*[a]	0.05 *(0.06)*	0.08 *(0.06)*	0.15 *(0.05)*[a]	0.09 *(0.03)*[a]
	Last	0.06 *(0.07)*	0.05 *(0.05)*	0.19 *(0.13)*[a]	0.04 *(0.04)*	0.08 *(0.06)*[a]	0.16 *(0.06)*[a]	0.09 *(0.03)*[a]
Regular	First	0.06 *(0.05)*	0.07 *(0.06)*	0.21 *(0.13)*[b]	0.03 *(0.04)*	0.08 *(0.07)*	−0.26 *(0.13)*[b]	0.27 *(0.08)*[b]
	Last	0.06 *(0.06)*	0.06 *(0.06)*	0.24 *(0.14)*[b]	0.04 *(0.04)*	0.06 *(0.05)*[b]	−0.28 *(0.13)*[b]	0.24 *(0.07)*[b]
Large	First	0.06 *(0.07)*	0.06 *(0.05)*	0.19 *(0.12)*[b]	0.04 *(0.05)*	0.08 *(0.07)*	−0.24 *(0.13)*[b]	0.27 *(0.08)*[b]
	Last	0.06 *(0.06)*	0.05 *(0.05)*	0.21 *(0.14)*[b]	0.04 *(0.04)*	0.07 *(0.05)*	−0.25 *(0.15)*[b]	0.24 *(0.07)*[b]

[a, b] Mean values within columns with unlike superscripts lower-case letters were significantly different (Bonferroni corrected) ($p < 0.05$).

Table 6
ANOVA of average facial expression intensities by portion size, section and its interaction for ice cream.

Facial expression	$F_{portion\ size}$	$F_{section}$	$F_{portion\ size * section}$
Angry	0.4	**5.7***	0.4
Disgusted	**4.3***	**18.4*****	2.1
Sad	**22.2*****	**11.7****	1.26
Scared	**8.3****	0.9	**4.7***
Surprised	**9.6*****	**13.2*****	**9.5*****
Valence	**1602.2*****	3.7	3.3
Arousal	**926.9*****	**4.1***	**7.0****

F-values in bold are significant at (*) 0.05, (**) 0.01, (***) 0.001.

Post hoc pairwise comparisons (Bonferroni corrected with adjusted p-value < 0.003), to identify the significant pairs of the levels of this linear mixed model, showed the following: the mean intensity of *sad* was significantly lower for the small portion, as compared to the regular portion ($p < 0.001$). For *surprised*, the mean intensity was significantly higher for the last section of the small portion, as compared to the last section of the regular portion ($p < 0.001$). Participants showed a higher mean intensity of negative facial expressions (*valence*) during the regular and large portion, as compared to the small portion ($p < 0.001$) and were more aroused (*arousal*) during the regular and large portion as compared to the small portion ($p < 0.001$) (see Table 5).

3.4.2. Pizza

Table 7 shows the mean intensities *(±SD)* in facial expressions for five basic emotions *(angry, disgusted, sad, scared, surprised)*, and *valence* and *arousal*, per portion size and per section. Table 8 summarizes the linear mixed model ANOVA results of the mean facial expression intensities by portion size, section and portion size*section (see also Fig. 6a and 6b). For pizza, portion sizes could be differentiated based on *angry* ($F(2,988) = 3.4$, $p = 0.03$), *disgusted* ($F(2, 986) = 5.7$, $p < 0.001$), *sad* ($F(2,984) = 5.8$, $p < 0.001$), *scared* ($F(2,986) = 3.0$, $p = 0.04$) and *arousal* ($F(2,990) = 5.4$, $p = 0.01$. Sections could be differentiated for *arousal* ($F(1,979) = 4.0$, $p = 0.05$). No significant portion size*section interactions effects were found. Post hoc pairwise comparisons (Bonferroni corrected) showed no significant differences.

4. Discussion

The aim of this study was to investigate dynamic changes in hedonic and emotional responses to two indulgent foods, ice cream and pizza, varying in portion size. In line with the notion there is a limit to the extent that larger portion sizes are better appreciated by consumers, we hypothesized that the regular portion sizes would evoke more positive hedonic and emotional responses compared to either the small (too little) or the large (too much) food portions. Main findings confirmed that the large portions were liked least, both for ice cream and pizza. In line with this, food-evoked emotional responses, when measured explicitly (TDE), resulted in similar profiles dominated by positive feelings such as *happy*, *relaxed* and *peace*, for the small and regular portions, whereas the large portions evoked more negative emotional responses (*bored*, *guilty*, *disgusted*) as compared to the small and regular portions. This was especially the case during consumption of the last section of the large portions, indicating that temporal changes in emotional responses not only vary between different portion sizes, but also within the larger portion sizes. With regard to the implicitly measured affective responses (facial expression), a less clear picture was observed. For ice cream, portion sizes and sections could be differentiated based on *disgusted, sad, scared* and *surprised* facial expressions, and on *valence* and *arousal*. For pizza, portion sizes could be differentiated based on *angry, disgusted, sad* and *scared* expressions, and on *arousal*. However, when looking at the absolute mean intensity scores (Table 5 and 7) differences are very small, suggesting that significant results from the linear mixed model ANOVA depend on the high number of observations (degrees of freedom), whereas the relevance of the observed differences in mean intensities seems very limited. There is one exception to this pattern, which is the mean intensity score for the dimensions *valence* and *arousal* for ice cream, with *valence* scores that are positive for the small portion and negative for the regular and large portion, and *arousal* being higher for the regular and large portion as compared to the small portion. This indicates that participants showed more negative facial expressions and were more aroused during consumption of the regular and large portions as compared to the small portion during consumption of ice cream.

