Physiology & Behavior 179 (2017) 478–486

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/physbeh

# Beyond expectations: The responses of the autonomic nervous system to visual food cues

Luz Verastegui-Tena[a], Aurelia Schulte-Holierhoek[b], Hans van Trijp[a], Betina Piqueras-Fiszman[a,*]

[a] Marketing and Consumer Behaviour Group, Wageningen University and Research Centre, Hollandseweg 1, 6706 KN Wageningen, Netherlands
[b] Division of Human Nutrition, Wageningen University and Research Centre, Stippeneng 4, 6708 WE Wageningen, Netherlands

ARTICLE INFO

*Keywords:*
ANS
Expectations
Heart rate
Skin conductance
Image perception
Tasting

ABSTRACT

Self-report measures rely on cognitive and rational processes and may not, therefore, be the most suitable tools to investigate implicit or unconscious factors within a sensory experience. The responses from the autonomic nervous system (ANS), which are not susceptible to bias due to their involuntary nature, may provide a better insight. Expectations are important for the consumer-product interaction and should be considered. However, research using ANS responses has not focused thoroughly on expectations. Our aim was to investigate the mechanisms underlying ANS responses by evaluating the reactions to different images when expectations about a product are created (before tasting the product) and when they are confirmed and disconfirmed (after tasting the product).

In a first study, seventy-five participants tasted four drinks (three identical soy-based drinks and one rice-based drink) and were told that they would be shown their main ingredient either before or after tasting. For the three identical drinks, the images shown were: worms, chocolate, and soy. Heart rate and skin conductance were measured during the procedure. The results showed that ANS responses followed similar patterns when images were presented before or after tasting. Heart rate decreased for all images, with the largest decrease found for chocolate and worms. Skin conductance increased, with the largest increase found for worms. To test whether the effects were solely caused by image perception, a second study was done in which forty participants only saw the images. The responses obtained were smaller and did not completely match those of the first study.

In conclusion, it could be said that the ANS responses of the first study were a result of the sensory processing and defense mechanisms happening during the creation and (dis)confirmation of expectations. The second study confirmed that visual perception alone could not account for these effects and that it led to smaller changes. Hence, it seems that the context of use influences the patterns and magnitude of ANS responses to food cues.

## 1. Introduction

Sensory and Consumer Science rely on self-reports to measure the consumers' perceptions of products as well as to characterize such products. These self-report measurements are based on cognitive and rational processes and, therefore, cannot answer questions related to other unconscious and implicit aspects of the consumer-product interaction [1,2]. Other routes might be able to give a better insight into the mechanisms underlying these unconscious processes.

There is a richness of reactions yet to be explored that may contribute to revealing how consumers perceive the world around them and in this context, food products. Among these reactions, the responses of the autonomic nervous system (ANS) may be a useful tool. The ANS is a component of the peripheral nervous system that is not under voluntary control. It is divided into a sympathetic and a parasympathetic branch, each relevant for specific situations. The first is relevant for emergency, "flight or fight" reactions, and exercise while the latter predominates in resting situations [3]. The ANS responses commonly measured include cardiovascular activity (heart rate variability), electrodermal activity (skin conductance and skin potential), skin temperature and blood pressure [4]. The branch of the autonomic nervous system represented in the measurement depends on the ANS response used. Skin conductance responses are related to sympathetic activity, heart rate variability reflects parasympathetic activity, while heart rate and blood pressure represent a combination of both branches [5].

ANS responses are not susceptible to self-report biases due to their involuntary nature. They are believed to precede the consumers' awareness and, as a result, proposed to reveal the preferences of consumers [6]. These characteristics hold some potential when it comes to food products, as it is sometimes difficult for consumers to express why

* Corresponding author.
*E-mail address:* betina.piquerasfiszman@wur.nl (B. Piqueras-Fiszman).

http://dx.doi.org/10.1016/j.physbeh.2017.07.025
Received 23 March 2017; Received in revised form 9 July 2017; Accepted 18 July 2017
Available online 20 July 2017
0031-9384/ 

they react the way they do [7]. Nevertheless, the understanding of ANS responses and their correct application in the food domain entails certain challenges. When using these measurements it is necessary to take into account the fact that the ANS is in charge of different tasks in our body. Bodily functions like breathing, the digestion of food, or even the movement of blood in our body may affect ANS responses as well as other non-affective and non-emotional responses, such as attention and mental effort [8].

Researchers in the food domain have attempted to find ANS patterns that can reflect implicit factors such as emotions and pleasantness but, unfortunately, the effects found are inconsistent and difficult to compare [9]. For instance, in a study with breakfast drinks, De Wijk et al. [10] found that there was a positive association between liking scores and heart rate but no differences in skin conductance. In a similar study, Danner et al. [2] studied the implicit and explicit reactions to different juice drinks and found no differences in heart rate. However, they found an increase in skin conductance level (SCL) compared to baseline for a pickled cabbage juice (sauerkraut) that had a low liking score and a low SCL increase for a common orange juice. Horio [11] measured the heart rate of participants when tasting stimuli such as quinine-HCl (bitter), MSG (umami), citric acid (sour), and sucrose (sweet) and found a negative correlation between liking and heart rate for the first three but no significant correlation between heart rate and liking for sucrose. There is a lack of clarity in most published studies regarding skin temperature. Danner et al. [2], He et al. [7], and Leterme et al. [12] did not find a significant difference in skin temperature between pleasant and unpleasant stimuli, while De Wijk et al. [13] found higher temperatures for liked foods in both children and young adults and Robin [14] found a higher skin temperature amplitude for unpleasant stimuli.

ANS responses to expectations may lead to clearer patterns than the factors currently assessed in the food domain. Expectations are a key factor in the consumer-product interaction. Food cues such as the sight of food elicit an array of physiological, physical, and cognitive processes [15]. Our brain interprets and integrates the information from previous experienced situations with the new information of the product in front of us [16]. Consumers already have a preconceived idea of the taste, texture, and other sensory characteristics of the food (sensory expectations) as well as how much they will like it before consuming it (hedonic expectations) [17]. All foods are evaluated according to these expectations and, after this process, a judgment is given [18].

The hedonic evaluation of a food will not be affected if the food the consumer is presented with matches their expectations. However, there might be a disparity between the expected experience with the product and the actual one; which would lead to a disconfirmation of expectations. In such cases, the following processes might take place: (a) a minimization of the difference and adjustment of the perception to what was expected (assimilation), (b) a maximization of the difference (contrast), (c) a negative evaluation of the product regardless of how it is perceived (generalized negativity), or (d) assimilation when there are small discrepancies and contrast as these discrepancies increase [16].

