Article

Food-Evoked Changes in Humans

Startle Response Modulation and Event-Related Brain Potentials (ERPs)

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Abstract. Two experiments investigate effects related to food intake in humans. In Experiment 1, we measured startle response modulation while study participants ate ice cream, yoghurt, and chocolate. Statistical analysis revealed that ice cream intake resulted in the most robust startle inhibition compared to no food. Contrasting females and males, we found significant differences related to the conditions yoghurt and chocolate. In females, chocolate elicited the lowest response amplitude followed by yoghurt and ice cream. In males, chocolate produced the highest startle response amplitude even higher than eating nothing, whereas ice cream produced the lowest. Assuming that high response amplitudes reflect aversive motivation while low response amplitudes reflect appetitive motivational states, it is interpreted that eating ice cream is associated with the most appetitive state given the alternatives of chocolate and yoghurt across gender. However, in females alone eating chocolate, and in males alone eating ice cream, led to the most appetitive state. Experiment 2 was conducted to describe food intake-related brain activity by means of source localization analysis applied to electroencephalography data (EEG). Ice cream, yoghurt, a soft drink, and water were compared. Brain activity in rostral portions of the superior frontal gyrus was found in all conditions. No localization differences between conditions occurred. While EEG was found to be insensitive, startle response modulation seems to be a reliable method to objectively quantify motivational states related to the intake of different foods.

Keywords: food consumption, emotion quantification, startle response modulation

Introduction

Most often, researchers have been interested in varying the motivational states of their study participants in order to investigate food-induced information processing under such controlled conditions (e.g., Macht, Roth, & Ellgring, 2002; O'Doherty et al., 2000; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001). Conversely, in 2006 Macht and Dettmer reported about everyday mood and emotions after eating a chocolate bar or an apple, one of the rare cases investigating the affective effects of food. In their study, 37 healthy and normal-weight women ate a chocolate bar, an apple, or nothing and rated their subjective state 5, 30, 60 and 90 min after eating. The result was that both chocolate and apple reduced hunger, elevated mood, and increased activation, though the effects of chocolate were stronger. Similarly, the present study intends to describe the effects of food on emotion-related functions in the human brain, albeit by means of electroencephalography (EEG) and by using startle response modulation (e.g., Lang, Bradley, & Cuthbert, 1990).

Startle response modulation has rarely been used to investigate food-induced motivational changes (e.g., Friederich et al., 2006; Lüthy et al., 2003), although it is well known from numerous other studies including clinical applications. Friederich et al. (2006) demonstrated the reliability of startle response modulation related to food pictures in patients with anorexia and bulimia nervosa. However, startle response modulation related to real food intake has (to our knowledge) never been investigated. The so-called startle response (see Blumenthal et al., 2005; Lang et al., 1990; Szabo, 1964; Vrana, Spence, & Lang, 1988; Yeomans & Frankland, 1996) denotes an evolutionary old and robust phenomenon. In fact, it is a sudden involuntary movement (muscle contraction) in response to an intense and unexpected stimulus with a steep rising time (e.g., loud noise) in order to withdraw the whole organism from harm. While stimulus modality is more or less irrelevant, experiments were most often conducted by using the acoustic canal to investigate the startle response. In the acoustic domain this automatic response is mediated via the nucleus cochlearis and the nucleus reticularis pontis caudalis which is part of the *reticular formation* (e.g., Yeomans & Frankland, 1996). From there, neurons directly project to motor neurons

DOI: 10.1027/0269-8803/a000003

that elicit respective muscle contractions. Strikingly, other neural circuits involved in emotion and motivation processing interact with a startle response modulating its magnitude (startle response modulation). This modulation was first described in animals (mostly rats), although startle response modulation has now long been introduced to human investigations (e.g., Grillon & Baas, 2003). In principle, it is suggested that the magnitude of this modulation correlates with an organism's ongoing motivational state (Vrana et al., 1988): The more aversive the motivational state, the more intense the startle response and vice versa. In their review, Filion, Dawson, and Schell (1998) mention that cognitive as well as emotional processing can modulate a startle response, especially when using long lead stimulation. Friederich et al. (2006) again emphasized that startle response modulation has been used because of its sensitivity to motivational states of approach (appetitive response) and withdrawal (aversive response). The strong benefit certainly is its objective character. No questionnaires or other methods demanding conscious verbal output have to be used. The startle response is an automatic response and not primarily influenced by intentional control and is resistant to demand effects and response biases that can interfere with verbal reports and voluntary motor responses (Friederich et al., 2006; Grillon & Baas, 2003). The neural network underlying the startle response works below the level of consciousness and therefore allows an objective description of very subjective motivational events.