Regarding arousal, feelings of hunger, liking and overall satisfaction, it was observed that participants felt calmer (less aroused) after consumption as compared to before, and this was irrespective of product or portion size for both ice cream and pizza. Hunger ratings also decreased from before to after consumption, with the strongest reduction in feelings of hunger after consumption of the large portions of ice cream and pizza, which is as expected. Interestingly, liking of and overall satisfaction with the products was not one to one related to portion sizes: liking and overall satisfaction were both higher for ice cream as compared to pizza. However, small portions were liked better than the large portions for both products. We also found a significant interaction effect between product and portion size. For ice cream, the small portion was liked better than the regular and the large portion, whereas for pizza the small and regular portion size was better liked than the large portion. This indicates that for both these indulgent, palatable and energy-dense foods, the large portion was liked the least. For overall satisfaction, participants were most satisfied with the regular portion of ice cream, as compared to the small and large portion, whereas for pizza, participants were most satisfied with the regular and large portion, but less with the small portion size.

In the present study participants were not asked to choose their preferred portion size, they were just asked to finish the different portions and report on their hedonic and affective responses. This hampers the interpretation of the results to a certain extent, as we cannot exclude that for some participants the portions served in this study, especially the large ones, deviate more from their preferred or typically consumed portions when eating ice cream or pizza, than for others. In hindsight, it would have been better if we had asked participants about preferred or typically consumed portion sizes for both products, as this information could have been included as a covariate in the analyses, which might have contributed to a better explanation and interpretation of the results. Sex and BMI may also influence preferred or typically consumed portions, as it can be expected that in general men prefer, or at least are more comfortable with larger portions of ice cream and pizza as a snack