In research, expectations are usually manipulated by using verbal or non-verbal information. Some studies, for example, use simple sensory information like taste or visual cues to assess their effect on hedonic expectations. The moment this information is presented plays a role on the impact it will have on the consumer [19]. For instance, the study by Lee et al. [20] showed that the timing in which the information about an unpleasant ingredient present in a beer was received affected the overall experience of the tasting. Participants had to taste and give their preference between two beers, one adulterated with an ingredient perceived as unpleasant and one unadulterated. The beer with the unpleasant ingredient was less liked when participants knew the ingredient before tasting it (and hence had particular expectations about its flavor) than those that tasted it blindly or before getting the information. This is because obtaining information about a product prior to its consumption creates expectations about the sensory properties of the product [21]. Our behavior is motivated to the same extent by the anticipation of pleasant situations, which we would like to experience, and the anticipation of unpleasant situations which we would like to avoid [22]. The expectations that are created through food cues (visual, auditory, or olfactory), or even by the thought of eating, lead to a variety of anticipatory responses in the body. These anticipatory responses can prepare the body to facilitate the digestion of food or they can diminish the negative consequences that are expected from food intake [23]. Changes in cardiac activity, skin conductance, and blood pressure have been measured in some studies in response to food cues. Nederkoorn et al. [23] looked at the physiological changes in normal subjects when exposed to liked foods and found that, compared to baseline, they led to an increase in heart rate, systolic blood pressure, temperature, and skin conductance level. De Wijk et al. [10] looked at the ANS responses while looking at three liked and disliked foods before they were consumed and found that skin conductance response increased while looking at disliked foods compared to liked foods but that heart rate did not differ. Vögele and Florin [24] found that food exposure led to an increase in skin conductance, blood pressure, and heart rate for both binge eaters and normal eaters compared to baseline and that eating led to a further increase in heart rate and blood pressure compared to food exposure. There are still some contradictions among the findings in studies. For example, Overduin and Jansen [25] found that exposing fasting and non-fasting subjects to food did not increase heart rate, skin conductance and salivation. Moreover, the physiological responses when observing food were similar to the ones when observing soap. Another study by Nederkoorn and Jansen [26], however, used a similar procedure with restrained and unrestrained eaters and found that unrestrained eaters showed an increase in heart rate when exposed to food compared to when exposed to soap.

While the aforementioned studies have looked at the anticipatory responses related to the creation of expectations, the efficacy of the ANS responses to capture them is still unclear. Moreover, the measurement of the changes related to the confirmation and disconfirmation of expectations has been neglected by such studies. A link between ANS responses and the disconfirmation of expectations has been previously hypothesized though not yet put into study. George Mandler stated that a disconfirmation of expectations will lead to an activation of the autonomic nervous system. In cases of assimilation, in which the disconfirmation is small, the activation will be low. However, the activation will increase in situations in which assimilation is not possible and it is necessary to modify an expectation [27]. Our study looks into Mandler's theory and evaluates the extent to which ANS responses can capture the reaction to specific visual stimuli as expectations are created and when these same expectations are confirmed and disconfirmed. For this purpose, two studies were conducted in which the ANS responses to the same visual cues were measured. For the first study, images of different valence were presented as main ingredients of food products that participants were asked to drink. The effect of the creation of expectations was measured through the anticipatory responses when the images were presented before consuming the drink. The confirmation and disconfirmation of expectations were assessed through the responses when presenting the images after consuming the drink. The incorporation of images of different valence would serve as an exploratory analysis to additionally test if the effect of the confirmation and disconfirmation of expectations would overrule that of valence. For the second study, participants saw the same images of the three ingredients but were not asked to drink the products. This was done to determine if the effects found were inherent to the image perception or a consequence of the creation or the (dis)confirmation of expectations.

Our hypotheses were: (1) given the increase in physiological responses found when exposed to food cues and the effect that information before a product has on its evaluation [13,20,23,26], the ANS responses during the creation of expectations would be stronger than the responses to the confirmation and disconfirmation of expectations; (2) in line with Mandler's theory regarding expectations, ANS responses

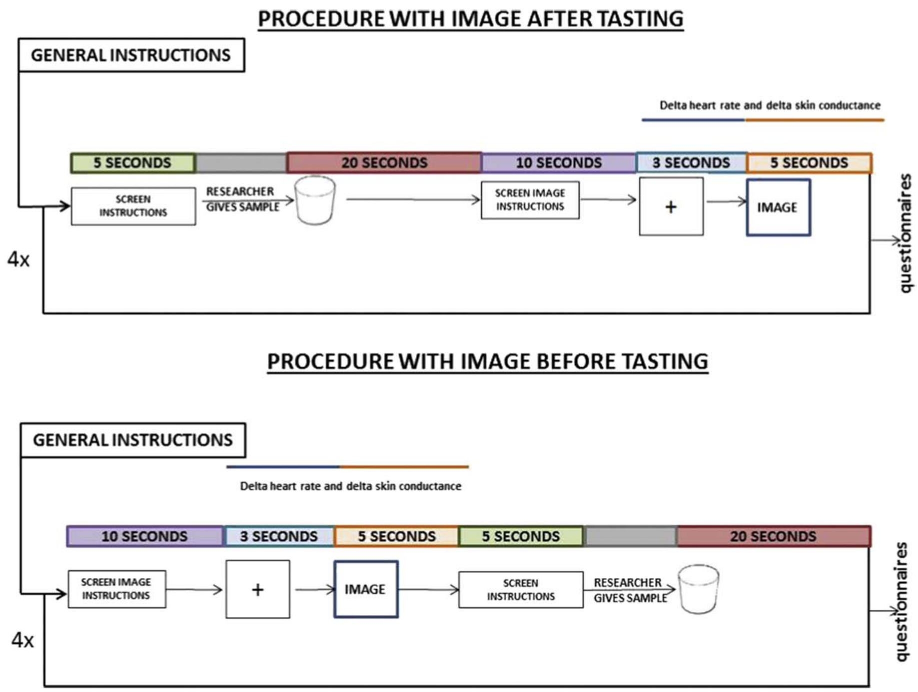


**Fig. 1.** Procedure of Study 1. Heart rate and skin conductance were measured while participants looked at images which were shown before or after tasting a sample. The (+) symbol relates to the fixation crossed that preceded each image.

were expected to be stronger for the images that disconfirmed expectations than for those images that confirmed them. The responses would capture the effect of the initial disconfirmation rather than that of valence. Hence, the responses for positive and negative images that disconfirm expectations were expected to be similar; (3) the differences in ANS responses would not be fully derived from the perception of the images. That is, the effects would only be seen when tasting was included in the design. Hence, we expected that in our second study we would not find the effects of Study 1.

In order to answer the aforementioned hypotheses correctly, certain subjective factors that can influence the intensity of the ANS responses were considered in the design. Given that our current focus is in the food domain, it was important to account for the fact that individuals with high food neophobia have a higher physiological arousal when presented to food stimuli [28]. Other factors accounted for included that subjects with high sensitivity to body signals have been found to experience emotions more intensely and that individuals with high emotional intensity (more intense experience of emotion) present stronger emotional responses to stimuli than individuals with a lower emotional intensity [29,30].