In humans, contractions of the musculus orbicularis oculi (responsible for an eyeblink) in response to a short loud noise was often chosen to investigate startle response modulation (Blumenthal et al., 2005; Landis & Hunt, 1939). Such muscle contractions can be quantified by electromyography (EMG). For the present study, this approach was chosen in order to objectively quantify the motivational state of human study participants eating different kinds of food. According to recently published guidelines for human startle eyeblink electromyographic studies (Blumenthal et al., 2005), acoustic white noise was presented via headphones as startle stimuli. Associated short involuntary eyeblinks were registered and quantified.

As mentioned above, we were also interested in recording brain activities related to food intake. Event-related potentials (ERPs) were already used to describe brain activity related to gustatory information processing (e.g., Schmitt, Mölle, Marshall, Hallschmid, & Born, 2001; Hallschmid, Mölle, Fischer, & Born, 2002; Hallschmid, Mölle, Wagner, Fehm, & Born, 2001). As a result, the *orbitofrontal cortex* has been described as a key structure involved in taste perception and reward appreciation. The combination of both experimental approaches is expected to represent a reliable contribution to objectively investigating motivational states of human subjects eating different kinds of food.

Methods

Study Participants

In total, 40 volunteers (20 females, 20 males) participated in the present study. They were university students without any neuropathological history. They all had normal or corrected-to-normal vision, and none of them particularly favored one of the provided kinds of food (as assessed by a questionnaire-based investigation). In the startle response experiment, 20 study participants (10 females, 10 males) were investigated. Their mean age was 26.4 years (SD = 3.5). In the EEG experiment, the other group of 20 study participants (10 females, 10 males) was investigated. Their mean age was 27 years (SD = 4.7).

Procedure

Startle Response Experiment

The acoustic stimulus to elicit a startle response, in our case a short eyeblink, was 50 ms white noise at 100 dB sound pressure level delivered via headphones. Two electrodes placed under the right eye were used for bipolar electromyography (EMG) of the musculus orbicularis oculi of the right eye of every study participant (plus one additional ground electrode). EMG sampling rate was 3000/s with no filtering.

Study participants were seated on a comfortable chair and viewed a TFT monitor in front of them used to present a video showing a fire burning for 50 min (visual standard situation). During the video presentation time four different food conditions were provided: "ice cream," "yoghurt," "chocolate," and "no food." Each condition lasted for 10 min and condition order was varied between study participants to eliminate any possible order effects. Study participants were asked to slowly eat a predefined amount of each food during the respective 10 min time window. While eating, they watched the video, and after 10 minutes new food was served according to a predefined list for standardized variation of food condition order between subjects. For every food condition four startle stimuli were presented with a random inter stimulus interval varying from 90 s to 150 s. At the very beginning of the experiment, before the commencement of the four food conditions, a first test startle stimulus was delivered in order to enable later consideration of individual differences in absolute startle response.

EEG Experiment

EEG signals were recorded from 61 equidistant sites using an electrode cap. Four additional electrodes were used in order to register eye movements for later artefact rejection. A bandpass filter from DC to 100 Hz was used. EEG was

registered with a sampling rate of 250/s. An offline bandpass filter from DC to 35 Hz was used for data analysis.