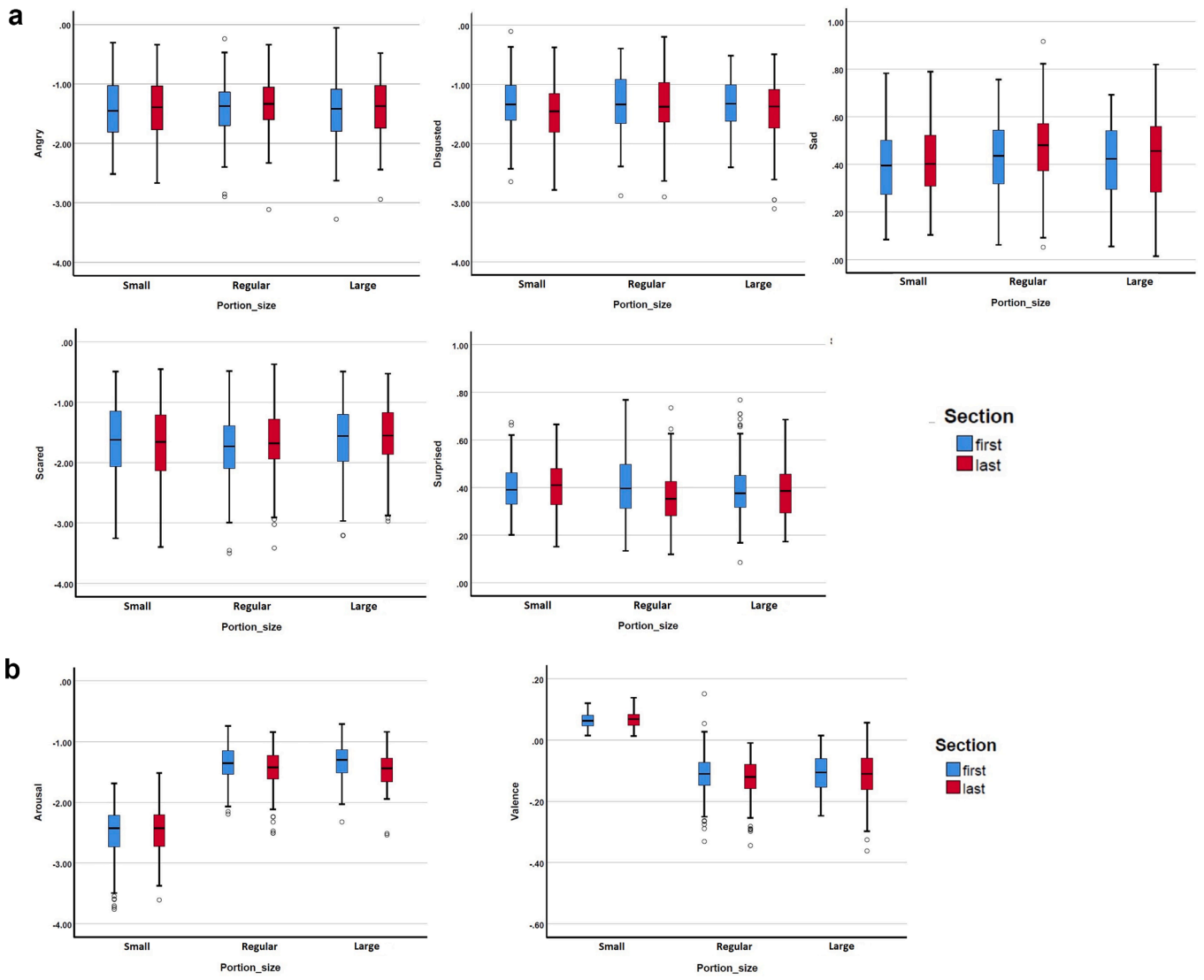

Fig. 5. a + 5b: Boxplots of the distribution of the transformed data (facial expressions per emotion (5a) and valence and arousal (5b)) for the different portion sizes and sections for ice cream. Outliers are represented by circles (○).

Table 7
Mean scores (±SD) of intensity for five basic emotions and the dimensions valence and arousal for facial expressions while eating different portion sizes of pizza.

Portion size	Section	Angry	Disgusted	Sad	Scared	Surprised	Valence	Arousal
Small	First	0.06 *(0.06)*	0.05 *(0.05)*	0.18 *(0.12)*	0.04 *(0.05)*	0.07 *(0.06)*	−0.21 *(0.13)*	0.26 *(0.06)*
	Last	0.07 *(0.10)*	0.06 *(0.05)*	0.17 *(0.13)*	0.04 *(0.05)*	0.07 *(0.06)*	−0.21 *(0.16)*	0.26 *(0.06)*
Regular	First	0.06 *(0.08)*	0.06 *(0.05)*	0.19 *(0.13)*	0.04 *(0.04)*	0.07 *(0.06)*	−0.22 *(0.14)*	0.26 *(0.07)*
	Last	0.06 *(0.06)*	0.05 *(0.04)*	0.21 *(0.14)*	0.04 *(0.04)*	0.06 *(0.06)*	−0.23 *(0.14)*	0.25 *(0.07)*
Large	First	0.07 *(0.06)*	0.07 *(0.06)*	0.17 *(0.12)*	0.04 *(0.05)*	0.06 *(0.05)*	−0.21 *(0.12)*	0.25 *(0.07)*
	Last	0.07 *(0.06)*	0.06 *(0.07)*	0.20 *(0.14)*	0.04 *(0.04)*	0.07 *(0.07)*	−0.24 *(0.15)*	0.24 *(0.07)*

compared to women, as may persons with a higher BMI compared to those with a lower BMI. In the present study, results were adjusted for effects of sex and BMI, but no effects were found. It has to be noted, however, that the majority of the subjects were women, and that all subjects had a normal BMI with a relatively low range. As a consequence, effects of sex and BMI could not be explored properly. Nevertheless, our findings are in line with previous studies showing that when consumers have to choose their preferred portion size, they are influenced by at least three expectations: 1) Will it satiate their hunger?, 2) How will it affect their weight and health?, and 3) How pleasurable will the food be? (Cornil & Chandon, 2016b; Labbe et al., 2017; Marteau et al., 2015). These studies showed that next to expected satiation, perceived healthfulness and expected tastiness are also drivers of portion selection, and that consumers differ in the extent they are more health- or hedonic-driven. Still, portion size is a key driver of energy intake: people eat more when served larger food portions and less when served smaller portions (Zlatevska et al., 2014). The increased availability and consumption of larger food portions is therefore of concern because of the associated risk of overweight and obesity (WHO, 2014). Hence, it is important to consider the potential impact of *reducing* portion sizes on consumption especially for indulgent and high energy-dense foods (Marteau et al., 2015). The challenge with reducing portion sizes is that no one likes the concept of 'less' (Herman et al., 2015), and 'bigger is better'(Chandon & Ordabayeva, 2009). Interestingly, the

Table 8
ANOVA of average facial expression intensities by portion size, section and its interaction for pizza.

Facial expressions	$F_{portion\ size}$	$F_{section}$	$F_{portion\ size\ *\ section}$
Angry	**3.4***	0.5	1.7
Disgusted	**5.7****	1.5	0.4
Sad	**5.8****	2.4	2.7
Scared	**3.0***	1.2	0.1
Surprised	3.0	0.2	1.1
Valence	2.4	0.0	0.8
Arousal	**5.4***	4.0	1.1

F-values in bold are significant at (*) 0.05, (**) 0.01, (***) 0.001.

results of the present study showed that people enjoyed small food portions about as much as regular food portions, both for a sweet product (ice cream) and a savory product (pizza). As expected, the large (too much) portions were liked least. In line with this, eating the small and regular portions resulted in similar (TDE) profiles dominated by positive feelings such as *happy*, *relaxed* and *peace*, whereas the large portions evoked more negative emotional responses (*bored*, *guilty*, *disgusted*). Up till now, most research investigated food-evoked emotions in relation to single bites or a maximum of three bites in a row (De Wijk et al., 2019; Gutjar et al., 2014; van Bommel et al., 2020). We are not aware of other research that has examined how portion size dynamically changes emotional responses to foods throughout full consumption. The current study suggests that a high energy-dense food that is simply downsized can still be perceived as enjoyable and rewarding as the regular portion size. This is supported by research in preschool children on snack portion control (Reale et al., 2018), and on reducing the portion size of a high energy-dense food (Carstairs et al., 2018). Reale and colleagues (2018) compared two methods on snack portion control: snack replacement which involved swapping high energy-dense snacks for fruits and vegetables, and snack reduction which involved reducing the size of high energy-dense snacks by 50%. The results showed that although parents expressed a more favorable attitude to snack replacement, snack reduction was also well received, and both strategies were found to be feasible and acceptable. In the study by Carstairs et al. (2018), the effect on intake was tested of reducing the portion size of a high energy-dense lunch item while varying the variety of the accompanying low energy-dense vegetables. It was shown that reducing the portion size of the high energy-dense lunch item reduced total energy intake, and offering a variety of vegetables, compared with a single vegetable, increased vegetable intake. However, using a variety of low energy-dense side dishes had no incremental value on downsizing the