## 2. Study 1

### 2.1. Materials and methods

#### 2.1.1. Procedure

*2.1.1.1. Screening and selection of participants.* Eighty-nine Dutch citizens ranging from 20 to 45 years of age were recruited from the Ede area and surroundings. Participants were excluded if they had a BMI higher than 24.9 kg/m$^2$ (calculated from self-reported height and weight), were color-blind or had any food-related allergies. Participants were given a summary of the procedure that would follow during the study and were asked to schedule an appointment if they agreed to participate. Ethical approval was obtained by the Social Sciences Ethics Committee of Wageningen University.

*2.1.1.2. Experiment session.* The study took place at Wageningen University, the Netherlands; in a well-lit white room. The room was equipped with a table, three chairs, and a computer with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA).

Participants were instructed to refrain from eating or drinking (except water) for 1 h before their appointment and to wear comfortable clothes for the study. The researcher explained the procedure to the participants, giving ample time for questions, and asked them to read and sign the informed consent. Once the informed consent was signed, the researcher started placing the sensor pads.

Heart rate and skin conductance responses were measured continuously throughout the whole study. For the measurement of heart rate, seven sensor pads (Kendall™ H98S8 60 mm micropore ECG electrodes) were placed on each participant; five were on the chest and two on the back. For the measurement of skin conductance, two sensors (Biopac® TSD 203 Electrodermal Response Transducer) were placed, one on the index finger and the other on the middle finger of the non-dominant hand. The researcher checked all signals to avoid any problems due to electrode misplacement. After all signals were checked, a baseline measurement was taken. For this measurement, participants were asked to remain still, to close their eyes, and to breathe normally for 1 min.

The study consisted of tasting drink samples and observing the images of the alleged main ingredients of the samples. The cover story given was that the aim of the research was to study the effect that the bodily reactions had on specific associations when the samples were tasted. Participants were told that they would try four different non-dairy drinks with a similar flavor but with a different main ingredient. Participants were randomly assigned to one of two possible conditions, ensuring that the male: female ratio between them was as similar as possible. The moment the ingredient was shown on the screen varied depending on the assigned condition (Fig. 1). In one condition, participants were shown the image of the main ingredient before tasting the sample (and so forth for the other three samples). For the other condition the design was reversed: participants were shown the image of the main ingredient after the actual tasting of the sample. In reality three of the samples given were the same and one was different to ensure the effectiveness of our design (see Section 2.1.2). For the three identical samples, different images were randomly shown (one neutral, one positive, and one negative, see Section 2.1.3).

Participants were seated in front of a computer and instructed to taste the samples (25 ml) with their eyes closed, leave the sample in their mouth for 20 s and swallow it afterwards. We chose 20 s to give them the impression that the corresponding ingredient would be

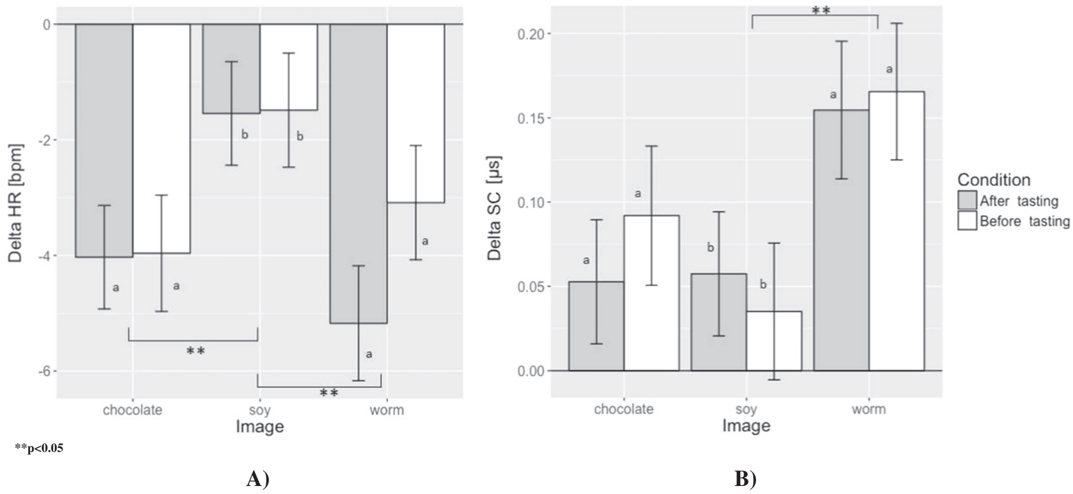


**Fig. 2.** Adjusted mean ( ± SE) of (A) delta heart rate (beats per minute) and (B) delta skin conductance (µs) during the presentation of the images before (N = 34) or after tasting (N = 41). Different letters indicate a significant difference between the group images (Tukey's HSD test, $p < 0.05$).

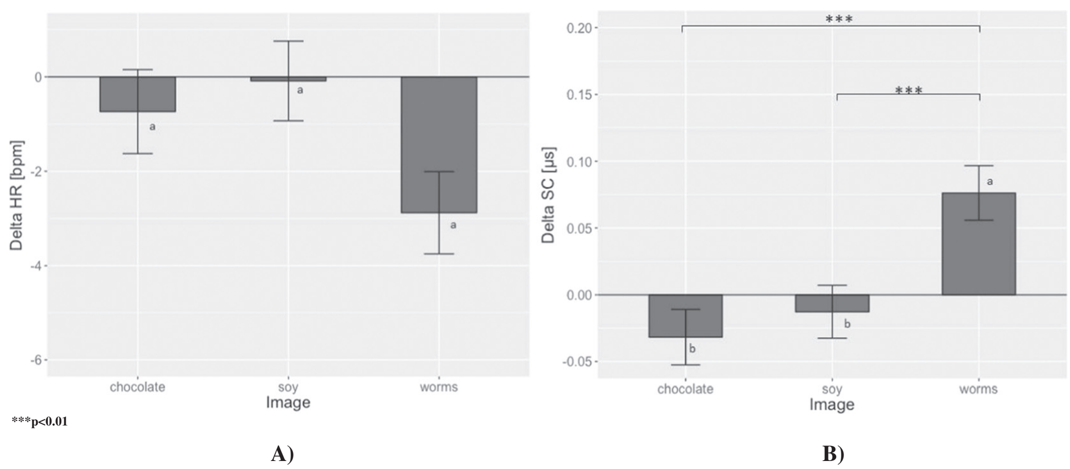


**Fig. 3.** Adjusted mean ( ± SE) of (A) delta heart rate (bpm) and (B) delta skin conductance (µs) during the presentation of the images in Study 2 (N = 40). Different letters indicate a significant difference between the group images (Tukey's HSD test, $p < 0.05$).

present in their mouth for a long time. Participants ate a water cracker (Carr's Original table water, Carr's of Carlisle, UK) and took a sip of water before tasting each sample in order to cleanse their palate. To ensure that they were familiar with the procedure and that all samples were correctly swallowed, they practiced with a water sample first. All images were shown for 5 s and were preceded by a fixation cross that lasted 3 s. To avoid any influence from the movements done during the tasting, a gap of 10 s was added between the tasting of each sample and the presentation of the next image. Participants were asked to avoid any movement and to breathe normally while watching the images (Figs. 2 and 3).