Stimulus delivery was done with filled plastic syringes, which were pressed out by study participants themselves. Those syringes (without a needle) were filled with all foods of interest (low viscosity edibles) prior to the experiment and kept in a refrigerator. For every study participant 40 syringes were filled with ice cream, 40 with yoghurt, 40 with a sweet soft drink, and 40 with water to provide a control condition. In total, 160 stimulus presentations were provided for every study participant. Five consecutive syringes including the same stimulus represented one presentation block. Consequently, eight such blocks were provided per stimulus condition (for a total of 32 blocks). Stimuli varied between blocks in random order (across study participants) and were controlled by the experimenter, who handed out all syringes successively. The first syringe was handed out after commencement of the EEG registration. A red cross was presented for 7 s to 15 s on a computer monitor positioned in front of a comfortable seat where study participants had been placed. During this time, participants were instructed to bring the respective syringe close to the mouth and to be ready to press out its content into the mouth. Then, an orange cross was presented for 1 s associated with the instruction to await a following green cross and then to start pressing out the content as soon as it appears and to keep the content on the tongue without moving the jaw and tongue until the end of the green cross period (12 s). After that a white cross appeared for 1 s associated with the instruction to swallow the content and to put the syringe away in order to be ready for the next go. Stimulus delivery was trained before the actual start of the experiment.

Statistical Analyses

Startle Response Experiment

All EMG data were filtered offline from 60 to 800 Hz. They were rectified and finally 300 data points within a time window of 100 ms (starting 35 ms after the onset of the acoustic stimulus) were averaged to end up with a single number representing one startle response associated with a distinct food condition. In fact, four such numbers per food condition and per subject resulted from this experimental design. The last three numbers were then taken as dependent variables for ANOVA calculation. Food condition was introduced as within subject factor with four levels (ice cream, yoghurt, chocolate, no food) and gender was used as between subject factor (two levels; females and males). In addition, the startle response related to the first test startle stimulus was used as a covariate in order to eliminate interindividual differences related to baseline startle responses.

EEG Experiment

Preprocessing of EEG Data

First, eye movements and blink artifacts were eliminated offline using a linear regression approach with channel-specific correction parameters (Bauer & Lauber, 1979). EOG parameters were determined separately for vertical and horizontal eye movements in an EOG calibration task. Blink coefficients were calculated using a template matching procedure. After EOG and blink correction epochs from 5 s before to 11 s after stimulus (green cross) onset were defined.

Second, an artifact-rejection procedure based on independent component analysis was applied. To this end, extracted SCP time series across all conditions were decomposed per subject into temporal independent but spatially fixed components using an extended-infomax algorithm (Makeig, Jung, Bell, Ghahremani, & Sejnowski, 1997). Each resulting independent component was comprised of its activation time course and an associated spatially component sensor map. Additionally, frequency spectra as well as equivalent dipole source localizations were calculated for each component. Based on these measures, independent components that could not directly be related to brain activity were discarded. Subsequently, all non-artifact components were projected back, and the resulting artifact free single-trials were averaged separately for each condition with the baseline being the mean amplitude of the 1 s epoch preceding the task (yellow cross). Furthermore, the grand mean for each condition across all subjects was calculated. The mean amplitudes over 250 ms epochs in the range of 1.5 s to 7 s after stimulus onset were determined for all single-subject averages and the grand means to receive smoothed signals. These extracted signals were then used for source localization.

Source Localization

Standardized low resolution brain electromagnetic tomography (sLORETA, Pascual-Marqui, 2002), version 2006-July available from the KEY Institute for Brain-Mind Research at the University of Psychiatry, Zurich; an associated Institute of the University of Zurich, Switzerland, was used to calculate statistical maps of the underlying neural generators. Unlike LORETA (Pascual-Marqui, Michel, & Lehmann, 1994), sLORETA is a distributed source modeling method that does not compute current density estimates, but statistical scores. These scores are derived by performing a location-wise inverse weighting of the results of a minimum norm least squares (MNLS) analysis with their estimated variance. These variance measures are computed from the prior source variances and the measurement noise (Pascual-Marqui, 2002; Wagner, Fuchs, & Kastner, 2004). For the inverse solution sLORETA uses a realistic head model with a spatial resolution of 5 × 5 × 5 mm, resulting in 6239 cortical gray matter voxels, cal-

culated from the MNI152 template (Mazziotta et al., 2001) using the boundary element method (see Fuchs, Kastner, Wagner, Hawes, & Ebersole, 2002 for details about the head model). Under ideal conditions sLORETA has proved to have zero localization error (Greenblatt, Ossadtchi, & Pflieger, 2005; Sekihara, Sahani, & Nagarajan, 2005) and is capable of localizing multiple point sources with low resolution even under the presence of noise (Wagner et al., 2004).