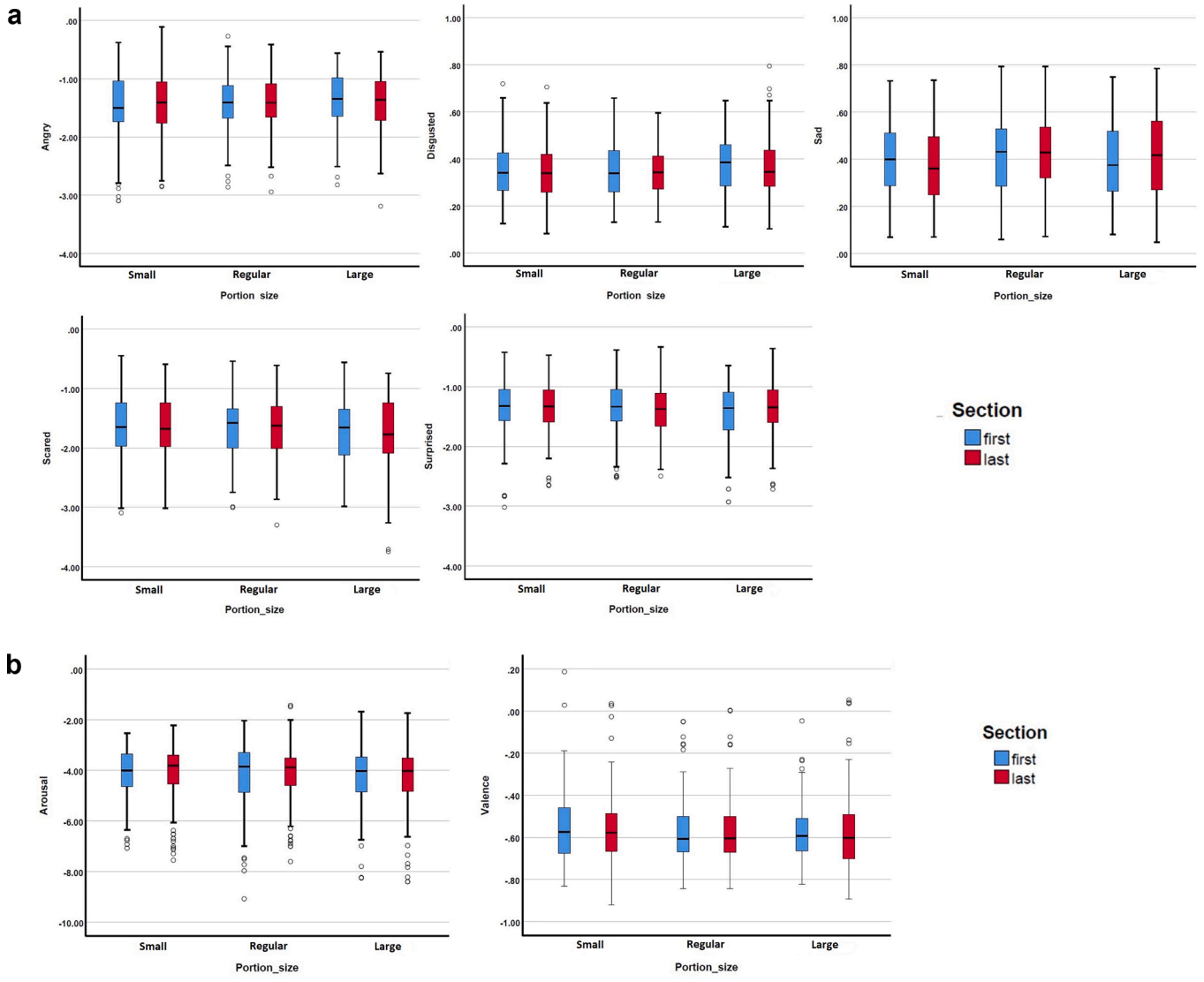

Fig. 6. a + 6b: Boxplots of the distribution of the transformed data (facial expressions per emotion (6a) and valence and arousal (6b)) for the different portion sizes and sections for pizza. Outliers are represented by circles (○).

high energy-dense food (Carstairs et al., 2018).

Future research should further explore downsizing strategies to facilitate the design of smaller portions of high energy-dense foods that consumers enjoy and are willing to buy and eat over and over again: 1) what are the boundaries or 'how low can you go while feeling just as satisfied?', and 2) what is the ideal size range of products to induce positive emotions?