At the end of the study, participants filled out four questionnaires about the remembered sensory characteristics of each sample, the Food Neophobia Scale (FNS) [31], the Private Body Consciousness (PBC) Scale [32], and the reduced Emotional Intensity Scale (EIS-R) [33]. The FNS scale consists of a 10 item questionnaire to measure the avoidance or reluctance to eat novel foods [31]. The PBC scale measures on a 5 item questionnaire the sensitivity to internal bodily sensations [32]. Finally, the EIS-R consists of 17 items representing different emotional experiences, 9 measure positive emotional intensity factors and 6 measure negative emotional intensity factors.

Once participants had finished, they were asked to guess the aim of the study and to give any additional comments. This was done to ensure that any lack of significant results was not due to the participants guessing the aim of the study. After giving their answer, participants were debriefed. They were told which information was false, the real nature of the samples they had tested, and the main objective of the study.

#### 2.1.2. Tasting samples

In order to correctly prevent any influence related to the liking of the samples' flavor, we selected a drink whose flavor would be regarded as neutral. The three repeated samples given in this study consisted of a commercially available unsweetened soy drink (AH zachte soja drink ongezoet, Albert Heijn B.V., Zaandam NL). To improve the taste of the drink, one pill of sweetener (Natrena zoetjes DE Master blenders, Amsterdam the Netherlands) was diluted in 5 ml of hot water and then added to 250 ml of the soy drink.

Pretests with only this soy drink as the tasting stimulus revealed that participants could tell that the three samples were the same. Therefore, a rice drink sample was added and allocated randomly at either the second or the third position in order to prevent having the soy drink presented together three times. The rice drink was prepared in a manner that would ensure that, although participants could tell the sample was different, it was still similar to the soy one which further helped our cover story. It consisted of a combination of 200 ml of a rice drink (Rice Dream, Original organic, Hain Europe NV, Aalter Belgium) and 100 ml of the unsweetened soy drink (AH zachte soja drink ongezoet).

The aforementioned drinks were chosen after pretests with three drinks (sweet soy drink, unsweetened soy drink, and coffee milk) showed that the unsweetened soy drink was the most difficult one to recognize by consumers. We also found that the unsweetened soy drink was disliked by people. Adding the sweetener, however, allowed us to increase the liking at a level in which it was not highly liked nor disliked (liking score = 4.9 ± 1.8 on a 7-point scale) while still ensuring that the drink was not easily recognized. All samples were stored in the fridge and taken out 1 h before the participant's appointment. The samples were served in 30 ml plastic cups.

#### 2.1.3. Visual stimuli

Four images were presented depicting the supposed "main ingredient" of each of the samples. As mentioned above, for the three soy drink samples, three different images (one neutral, one positive, and one negative) were shown. The neutral image consisted of a picture of soy (opened soybean pods), which depicted the real ingredient of the drink. The positive image was a picture of chocolate (dark chocolate) and the negative image was a picture of worms (grub worms). We chose these pictures because insects and chocolate had previously been categorized as negative and positive in other studies [34,35]. The fourth image shown was rice (handful of rice), the main ingredient of the sample that was different from the others in our design. The soy, worms and rice images showed the raw versions of the ingredients. All images were presented in random order except for the rice image which, for the reasons stated previously (see Section 2.1.2), was shown either in the second or the third position. The images used were standardized to a resolution of 450 × 600, 96 dpi sRGB format and set on a white background.

#### 2.1.4. Physiological measurements

Heart rate and skin conductance were measured with the VU-AMS version 3.9 [36]. The ECG had a sampling rate of 1000 Hz and heart rate was obtained from the time between two adjacent R waves. Skin conductance was sampled at a rate of 10 Hz with a signal range between 0 and 95 μs. The signal was filtered both in forward and reverse direction with a low pass filter with a cut off frequency of 2 Hz.

#### 2.1.5. Data treatment and analysis

Heart rate and skin conductance data were extracted and visually inspected for artifacts with the VU DAMS program (version 3.9). For each image, two labels were created: one for the 3 s in which the fixation cross was shown and the other for the 5 s in which each image was shown. The statistical software R version 3.2.2 was used for the analyses of the ANS responses data obtained from the VU DAMS labels. Only the data of the images that corresponded to the three soy samples were analyzed.

The deviation from the baseline for heart rate (delta heart rate) and skin conductance (delta skin conductance) was calculated for each image. We used the average heart rate and average skin conductance from the fixation cross preceding each image as a baseline. To test if the ANS responses differed between images and conditions, the image effect on heart rate and skin conductance was analyzed by means of a mixed model anova stating subject as random factor and the variables image, condition (seeing the image before or after tasting), order of presentation of the images, as well as the interactions between the image and the order, and the image and the condition as fixed factors. The variables gender, age and BMI were assessed in separate models, as previous literature has found differences in ANS responses related to these factors [37–39]. These variables were only added to the main model if their inclusion affected the general outcome of the model. Post hoc analyses for image effects were performed using Tukey's HSD test for multiple comparisons. Additional permutation tests were carried out for the heart rate and skin conductance models when they did not fulfill the normality assumption.

##### 2.1.5.1. Relationship of ANS with reported food neophobia, body consciousness and emotional intensity.

To test the effect of food neophobia, participants were divided into high food neophobics (score higher than 35) and low food neophobics (score lower than 35) on the FNS scale. For both delta heart rate and skin conductance response, a mixed model anova with image, food neophobia and the interaction between the image and food neophobia as fixed factors and subject as random factor was used. To test the effect of private body consciousness, participants were divided into high PBC (higher than the median) and low PBC (lower than the median) and the same model that was used to test the effect of food neophobia was applied. Likewise, for the EIS-R scores the positive and negative subscales were used to divide participants into high and low groups for positive and negative emotions respectively and the effect of both was tested with the same mixed model anova used for FNS and PBC.

### 2.2. Results

Eighty-nine participants completed the study. Seven participants guessed the main aim and were removed from further analysis. The data of four participants could not be used: two due to mistakes during the execution of the study, one due to an error in the electrode placement and one due to a mistake in the software. Two participants showed a higher than normal quantity of ectopic beats and were therefore also excluded from the data analysis. One participant decided to stop with the study. In total, the data of 75 participants, 44 females (mean age = 28.3 ± 6.7, mean BMI = 21.6 ± 1.6 kg/$m^2$) and 31 males (mean age = 30.4 ± 6.9, mean BMI = 22.5 ± 1.4 kg/$m^2$) was used. The demographics of the sample, divided by condition, can be found in Table 1.

#### 2.2.1. Effect of the images during the creation and confirmation/disconfirmation of expectations on heart rate and skin conductance

The following section describes the results of the analyses done to assess the changes in ANS responses caused by images of different valence when expectations are created (presentation before tasting) and when expectations are confirmed and disconfirmed (presentation after tasting). Results for the mixed model analysis for the effect of ingredient images can be found in Table 2. The addition of gender, age and BMI did not affect the main outcome. As a result, the main model (see Section 2.1.5. Data treatment and analysis) was used.