Although sLORETA calculates pseudostatistical values that can be used for hypothesis testing, it is recommended to view them as estimates of neural activity. Thus, for a descriptive analysis of the resulting brain images a 99% confidence interval (CI) of the grand mean activity values was calculated for each condition. Voxels lying outside of the confidence interval throughout the whole analysis interval were termed significantly activated. For the comparisons of the different conditions the sLORETA activity measures were applied to statistical nonparametric mapping (SnPM, Nichols & Holmes, 2002). Condition differences were assessed pairwise by calculating dependent-sample *t*-values for each voxel across all timepoints using subject-wise normalized log-transformed sLORETA values. Group differences (female vs. male) were assessed by independent-sample *t*-tests using subject-wise normalized and log-transformed sLORETA values. The resulting T-max statistics were based on 5,000 permutations – randomly drawn condition configurations tested against the original configuration. The two-tailed significance threshold was set at $p \leq .05$; no correction for multiple comparisons is needed since this is already inherently accounted for. Coordinates in MNI space, anatomical structures, and Brodmann areas for all significantly activated regions are reported.

Results

Startle Response Experiment

The mean test startle response across all study participants was 11.84 µV (*SD* = 7.11). The mean startle responses related to single food conditions were 9.91 µV (*SD* = 5.89) for ice cream, 10.45 µV (*SD* = 8.11) for yoghurt, 10.61 µV (*SD* = 7.82) for chocolate, and 10.95 µV (*SD* = 6.79) for no food (see Figure 1). The main effect of Food condition as calculated with ANOVA was not significant, $F(1, 879) = 2.014$, $p = .152$; Greenhouse-Geisser corrected. Introducing test startle response as a covariate ANOVA revealed a significant Food condition and Test startle response interaction, $F(1, 879) = 3.766$, $p = .036$; Greenhouse Geisser corrected, demonstrating that the distribution of Food condition responses depends on the individual response level. Linear contrasts comparing each food condition separately with the condition no food (again with test startle response as a covariate) revealed

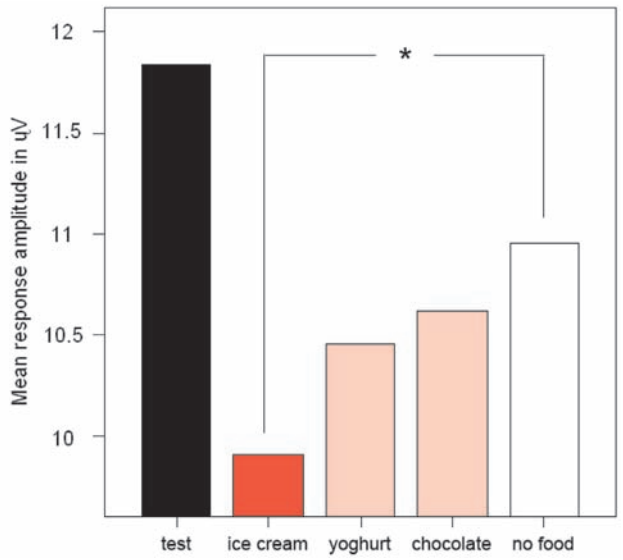

Figure 1. Mean startle response amplitudes related to all food conditions and related to the very first test startle stimulus across all 20 study participants. Note that all food conditions elicited lower startle responses than the first test startle stimulus. *Ice cream* elicited the lowest startle response indicating the most appetitive motivational state. Only the difference between *ice cream* and *no food* is statistically significant if pair-wise compared (as indicated).