The present study used a toolbox of measuring techniques, i.e., facial expressions as implicit measure and Temporal Dominance of Emotions (TDE) and subjective self-report questionnaires (e.g. liking, arousal) as explicit measures. The one supports and validates the other (Brouwer et al., 2017; Brouwer et al., 2019), and each type of measure (implicit and explicit) provides complementary information (Bell et al., 2018; De Wijk & Noldus, 2021). However, with regard to the implicitly measured affective responses (facial expression), we observed data that were difficult to interpret. The differences in absolute mean intensity scores across the different emotions, valence and arousal were very small and the relevance of the observed differences in mean intensities seemed to be limited. In hindsight, the implicit measurement of facial expressions may not have been a suitable method to use in this context and was therefore less effective in measuring emotional effects of consumption of foods. Recently, de Wijk & Noldus (2021) published a review in which they indicated that under tightly controlled laboratory conditions and with well-liked foods, implicit measures fail to demonstrate clear advantages over explicit measures. Whereas explicit measures capture especially the sensory aspects of the food itself, implicit measures appear to capture the total food experience from pre- to post-consumption, including the food itself but also factors such as the physical and social context in which foods are consumed in real-life (Bisogni et al., 2007). In the current study, participants were sitting alone in tightly controlled laboratory sensory booths. Indeed, the measurement of facial expressions may be more suitable for social contexts in which facial expressions communicate experiences to others: expressions signaling happiness assure the fellow consumer that the food is delicious and encourages the fellow consumer to join eating the product as well (De Wijk et al., 2019; De Wijk & Noldus, 2021). Finally, emotions are discrete and short-lived feeling experiences that are caused by a specific event, in this case the sight, smell and taste of food (Grandjean et al., 2008; Scherer, 2009). Facial expressions evolve over short time windows (milliseconds), and we reason therefore that facial expressions may be less suitable to pick up slower emotional responses over longer time frames (minutes) throughout full consumption.

An important strength of this study is that hedonic and emotional responses were measured throughout realistic eating experiences, i.e., full food portions as opposed to single bites as mostly done in previous sensory research. Also, the products included in the study were chosen to be indulgent and high in energy density from both the sweet and savory domain. A limitation of the study is that the extent to which the portions of ice cream and pizza were experienced as being 'small', 'regular' or 'large' by the participants may have been influenced by individual differences in preferred or typically consumed portions of these specific products. Also, the study population consisted of young normal weight adults, mostly women, from a University in the Netherlands. It is therefore recommended to replicate these findings using a broader range of products and a more representative sample across different countries. It would be of particular interest and relevance to investigate whether the findings of the present study will transfer to less indulgent, healthy low energy-dense foods such as fruits and vegetables. A large literature base exists on interventions and strategies to increase intake of fruits and vegetables (for recent reviews see (Hodder et al., 2019; Wallace et al., 2020), which remains a big challenge given that the majority of people, both adults and children still do not meet the daily recommended intake of fruits and vegetables (WHO, 2015). Whereas for indulgent, high energy-dense foods, a reduction in portion size seems desirable, for healthy foods the question would be to what extend portions sizes of e.g. fruits and vegetables could be increased while still being acceptable to consumers and resulting in positive emotional responses.

As mentioned earlier, the present research was conducted under controlled laboratory conditions: participants ate each product alone in sensory booths and were exposed to each food portion only once. This is completely different from real-life experiences in which you eat a product together with other people such as family and friends, in different contexts, e.g., at home or work, in a restaurant. Previous research has demonstrated that the context in which products are consumed is an important factor in shaping food perceptions and experiences (Meiselman, 2006; Zandstra & Lion, 2019). Therefore, a different pattern in hedonic and emotional responses may have been observed when people would have been exposed to the food products in real-life contexts (i.e., at the beach or at home/in a restaurant). It also remains unclear how these hedonic and emotional responses to different portion sizes of foods evolve over repeated consumption. This clearly represents an opportunity for future research.

Ultimately, this study has important implications for health care professionals and food industry to support people's food choices in a healthier direction. We know that portions are getting bigger and as a result, people are eating more. 'Portion distortion' is unfortunately becoming the new norm. For dieticians and other health care professionals, the research could be used as a tool to help people to understand what a balanced portion looks like in order to maintain a healthy diet. For food industry, it is important to continue to design and provide smaller food portions of regular size products that people love. This study shows that one way to promote healthier eating behaviors is to offer smaller portions of foods to decrease total energy intake, while still providing emotionally rewarding experiences and pleasure.

5. Conclusions

The current study tracking sensations and emotions throughout full consumption suggests a better emotional experience for small and regular food portions than large (too much) food portions of indulgent high energy-dense foods. Interestingly, people enjoyed small food portions about as much as regular food portions. These findings contribute to a better understanding of the role of emotions in the consumption experience of food products varying in portion size and will help to identify the ideal size of a food product for inducing a positive emotional response.