##### 2.2.1.1. Heart rate.

Delta heart rate was significantly different between images ($p = 0.011$). Post hoc tests revealed that the main differences for the images were between the worms and the soy images and the chocolate and the soy images, with a larger decrease for the chocolate and worms images than for the soy image. There was no significant effect for condition ($p = 0.350$) nor for the order of presentation between the images ($p = 0.454$). We found no significant effects for any of the interactions. These results indicate that observing the positive (chocolate) and negative (worms) images led to a stronger decrease in heart rate than observing the neutral image (soy). Contrary to what was expected, the moment the image was presented (either before or after tasting) did not have an effect in these responses.

**Table 1**
Demographics of the sample of Study 1, divided by condition (N = 75).

| | Image after tasting | Image before tasting | *p*-Value |
|---|---|---|---|
| N | 41 | 34 | – |
| Gender | | | |
| Female | 24 | 20 | 0.953[a] |
| Male | 17 | 14 | |
| Age (years) | 28.7 ± 7.0 | 29.7 ± 6–6 | 0.238[b] |
| BMI (kg/$m^2$) | 21.9 ± 1.5 | 21.9 ± 1.7 | 0.744[b] |

[a] *p*-Value calculated with Welch's *t* test.
[b] *p*-Value calculated with Chi-square test.

**Table 2**
Results of the mixed model anova considering image, condition, order of presentation, and two-way interactions with the image (N = 75).

| | Image | | | Before or after tasting | | | Order of presentation | | | Image* before or after tasting | | | Image* order | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | df | F | *p* | df | F | *p* | df | F | *p* | df | F | *p* | df | F | *p* |
| Delta heart rate (bpm) | 2 | 4.680 | 0.011** | 1 | 0.882 | 0.350 | 3 | 0.877 | 0.454 | 2 | 0.803 | 0.450 | 6 | 0.797 | 0.574 |
| Skin conductance response (μs) | 2 | 4.5 | 0.012** | 1 | 0.07 | 0.787 | 3 | 8.1 | < 0.001*** | 2 | 0.4 | 0.694 | 6 | 1.3 | 0.270 |

** Significance at $p < 0.05$.
*** Significance at $p < 0.01$.

*2.2.1.2. Skin conductance*. Delta skin conductance was significantly different for each image ($p = 0.012$). Post hoc tests revealed that the main difference for the image effect was between the worms and soy images, with the worms showing a higher skin conductance response. The difference between the worms and the chocolate was not significant ($p = 0.07$). We found a significant effect for the order of presentation of the images ($p < 0.001$) but not for the interaction between the image and the order of presentation ($p = 0.270$). There was no significant effect for condition ($p = 0.787$) or for the interaction between the image and the condition ($p = 0.694$). These results indicate that, contrary to what was expected, only observing the negative image (worms) led to a higher skin conductance than observing the positive (chocolate) and the neutral image (soy) and that this effect was found regardless of the moment the image was presented (either before or after tasting).

#### 2.2.2. Effect of food neophobia, body consciousness and emotional intensity

From our sample of 75 participants, only five showed high food neophobia (score higher than 35) on the FNS scale. It was, therefore, not possible to perform a valid analysis of the effects of food neophobia. Regarding PBC, 38 participants scored high on the body consciousness scale and 37 scored low. The mixed model anova showed no effect of PBC on any of the ANS responses ($p = 0.908$ for delta heart rate and $p = 0.566$ for delta skin conductance). Analyses of the effect of emotional intensity showed no significant effect for both positive ($p = 0.188$ for delta heart rate and $p = 0.254$ for skin conductance) and negative ($p = 0.950$ for delta heart rate and $p = 0.105$ for skin conductance) emotions.

## 3. Study 2

### 3.1. Procedure

#### 3.1.1. Screening and selection of participants

A sample of forty Dutch participants ranging from 20 to 45 years of age was selected. Participants were students and staff members recruited from the Wageningen area and surroundings. They were excluded if they had participated in Study 1, had a BMI higher than 24.9 kg/m$^2$, were color-blind or had any food related allergies. The Social Sciences Ethics Committee of Wageningen University approved the study.

#### 3.1.2. Experiment session

The study took place in the same room as in Study 1. Participants were instructed to wear comfortable clothes to ensure there would not be any problems with the measurements. On the day of their appointment, participants signed an informed consent before the researcher started placing the sensor pads. All sensor pads were placed as specified in the procedure of Study 1. Participants were informed that they would be shown some images on the computer screen. Before the presentation started, participants were asked to remain still, to close their eyes, and to breathe normally for 1 min.

The study consisted of a presentation of the images, in random order, shown in Study 1 (chocolate, soy, rice, worms). OpenSesame version 3.1.2 [40], a software similar to that of Study 1, was used for the presentation of the images. Participants were told that they would be shown images of ingredients used in newly-developed soy-like drinks. Before the presentation, the researcher made sure participants understood there was no tasting involved. All images were shown for 5 s and were preceded by a fixation cross that lasted 3 s. Heart rate and skin conductance responses were measured throughout the whole study. Participants were asked to avoid any movement and to breathe normally while watching the images. At the end of the presentation, participants filled out a questionnaire that contained questions about the images shown. Once participants had finished the test, they were debriefed.

#### 3.1.3. Physiological measurements, data treatment and analysis

Heart rate and skin conductance were measured with the same VU-AMS version 3.9 used in study 1 [36]. All data were treated similarly as in the previous study. Using the VU DAMS program (version 3.9), the data were extracted, visually inspected for artifacts and labelled. Analyses were done with the statistical software R version 3.2.2.

To test if the ANS responses differed between images, the image effect on heart rate and skin conductance was analyzed by means of a mixed model anova stating subject as random factor and the variables image, order of presentation of the images, as well as the interaction between the image and the order as fixed factors. Gender, age and BMI were only added to the model when their inclusion affected the main outcome. Permutation tests were carried out when the heart rate and skin conductance models did not fulfill the normality assumption. Post hoc analyses for image effects were performed using Tukey's HSD test for multiple comparisons.

### 3.2. Results

From our subsample of 40 participants, 24 were female (mean age = 21.5 ± 2.3, mean BMI = 21.9 ± 1.9 kg/m$^2$) and 16 were male (mean age = 23.1 ± 3.6, mean BMI = 21.45 ± 2.1 kg/m$^2$).

#### 3.2.1. Effect of images on heart rate and skin conductance

The following section describes the results of the analysis done to assess if ANS responses differ upon exposure to images of different valence. This was done to determine if the effects found in Study 1 are a product of the image perception alone. Results for the mixed model analysis for the effect of ingredient images can be found in Table 3. The addition of gender, age and BMI did not affect the main outcome. As a result, the main model (see Section 3.1.3. Physiological measurements, data treatment and analysis) was used.

*3.2.1.1. Heart rate*. The differences in delta heart rate between images were just marginally significant ($p = 0.06$). There was no significant effect for the order of presentation between the images ($p = 0.087$) nor for the interaction between image and order ($p = 0.789$). This result indicates that heart rate did not change when observing images of different valence. This is different to what was seen in Study 1 and, therefore, in line with our expectations.