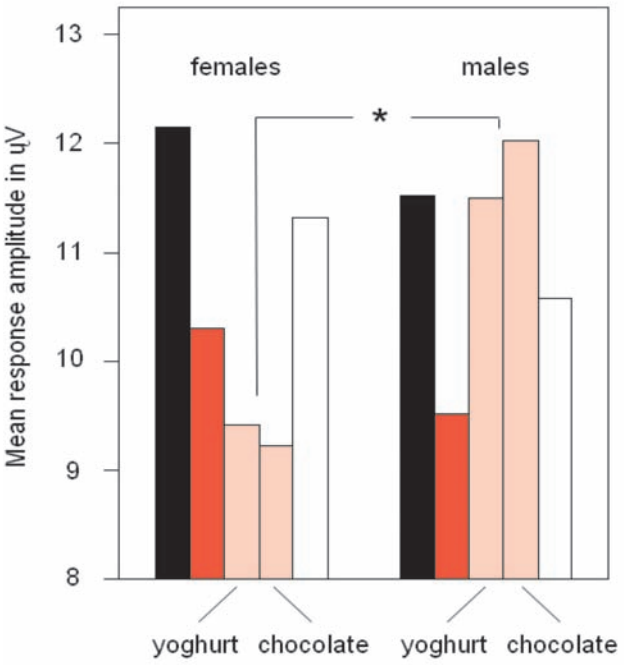

Figure 2. Mean startle response amplitudes related to all food conditions and related to the very first test startle stimulus for females and males separately. Note that the conditions *ice cream* (red bar) and *no food* (white bar) elicited similar startle responses in females and males. However, *yoghurt* and *chocolate* are associated with significantly different startle responses with respect to gender (significant differences are indicated).