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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References

Bell, L., Vogt, J., Willemse, C., Routledge, T., Butler, L. T., & Sakaki, M. (2018). Beyond self-report: A review of physiological and neuroscientific methods to investigate consumer behavior. *Frontiers in Psychology, 9*(SEP). https://doi.org/10.3389/fpsyg.2018.01655

Bisogni, C. A., Falk, L. W., Madore, E., Blake, C. E., Jastran, M., Sobal, J., & Devine, C. M. (2007). Dimensions of everyday eating and drinking episodes. *Appetite, 48*(2), 218–231. https://doi.org/10.1016/j.appet.2006.09.004

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Brouwer, A. M., Hogervorst, M. A., Grootjen, M., van Erp, J. B. F., & Zandstra, E. H. (2017). Neurophysiological responses during cooking food associated with different emotions. *Food Quality and Preference, 62*, 307–316. https://doi.org/10.1016/j.foodqual.2017.03.005

Brouwer, A. M., Hogervorst, M. A., van Erp, J. B. F., Grootjen, M., van Dam, E., & Zandstra, E. H. (2019). Measuring cooking experience implicitly and explicitly: Physiology, facial expression and subjective ratings. *Food Quality and Preference, 78*. https://doi.org/10.1016/j.foodqual.2019.103726

Brunstrom, J. M. (2014). Mind over platter: Pre-meal planning and the control of meal size in humans. *International Journal Of Obesity, 38*, S9. Retrieved from 10.1038/ijo.2014.83.

Cardello, A. V., Meiselman, H. L., Schutz, H. G., Craig, C., Given, Z., Lesher, L. L., & Eicher, S. (2012). Measuring emotional responses to foods and food names using questionnaires. *Food Quality and Preference, 24*(2), 243–250. https://doi.org/10.1016/j.foodqual.2011.12.002

Carstairs, S. A., Caton, S. J., Blundell-Birtill, P., Rolls, B. J., Hetherington, M. M., & Cecil, J. E. (2018). Can reduced intake associated with downsizing a high energy dense meal item be offset by increased vegetable variety in 3–5-year-old children? *Nutrients, 10*(12). https://doi.org/10.3390/nu10121879

Chandon, P., & Ordabayeva, N. (2009). Supersize in One Dimension, Downsize in Three Dimensions: Effects of Spatial Dimensionality on Size Perceptions and Preferences. *Journal of Marketing Research, 46*(6), 739–753. https://doi.org/10.1509/jmkr.46.6.739_JMR6C

Cootes, T. F., Edwards, G. J., & Taylor, C. J. (2001). Active appearance models. *IEEE Transactions on pattern analysis and machine intelligence, 23*(6), 681–685.

Cornil, Y., & Chandon, P. (2016a). Pleasure as a Substitute for Size: How Multisensory Imagery Can Make People Happier with Smaller Food Portions. *Journal of Marketing Research, 53*(5), 847–864. https://doi.org/10.1509/jmr.14.0299

Cornil, Y., & Chandon, P. (2016b). Smaller food portions, pleasure as a substitute for size: How multisensory imagery can make people happier with. *Journal of Marketing Research, 53*(5), 847–864. https://doi.org/10.1509/jmr.14.0299

Dalenberg, J. R., Gutjar, S., Ter Horst, G. J., De Graaf, K., Renken, R. J., & Jager, G. (2014). Evoked emotions predict food choice. *PLOS ONE, 9*(12). https://doi.org/10.1371/journal.pone.0115388

De Wijk, R. A., Kaneko, D., Dijksterhuis, G. B., van Zoggel, M., Schiona, I., Visalli, M., & Zandstra, E. H. (2019). Food perception and emotion measured over time in-lab and in-home. *Food Quality and Preference, 75*, 170–178. https://doi.org/10.1016/j.foodqual.2019.02.019

De Wijk, R. A., Kooijman, V., Verhoeven, R. H. G., Holthuysen, N. T. E., & de Graaf, C. (2012). Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods. *Food Quality and Preference, 26*(2), 196–203. https://doi.org/10.1016/j.foodqual.2012.04.015

De Wijk, R. A., & Noldus, L. P. J. J. (2021). Using implicit rather than explicit measures of emotions. *Food Quality and Preference, 92*, Article 104125. https://doi.org/10.1016/j.foodqual.2020.104125

Delarue, J., & Sieffermann, J. M. (2004). Sensory mapping using Flash profile. Comparison with a conventional descriptive method for the evaluation of the flavour of fruit dairy products. *Food Quality and Preference, 15*(4), 383–392. https://doi.org/10.1016/S0950-3293(03)00085-5

Dijksterhuis, G. (2016). New product failure: Five potential sources discussed. *Trends in Food Science and Technology, 50*, 243–248. https://doi.org/10.1016/j.tifs.2016.01.016

Diliberti, N., Bordi, P. L., Conklin, M. T., Roe, L. S., & Rolls, B. J. (2004). Increased Portion Size Leads to Increased Energy Intake in a Restaurant Meal. *Obesity Research, 12*(3), 562–568. https://doi.org/10.1038/oby.2004.64

Edwards, J. S. A., Meiselman, H. L., Edwards, A., & Lesher, L. (2003). The influence of eating location on the acceptability of identically prepared foods. *Food Quality and Preference, 14*(8), 647–652. https://doi.org/10.1016/S0950-3293(02)00189-1

Galmarini, M. V., Visalli, M., & Schlich, P. (2017). Advances in representation and analysis of mono and multi-intake Temporal Dominance of Sensations data. *Food Quality and Preference, 56*, 247–255. https://doi.org/10.1016/j.foodqual.2016.01.011