*3.2.1.2. Skin conductance*. The differences in delta skin conductance between images were significant ($p < 0.001$). Post hoc tests revealed

**Table 3**
Results of the mixed model anova considering image, order of presentation, and the interaction order: image (N = 40).

| | Image | | | Order of presentation | | | Image* order | | |
|---|---|---|---|---|---|---|---|---|---|
| | df | F | $p$ | df | F | $p$ | df | F | $p$ |
| Delta heart rate (bpm) | 2 | 2.95 | 0.06 | 3 | 2.26 | 0.087 | 6 | 0.52 | 0.789 |
| Skin conductance response (μs) | 2 | 7.9 | < 0.001*** | 3 | 21.8 | < 0.001*** | 6 | 2.36 | 0.04** |

** Significance at $p < 0.05$.
*** Significance at $p < 0.01$.

that the main differences were between the worms and the chocolate images and between the worms and the soy images, with the worms having the highest skin conductance response. We additionally found a significant effect for the order of presentation of the images ($p < 0.001$) and for the interaction between the image and the order of presentation ($p = 0.04$). The worms and soy images had a higher skin conductance when they were in the first position compared to the other three but this was not seen for the chocolate image. The results indicate that the changes in skin conductance for the negative image (worms) differed from those for the positive (chocolate) and neutral images (soy). In line with our expectations, these changes were different and smaller than what was found in Study 1. Moreover, they were dependent on the order in which the images were presented.

## 4. General discussion

The aim of this work was to evaluate the ANS responses to images of different valence related to a product when expectations are created (presented before tasting) and when they are confirmed or disconfirmed (presented after tasting) and to further determine if the effects found are due to the image perception alone.

An important finding of this work is that the ANS responses when the images were presented before the tasting were similar to those when the images were presented after. The changes in heart rate and skin conductance between the two conditions did not reach statistical significance. Whenever similar results are found between two conditions, the common interpretation is that they share a common mechanism. However, in the case of our results, this interpretation may not be correct. It may be that the anticipatory reaction from seeing the image before tasting ("I am about to taste this!") had a magnitude similar to that of the confirmation and disconfirmation of the expectations created by the image once the sample had been tasted ("I just tasted this!"). Hence, both conditions (seeing the image before or after tasting) led to similar ANS response patterns even though they were driven by different behavioral mechanisms.

Our results show that the changes in ANS responses differed for heart rate and skin conductance. In the case of heart rate responses, the images with both a positive (chocolate) and a negative valence (worms) showed a larger cardiac deceleration than the neutral image (soy). An effect of valence on heart rate is commonly seen in studies, but what is usually found is that negative stimuli lead to a lower heart rate than positive stimuli. Consequently, negative stimuli should have led to a stronger cardiac deceleration [41]. This is different from what we found in our study, which might lead to the belief that the ANS responses were able to measure the effect of the disconfirmation of expectations regardless of valence. However, according to Bradley et al. [42], the cardiac responses related to picture viewing seem to be more tightly linked to sensory processing. Heart rate deceleration, the usual response to the perceptions of visual stimuli, is a sign of attentional and incoming sensory information. Attention will more likely happen for stimuli that hold a significance/potential impact to the self than for neutral stimuli [43]. This goes in hand with Lacey and Lacey's theory, which states that deceleration accompanies the motivation to note and detect events while acceleration motivates ignoring certain events. When there is something that subjects find attractive or pleasant, attention is increased. Attention, however, can also be increased when subjects see something negative or aversive as this is a biologically advantageous mechanism [44]. Hence, we need to consider that, compared to the neutral image, the images with a positive and a negative valence might have had the same effect on motivation and, in consequence, directed the attention of participants to the same extent for the incoming sensory information.

For the skin conductance responses, only the worms image led to a higher skin conductance than the soy image, while no differences between the responses to the soy and the chocolate image were observed. The measurement of skin conductance in psychophysiology is related to the responsiveness of the humane eccrine sweat glands to emotional stimuli. If a stimulus increases the defensive or appetitive motivation systems of a person, the skin conductance will increase. Whether a negative or a positive stimulus leads to a similar activation depends on the content and proportion of arousal of the stimulus [42]. The soy image triggered a low activation due to its neutral valence and congruence. Regarding the worms and chocolate image, it is possible that the worms image triggered a stronger defensive response than the appetitive response for the chocolate and therefore only the worms were significantly different from the soy. Food aversions might also have had an effect on the strong defense activation found for worms. Food aversions are usually linked to unpleasantness due to the nausea and vomiting that happen when a dangerous food is ingested [45,46]. This link might have strengthened the response to the worms image.

Study 2 showed that presenting the same images without making participants believe that they will taste them led to changes in ANS responses that did not completely match those of Study 1. The worms image led to a stronger cardiac deceleration and a higher skin conductance than the chocolate and soy images. These changes, however, only reached statistical significance for skin conductance. Nevertheless, the patterns observed in Study 2 are in line with what has been found in previous research regarding visual stimuli (stronger cardiac deceleration for unpleasant stimuli and increased skin conductance for arousing stimuli) [41,47,48]. Given that the responses in Study 1 and Study 2 differ, it is likely that the changes in ANS responses obtained in Study 1 are not fully due to visual perception.

It remains to be determined whether the size of the changes obtained in Study 2 for both heart rate and skin conductance could be considered as physiologically relevant. The highest mean difference obtained in skin conductance between the baseline and the image was 0.08 μs while skin conductance responses related to novel, unexpected, significant or aversive stimuli often range between 0.2 and 1.0 μs [49]. Likewise, the heart rate differences between the baseline and the image for the soy and chocolate images did not reach one beat. Published studies have found larger differences in heart rate and skin conductance when observing stimuli than the ones encountered in Study 2. For instance, Bradley et al. [48] found changes between baseline and picture presentation of $1.1 \pm 0.69$ bpm and of $-0.24 \pm 0.10$ μs, for heart rate and skin conductance respectively, while observing pleasant pictures that cue safety and of $-1.2 \pm 0.63$ bpm and $-0.20 \pm 0.10$ μs for unpleasant pictures that cue safety. Overduin and Jansen [25] found that the changes in non-fasting subjects between baseline and the presentation of a food were of $3.6 \pm 4.1$ bpm for heart rate and of $1.82 \pm 1.5$ μs for skin conductance. Fasting subjects had heart rate changes of 6.8 ± 4.9 bpm and skin conductance changes of 0.47 ± 1.1 μs. It should be noted, however, that other factors from both study designs may have been playing a role in the magnitude of the responses. Bradley's study, for instance, used connotations linked with safety and threat and hence the responses to the images were more extreme. Likewise, the design of Overduin's study allowed other cues related to the exposure of each food (e.g., odor) to contribute in making the experience stronger.