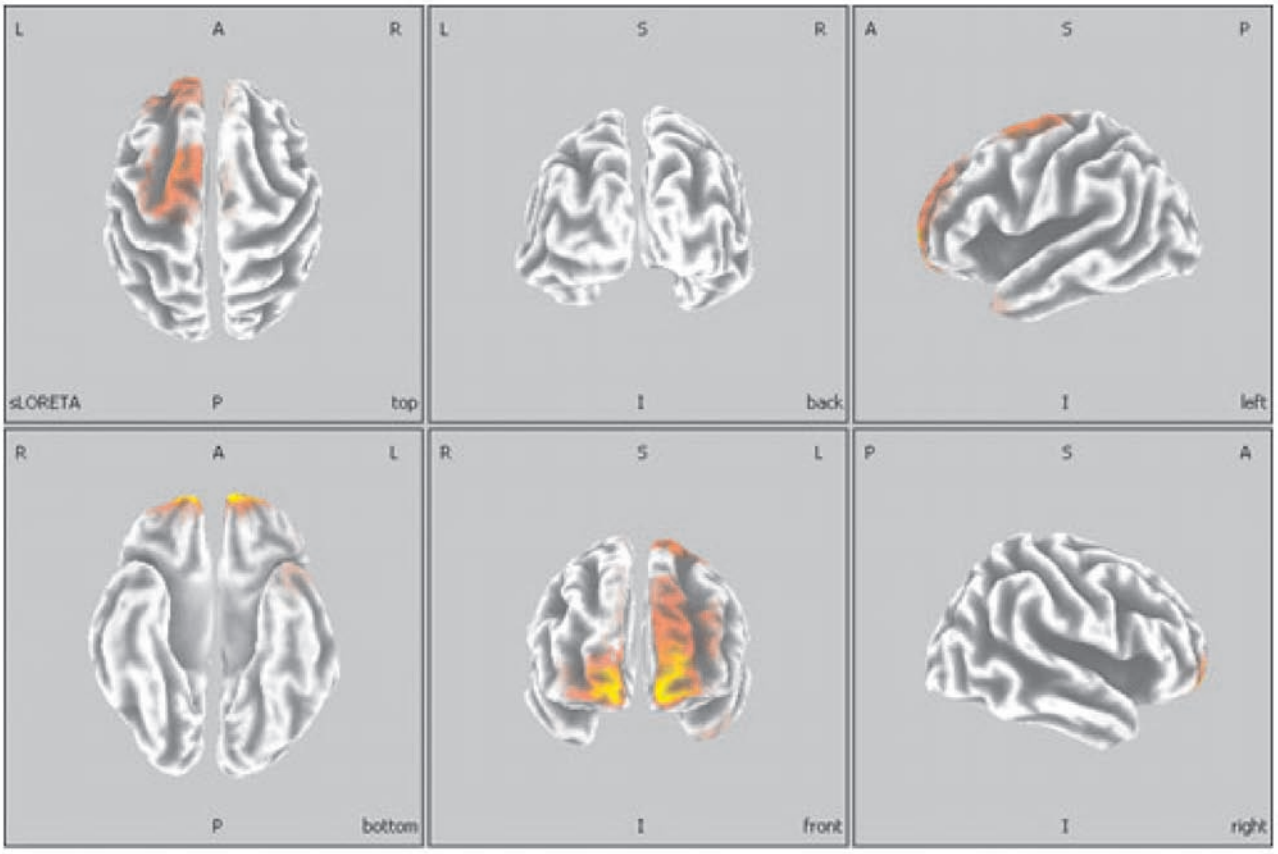

Figure 3. Reconstructed source-magnitude image for the grand mean data of the *ice cream* condition to provide an example (there were no significant differences between food conditions). Colored voxels exceed the threshold of the 99% confidence interval constructed for the time interval 2000 ms – 7000 ms.

Table 1. Anatomical areas, MNI coordinates, and Brodmann areas of grand mean activity clusters exceeding the 99% confidence interval in the time interval of 2000 ms – 7000 ms poststimulus

	Anatomical area	X	Y	Z	Brodmann area	Activation
Ice-cream	orbitofrontal, rostral superior frontal gyrus	–5	65	–10	11	2.38
	premotor cortex, caudal superior frontal gyrus	–23	–10	71	6	1.42
Yoghurt	orbitofrontal, rostral superior frontal gyrus	10	65	–5	10	3.22
	caudal superior frontal gyrus	–24	–5	71	6	0.57
Cola	orbitofrontal, rostral superior frontal gyrus	–20	65	–10	11	4.43
	Superior Parietal Lobe	–18	–66	65	7	1.42
Water	orbitofrontal, rostral medial frontal gyrus	10	65	–15	11	2.00
	caudal superior frontal gyrus	–20	–12	70	6	0.20

the only significant result related to ice cream versus no food, $F(1) = 6.637$, $p = .019$; Greenhouse Geisser corrected. For the comparison yoghurt and no food the result was $p = .528$, $F(1) = 0.414$, and for the comparison of chocolate and no food the result was $p = .326$, $F(1) = 1.02$. There is strong evidence that the Food condition ice cream was associated with the largest startle response inhibition, which is interpreted as to be associated with the most appetitive motivational status.

Further, for females alone, the mean startle response associated with ice cream was 10.31 µV (*SD* = 5), associated with yoghurt it was 9.42 µV (*SD* = 3.5), with chocolate it was 9.2 µV (*SD* = 5), and associated with no food it was 11.3 µV (*SD* = 5.8). For males alone, the mean startle response associated with ice cream was 9.5 (*SD* = 6.9), associated with yoghurt it was 11.49 (*SD* = 11.14), with chocolate it was 12.02 (*SD* = 9.96), and associated with no food it was 10.58 (*SD* = 7.9). The between-subject factor Gender interacted significantly with Food condition, $F(3) = 3.105$, $p = .035$; Greenhouse Geisser cor-

rected. Finally, linear contrasts comparing the no food condition separately with all other conditions revealed that the condition chocolate was the only one associated with a significant gender effect, $F(1) = 10.554$, $p = .005$; Greenhouse Geisser corrected. Figure 2 illustrates all mean startle responses separated according to gender as bar diagrams. While the pattern of startle responses related to the conditions Test startle response, ice cream and no food was very similar between females and males the remaining two conditions yoghurt and chocolate obviously differed. In females, chocolate elicited the most reduced startle response followed by yoghurt and ice cream. In males, ice cream elicited the most reduced startle response, followed by yoghurt and chocolate which both elicited increased startle responses compared to the control condition of no food. It can be summarized that the conditions yoghurt and chocolate are subject to gender differences, whereas ice cream seems to elicit the most constant startle response across gender.

EEG Experiment

The preprocessing routine revealed an average of 13 independent components per subject (min. 7, max. 28) that could directly be related to brain activity. The data of one female subject had to be excluded because of excessive movement artifacts.