Grandjean, D., Sander, D., & Scherer, K. R. (2008). Conscious emotional experience emerges as a function of multilevel, appraisal-driven response synchronization. *Consciousness and Cognition, 17*(2), 484–495. https://doi.org/10.1016/j.concog.2008.03.019

Gutjar, S., Dalenberg, J. R., de Graaf, C., de Wijk, R. A., Palascha, A., Renken, R. J., & Jager, G. (2015). What reported food-evoked emotions may add: A model to predict consumer food choice. *Food Quality and Preference, 45*, 140–148. https://doi.org/10.1016/j.foodqual.2015.06.008

Gutjar, S., de Graaf, C., Kooijman, V., de Wijk, R. A., Nys, A., ter Horst, G. J., & Jager, G. (2014). The role of emotions in food choice and liking. *Food Research International, 76*(2), 216–223. https://doi.org/10.1016/j.foodres.2014.12.022

Haynes, A., Hardman, C. A., Halford, J. C. G., Jebb, S. A., Mead, B. R., & Robinson, E. (2020). Reductions to main meal portion sizes reduce daily energy intake regardless of perceived normality of portion size: A 5 day cross-over laboratory experiment. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1). https://doi.org/10.1186/s12966-020-0920-4

Hetherington, M. M., & Blundell-Birtill, P. (2018). The portion size effect and overconsumption–towards downsizing solutions for children and adolescents. *Nutrition Bulletin, 43*, 61–68. https://doi.org/10.1111/nbu.12307

Hetherington, M. M., Rolls, B. J., & Burley, V. J. (1989). The time course of sensory-specific satiety. Retrieved from *Appetite, 12*(1), 57–68 https://www.scopus.com/inward/record.uri?eid=2-s2.0-0024618834&partnerID=40&md5=92571bd5ae9aa9439ec02cf1ea03e3b1.

Hetherington, M. M., Blundell-Birtill, P., Caton, S. J., Cecil, J. E., Evans, C. E., Rolls, B. J., & Tang, T. (2018). Understanding the science of portion control and the art of downsizing. *Proceedings of the Nutrition Society, 77*(3), 347–355. https://doi.org/10.1017/S0029665118000435

Herman, C. P., Polivy, J., Pliner, P., & Vartanian, L. R. (2015). Mechanisms underlying the portion-size effect. *Physiol Behav, 144*, 129–136. https://doi.org/10.1016/j.physbeh.2015.03.025

Hodder, R. K., O'Brien, K. M., Stacey, F. G., Tzelepis, F., Wyse, R. J., Bartlem, K. M., … Wolfenden, L. (2019). Interventions for increasing fruit and vegetable consumption in children aged five years and under. *Cochrane Database of Systematic Reviews, 2019*(11). https://doi.org/10.1002/14651858.CD008552.pub6

Jager, G. (2016). Short-term Time Structure of Food-related Emotions: Measuring Dynamics of Responses. In *Emotion Measurement* (pp. 273–298). Elsevier Inc.

Jager, G., Schlich, P., Tijssen, I., Yao, J., Visalli, M., de Graaf, C., & Stieger, M. (2014). Temporal dominance of emotions: Measuring dynamics of food-related emotions during consumption. Retrieved from *Food Quality and Preference., 37*, 87–99 http://www.scopus.com/inward/record.url?eid=2-s2.0-84901296325&partnerID=40&md5=250228fcb675c5264e5a5a4aa35a64ae.

Kaneko, D., Toet, A., Brouwer, A. M., Kallen, V., & van Erp, J. B. F. (2018). Methods for evaluating emotions evoked by food experiences: A literature review. *Front Psychol, 9*(JUN). https://doi.org/10.3389/fpsyg.2018.00911

King, S. C., & Meiselman, H. L. (2010). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference, 21*(2), 168–177. https://doi.org/10.1016/j.foodqual.2009.02.005

King, S. C., Meiselman, H. L., & Carr, B. T. (2010). Measuring emotions associated with foods in consumer testing. *Food Quality and Preference, 21*(8), 1114–1116. https://doi.org/10.1016/j.foodqual.2010.08.004

Köster, E. P. (2003). The psychology of food choice: Some often encountered fallacies. *Food Quality and Preference, 14*(5–6), 359–373. https://doi.org/10.1016/S0950-3293(03)00017-X

Köster, E. P., & Mojet, J. (2015). From mood to food and from food to mood: A psychological perspective on the measurement of food-related emotions in consumer research. *Food Research International, 76*(P2), 180–191. https://doi.org/10.1016/j.foodres.2015.04.006

Labbe, D., Rytz, A., Godinot, N., Ferrage, A., & Martin, N. (2017). Is portion size selection associated with expected satiation, perceived healthfulness or expected tastiness? A case study on pizza using a photograph-based computer task. *Appetite, 108*, 311–316. https://doi.org/10.1016/j.appet.2016.10.012

Loijens, L., & Krips, O. (2019). FaceReader Methodology Note. In N. I. Technology (Ed.), *Wageningen*. The Netherlands.

Marteau, T. M., Hollands, G. J., Shemilt, I., & Jebb, S. A. (2015). Downsizing: Policy options to reduce portion sizes to help tackle obesity. *BMJ (Online), 351*. https://doi.org/10.1136/bmj.h5863

Meiselman, H. L. (2006). The role of context in food choice, food acceptance and food consumption. In *The Psychology of Food Choice* (pp. 179–199). CABI Publishing.