The abovementioned differences pinpoint the importance of the whole multisensory experience and the context while testing the consumers' responses to food products. In Study 2, showing the images without any particular connotations might have led to a lack of engagement from participants. Noseworthy et al. [50] had previously shown that participants that are bored or less interested (low aroused state) do not show differences in skin conductance when presented with images with incongruities. Participants from Study 2 may not have found the sensory experience relevant to their needs and, consequently, the mechanisms related to image perception were weak. In contrast, the responses of the participants from Study 1, where there was a tasting related to the images, were of a larger magnitude. It seems, therefore, that ensuring that participants find the sensory experience relevant (e.g., by telling them that they will taste what is shown) is of importance for the measurement of strong ANS responses to food products.

Our study has certain limitations. Even though heart rate and skin conductance responses were also measured at the moment of tasting in Study 1, the breathing patterns and movements of the participants were not fully controlled during this moment. As a consequence, the data during the moment of tasting contained noise and could not be additionally considered for this work. In addition to this, we did not ask participants to rate their liking of the sample immediately after each tasting. Such data could have allowed us to assess the link between expectations, liking and ANS responses. Regarding the responses found for the images in Study 1, further studies should be conducted to confirm our findings about what these responses represent. This may be challenging as the variety of ANS measures, units and procedures used in published studies make comparisons difficult. It is necessary to develop a standardized measurement procedure which should be followed by future studies in order to have comparable results.

The present work attempted to assess and complement Mandler's theory by capturing the ANS responses when expectations are created and when they are confirmed and disconfirmed. The obtained results bring more insight into the validity of the use of ANS responses in the food domain and help understand the processes captured by ANS responses when presented to visual stimuli. Moreover, it considers that in some cases the differences in ANS responses might not be meaningful from a physiological point. Future research should look further into this topic considering that ANS responses are more insightful under a certain context of use. For example, the testing of novel foods that contain ingredients with a variety of scores in the arousal and pleasantness dimensions might be of interest. When designing such tests, however, it is necessary to consider the possibility that ANS responses may be more sensitive to relevant situations that show contrast (positive vs negative, safety vs threat) rather than similarity. In the case of novel foods, a potential contrast could be comparing the responses when first experiencing the product to those of subsequent tastings. The changes in ANS responses after continuous exposure to these foods might help capture the principles of acceptability.

## 5. Conclusion

The present work evaluated the changes in ANS responses related to observing images of different valence when expectations are created and when they are confirmed and disconfirmed. To the best of our knowledge, this is the first study to propose these two mechanisms together to help explain our physiological responses to food stimuli. The results of our research showed that the ANS responses obtained through the anticipatory responses related to the creation of expectations did not greatly differ from those measured during the confirmation and disconfirmation of expectations. In both cases, positive and negative images led to a stronger cardiac deceleration than neutral images. Moreover, the negative image led to a higher skin conductance than the positive and neutral image. The ANS responses obtained were a result of the sensory processing and defense mechanisms happening during the creation and (dis)confirmation of expectations. The second study confirmed that the effects were not fully due to visual processing. Hence, it seems that the context of use has an influence on the patterns and magnitude of the ANS responses to food cues. It is necessary for the individual to find the sensory experience relevant in order to have an effect large enough to be considered significant (both statistically and physiologically).

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Funding

This work is part of the FOCOM project, which was supported by the European Regional Development Fund and the Dutch provinces Gelderland and Overijssel (Grant number 2011P017004). The content of the paper reflects only the views of the authors.

## Acknowledgements

The authors would like to thank Essensor B.V. for their help with the recruitment of participants, Priya Dewansingh, MSc for her support during the execution of Study 1 and Tiffany Oei, MSc for her help in the editing and proofreading of the manuscript.

## References

[1] E.P. Köster, The psychology of food choice: some often encountered fallacies, Food Qual. Prefer. 14 (2003) 359–373.
[2] L. Danner, S. Haindl, M. Joechl, K. Duerrschmid, Facial expressions and autonomous nervous system responses elicited by tasting different juices, Food Res. Int. 64 (2014) 81–90.
[3] L.K. McCorry, Physiology of the autonomic nervous system, Am. J. Pharm. Educ. 71 (2007).
[4] A. Kistler, C. Mariauzouls, K. von Berlepsch, Fingertip temperature as an indicator for sympathetic responses, Int. J. Psychophysiol. 29 (1998) 35–41.
[5] R.A. de Wijk, S. Boesveldt, Responses of the autonomic nervous system to flavours, Multisensory Flavor Perception: From Fundamental Neuroscience Through to the Marketplace, Woodhead Publishing, 2016.
[6] W.B. Mendes, E. Harmon-Jones, J.S. Beer, Assessing Autonomic Nervous System Activity. Methods in Social Neuroscience, Guilford Press, New York, NY, US, 2009, pp. 118–147.
[7] W. He, S. Boesveldt, C. de Graaf, R.A. de Wijk, Dynamics of autonomic nervous system responses and facial expressions to odors, Front. Psychol. 5 (2014).
[8] K. Quigley, K. Lindquist, L. Feldman-Barret, Inducing and measuring emotion and affect. Tips, tricks and secrets, in: H.T. Reis, C.M. Judd (Eds.), Handbook of Research Methods in Social and Personality Psychology, Cambridge University Press, 2014, pp. 238–239.
[9] I.B. Mauss, M.D. Robinson, Measures of emotion: a review, Cognit. Emot. 23 (2009) 209–237.
[10] R.A. de Wijk, W. He, M.G.J. Mensink, R.H.G. Verhoeven, C. de Graaf, ANS responses and facial expressions differentiate between the taste of commercial breakfast drinks, PLoS One 9 (2014) e93823.
[11] T. Horio, Effects of various taste stimuli on heart rate in humans, Chem. Senses 25 (2000) 149–153.
[12] A. Leterme, L. Brun, A. Dittmar, O. Robin, Autonomic nervous system responses to sweet taste: evidence for habituation rather than pleasure, Physiol. Behav. 93 (2008) 994–999.
[13] R.A. de Wijk, V. Kooijman, R.H.G. Verhoeven, N.T.E. Holthuysen, C. de Graaf, Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods, Food Qual. Prefer. 26 (2012) 196–203.
[14] O. Robin, S. Rousmans, A. Dittmar, E. Vernet-Maury, Gender influence on emotional responses to primary tastes, Physiol. Behav. 78 (2003) 385–393.