Nestrud, M. A., Meiselman, H. L., King, S. C., Lesher, L. L., & Cardello, A. V. (2016). Development of EsSense25, a shorter version of the EsSense Profile®. *Food Quality and Preference, 48*, 107–117. https://doi.org/10.1016/j.foodqual.2015.08.005

Pineau, N., Schlich, P., Cordelle, S., Mathonnière, C., Issanchou, S., Imbert, A., … Köster, E. (2009). Temporal Dominance of Sensations: Construction of the TDS curves and comparison with time-intensity. *Food Quality and Preference, 20*(6), 450–455. https://doi.org/10.1016/j.foodqual.2009.04.005

Reale, S., Kearney, C. M., Hetherington, M. M., Croden, F., Cecil, J. E., Carstairs, S. A., … Caton, S. J. (2018). The feasibility and acceptability of two methods of snack portion control in United Kingdom (UK) preschool children: Reduction and replacement. *Nutrients, 10*(10). https://doi.org/10.3390/nu10101493

Rocha, C., Lima, R. C., Moura, A. P., Costa, T., & Cunha, L. M. (2019). Implicit evaluation of the emotional response to premium organic herbal infusions through a temporal dominance approach: Development of the temporal dominance of facial emotions (TDFE). *Food Quality and Preference, 76*, 71–80. https://doi.org/10.1016/j.foodqual.2019.04.001

Rode, E., Rozin, P., & Durlach, P. (2007). Experienced and remembered pleasure for meals: Duration neglect but minimal peak, end (recency) or primacy effects. *Appetite, 49*(1), 18–29. https://doi.org/10.1016/j.appet.2006.09.006

Rolls, B. J., Rolls, E. T., Rowe, E. A., & Sweeney, K. (1981). Sensory specific satiety in man. *Physiology and Behavior, 27*(1), 137–142. https://doi.org/10.1016/0031-9384(81)90310-3

RStudio Team. (2015). *RStudio: Integrated Development Environment for R*. Boston MA. Retrieved from http://www.rstudio.com/.

Scherer, K. R. (2005). What are emotions? and how can they be measured? *Social Science Information, 44*(4), 695–729. https://doi.org/10.1177/0539018405058216

Scherer, K. R. (2009). Emotions are emergent processes: They require a dynamic computational architecture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1535), 3459–3474. https://doi.org/10.1098/rstb.2009.0141

Schwartz, C., Lange, C., Hachefa, C., Cornil, Y., Nicklaus, S., & Chandon, P. (2020). Effects of snack portion size on anticipated and experienced hunger, eating enjoyment, and perceived healthiness among children. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1). https://doi.org/10.1186/s12966-020-00974-z

Sørensen, L. B., Møller, P., Flint, A., Martens, M., & Raben, A. (2003). Effect of sensory perception of foods on appetite and food intake: A review of studies on humans. *International Journal of Obesity, 27*(10), 1152–1166. https://doi.org/10.1038/sj.ijo.0802391

Van Bommel, R., Stieger, M., Visalli, M., de Wijk, R., & Jager, G. (2020). Does the face show what the mind tells? A comparison between dynamic emotions obtained from facial expressions and Temporal Dominance of Emotions (TDE). *Food Quality and Preference, 85*. https://doi.org/10.1016/j.foodqual.2020.103976

Wallace, T. C., Bailey, R. L., Blumberg, J. B., Burton-Freeman, B., Chen, C. Y. O., Crowe-White, K. M., … Wang, D. D. (2020). Fruits, vegetables, and health: A comprehensive narrative, umbrella review of the science and recommendations for enhanced public

policy to improve intake. *Critical Reviews in Food Science and Nutrition, 60*(13), 2174–2211. https://doi.org/10.1080/10408398.2019.1632258

Who. (2014). Limiting portion sizes to reduce the risk of childhood overweight and obesity: Biological, behavioural and contextual rationale. Retrieved from http://www.who.int/elena/bbc/portion_childhood_obesity/en/.

Who. (2015). European Food and Nutrition Action Plan 2015–2020. Retrieved from https://www.euro.who.int/_data/assets/pdf_file/0003/294474/European-Food-Nutrition-Action-Plan-20152020-en.pdf#:~:text=By%20adopting%20the%20WHO%20European%20Food%20and%20Nutrition, noncommunicable%20diseases%20seen%20across%20the%20WHO%20European%20Region.

Zandstra, E. H., & El-Deredy, W. (2011). Effects of energy conditioning on food preferences and choice. *Appetite, 57*(1), 45–49. https://doi.org/10.1016/j.appet.2011.03.007

Zandstra, E. H., & Lion, R. (2019). In-home testing – Bringing lab results to the real world. In H. L. Meiselman (Ed.), *Context: The Effects of Environment on Production Design and Evaluation* (pp. 67–85). Woodhead Publishing.

Zlatevska, N., Dubelaar, C., & Holden, S. S. (2014). Sizing up the Effect of Portion Size on Consumption: A Meta-Analytic Review. *Journal of Marketing, 78*(3), 140–154. https://doi.org/10.1509/jm.12.0303