[15] L.N. van der Laan, D.T.D. de Ridder, M.A. Viergever, P.A.M. Smeets, The first taste is always with the eyes: a meta-analysis on the neural correlates of processing visual food cues, NeuroImage 55 (2011) 296–303.
[16] B. Piqueras-Fiszman, C. Spence, Sensory expectations based on product-extrinsic food cues: an interdisciplinary review of the empirical evidence and theoretical accounts, Food Qual. Prefer. 40 (Part A) (2015) 165–179.
[17] P. Tarancón, T. Sanz, S. Fiszman, A. Tárrega, Consumers' hedonic expectations and perception of the healthiness of biscuits made with olive oil or sunflower oil, Food Res. Int. 55 (2014) 197–206.
[18] H.T. Lawless, H. Heymann, Sensory Evaluation of Food: Principles and Practices, Springer, 1999.
[19] A.V. Cardello, Measuring consumer expectations to improve food product development, Consumer-Led Food Product Development, Woodhead Publishing, 2007, pp. 223–261.
[20] L. Lee, S. Frederick, D. Ariely, Try it, you'll like it: the influence of expectation, consumption, and revelation on preferences for beer, Psychol. Sci. 17 (2006) 1054–1058.
[21] O. Davidenko, J. Delarue, A. Marsset-Baglieri, G. Fromentin, D. Tomé, N. Nadkarni, et al., Assimilation and contrast are on the same scale of food anticipated-experienced pleasure divergence, Appetite 90 (2015) 160–167.
[22] E. Fonberg, Control of emotional behaviour through the hypothalamus and amygdaloid complex, CIBA Found. Symp. 8 - Physiology, Emotion and Psychosomatic Illness, John Wiley & Sons, Ltd., 2008, pp. 131–161.
[23] C. Nederkoorn, F.T.Y. Smulders, A. Jansen, Cephalic phase responses, craving and food intake in normal subjects, Appetite 35 (2000) 45–55.
[24] C. Vögele, I. Florin, Psychophysiological responses to food exposure: an experimental study in binge eaters, Int. J. Eat. Disord. 21 (1997) 147–157.
[25] J. Overduin, A. Jansen, Food cue reactivity in fasting and non-fasting subjects, Eur. Eat. Disord. Rev. 4 (1996) 249–259.
[26] C. Nederkoorn, A. Jansen, Cue reactivity and regulation of food intake, Eat. Behav. 3 (2002) 61–72.
[27] G. Mandler, The structure of value: accounting for taste, in: M.S. Clark, S.T. Fiske (Eds.), Affect and Cognition: 17th Annual Carnegie Mellon Symposium on Cognition, Taylor & Francis, 2014, pp. 22–23.
[28] B. Raudenbush, A. Capiola, Physiological responses of food neophobics and food neophilics to food and non-food stimuli, Appetite 58 (2012) 1106–1108.
[29] O. Pollatos, E. Traut-Mattausch, H. Schroeder, R. Schandry, Interoceptive awareness mediates the relationship between anxiety and the intensity of unpleasant feelings, J. Anxiety Disord. 21 (2007) 931–943.
[30] R.M. McFatter, Emotional intensity: some components and their relations to extra version and neuroticism, Personal. Individ. Differ. 24 (1998) 747–758.
[31] P. Pliner, K. Hobden, Development of a scale to measure the trait of food neophobia in humans, Appetite 19 (1992) 105–120.
[32] L.C. Miller, R. Murphy, A.H. Buss, Consciousness of body: private and public, J. Pers. Soc. Psychol. 41 (1981) 397–406.
[33] M. Geuens, P. de Pelsmacker, Validity and reliability of scores on the reduced emotional intensity scale, Educ. Psychol. Meas. 62 (2002) 299–315.
[34] E.T. Berkman, M.D. Lieberman, Approaching the bad and avoiding the good: lateral prefrontal cortical asymmetry distinguishes between action and valence, J. Cogn. Neurosci. 22 (2010) 1970–1979.
[35] B. Piqueras-Fiszman, A.A. Kraus, C. Spence, "Yummy" versus "Yucky"! Explicit and implicit approach–avoidance motivations towards appealing and disgusting foods, Appetite 78 (2014) 193–202.
[36] E.J.C. de Geus, G.H.M. Willemsen, C.H.A.M. Klaver, L.J.P. van Doornen, Ambulatory measurement of respiratory sinus arrhythmia and respiration rate, Biol. Psychol. 41 (1995) 205–227.
[37] F.M. Kopacz, B.D. Smith, Sex differences in skin conductance measure as a function of shock threat, Psychophysiology 8 (1971) 293–303.
[38] E. Carrillo, L. Moya-Albiol, E. González-Bono, A. Salvador, J. Ricarte, J. Gómez-Amor, Gender differences in cardiovascular and electrodermal responses to public speaking task: the role of anxiety and mood states, Int. J. Psychophysiol. 42 (2001) 253–264.
[39] I. Antelmi, R.S. De Paula, A.R. Shinzato, C.A. Peres, A.J. Mansur, C.J. Grupi, Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease, Am. J. Cardiol. 93 (2004) 381–385.
[40] S. Mathôt, D. Schreij, J. Theeuwes, Open Sesame: an open-source, graphical experiment builder for the social sciences, Behav. Res. Methods 44 (2012) 314–324.
[41] A.-M. Brouwer, N. van Wouwe, C. Mühl, J. van Erp, A. Toet, Perceiving blocks of emotional pictures and sounds: effects on physiological variables, Front. Hum. Neurosci. 7 (2013) 295.
[42] M.M. Bradley, P.J. Lang, The International Affective Pictures System (IAPS) in the study of emotion and attention, in: J.A. Coan, J.B. Allen (Eds.), Handbook of Emotion Elicitation and Assessment, Oxford University Press, USA, 2007, pp. 29–46.
[43] J.P. Sánchez-Navarro, J.M. Martínez-Selva, G. Torrente, F. Román, Psychophysiological, behavioral, and cognitive indices of the emotional response: a factor-analytic study, Span. J. Psychol. 11 (2008) 16–25.
[44] B.C. Lacey, J.I. Lacey, Studies of heart rate and other bodily processes in sensorimotor behaviour, in: P.A. Obrist, A.H. Black, J. Brener, L.V. Dicara (Eds.), Cardiovascular Psychophysiology: Current Issues in Response Mechanisms, Biofeedback and Methodology, Transaction Publishers, 2007.
[45] E.E. Midkiff, I.L. Bernstein, Targets of learned food aversions in humans, Physiol. Behav. 34 (1985) 839–841.
[46] M. Profet, Pregnancy sickness as adaptation: a deterrent to maternal ingestion of teratogens, in: H.J.H. Barkow, H.L. Cosmides, J. Tooby (Eds.), The Adapted Mind: Evolutionary Psychology and the Generation of Culture: Evolutionary Psychology and the Generation of Culture, Oxford University Press, USA, 1995, p. 328.
[47] A.O. Hamm, H.T. Schupp, A.I. Weike, Motivational organization of emotions: autonomic changes, cortical responses and reflex modulation, in: R.J. Davidson, K.R. Scherer, H.H. Goldsmith (Eds.), Handbook of Affective Sciences, Oxford University Press, New York, USA, 2002, pp. 187–194.
[48] M.M. Bradley, B. Moulder, P.J. Lang, When good things go bad: the reflex physiology of defense, Psychol. Sci. 16 (2005) 468–473.
[49] M.E. Dawson, A.M. Schell, D.L. Filion, The electrodermal system, in: J.T. Cacioppo, L.G. Tassinary, G.G. Berntson (Eds.), Handbook of Psychophysiology, 3rd ed., Cambridge University Press, New York, New York US, 2000, pp. 200–223.
[50] T.J. Noseworthy, F. Di Muro, K.B. Murray, The role of arousal in congruity-based product evaluation, J. Consum. Res. 41 (2014) 1108–1126.