Descriptive analysis of the different gustatory conditions (across subjects) revealed extended and stable activities in the medial and superior frontal cortices (rostral part) (Brodmann areas 10 and 11) of both hemispheres. For the ice cream condition the global maximum was localized at the left superior frontal gyrus (Brodmann area 11, MNI-coordinates: X = –5, Y = 65, Z = –10), for the yoghurt condition at the right superior frontal gyrus (BA 10, X = 10, Y = 65, Z = –5), for water at the right medial frontal gyrus (BA 11, X = 10, Y = 65, Z = –15), and for soft drink at the left superior frontal gyrus (BA 11, X = –20, Y = 65, Z = –10). Additional local maxima were observed for soft drink in the left parietal cortex (precuneus, BA 7) and for the other three conditions in the left lateral premotor area (BA 6). These maxima were activated only during the first half of the analysis interval and to a much lesser extent compared to the found prefrontal activations (see Table 1). Regions exceeding the confidence interval threshold for the ice-cream condition are demonstrated in Figure 3.

If we compare conditions pairwise using SnPM, no significant differences are found for any of the six comparisons, even if the significance threshold is lowered at a value of $p \leq 0.1$ and variances are smoothed to accomplish common variance across all variables. Analysis of group differences also did not elicit any significant differences between females and males for the four gustatory conditions. Again, no significance was achieved by lowering the threshold or smoothing the variances.

Discussion

Startle Response Modulation

The present investigation demonstrates that different foods evoke different motivational states in human beings as measured by startle response modulation. Strikingly, we first defined the baseline motivational state for every study participant (test startle response) and relative to that found that food intake can significantly modulate it. In particular, our data provide evidence that females are in the most appetitive motivational state while eating chocolate if yoghurt, ice cream and no food are the alternatives (see Figure 2). On the other hand, in males eating ice cream resulted in the most appetitive motivational state. In males, chocolate resulted in the strongest startle responses – even stronger than eating nothing and stronger than during the baseline period. It should also be mentioned that across gender eating ice cream was associated with the most consistently reduced startle response and had therefore the most positive effect on motivation. Our study participants were chosen on the condition of not favoring any particular food served during the experiments, which allows us to limit suggested interpretations with respect to two factors. First, particular ingredients may modulate motivation-related information processing through the sense of taste in association with the entire metabolism (physiological factors). In their study about so-called comfort foods, Wansink, Cheney, and Chan (2003) reported that at least part of the preference toward a particular kind of food can be based on a physiological need. They argue that for certain individuals certain foods can even have seemingly addictive qualities, and that part of the evidence for this relates to the fact that the body releases trace amounts of opiates elevating both mood and satisfaction when palatable foods are consumed. Although our study participants reported not having any preference toward a particular kind of food provided in our study, this might be an argument. Unfortunately, we do not have more detailed information related to this issue, especially with respect to food ingredients. It is suggested to exclude effects related to sugar, for instance, because sugar is an ingredient of both ice cream and chocolate which have a sweet taste but still resulted in significantly different startle response modulations. Similarly, ice cream and yoghurt are both cold but also elicited different startle response modulations.

The fact that motivation in females is most appetitive (as reflected by reduced startle responses) while eating chocolate sounds trivial with respect to everyday experience, but it is difficult to define scientific views. In fact, previous studies showed that females indeed like chocolate more than males do (Wansink et al., 2003; Zellner, Garriga-Trillo, Rohm, Centino, & Parker, 1999). But importantly, in the cross-cultural investigation by Zellner et al. (1999) comparing Spanish and American participants this difference was significant only for American women but not for Spanish women. This result represents evidence *against* a physiological basis for chocolate preference as argued by the authors. Yet there is an alternative inter-

pretation to be taken into account: Cultural backgrounds may be responsible for the present findings (psychological factors). Wansink et al. (2003) report that social factors can be related to psychological motivations toward the consumption of particular foods. They mention an animal study by Mason, Artz, and Reidinger (1984), who did experiments involving birds watching fellow birds become ill after feeding from a yellow cup. The observing birds subsequently avoided the yellow feeding cup. Similarly learned associations between the kinds of food we served to our study participants and distinct social backgrounds may play a role. For example, ice cream might be associated with summer, the seashore, and friends and therefore elicit positive motivations and emotions. This phenomenon may actually represent the basis for our consistent finding that, compared to no food, ice cream resulted in similar positive effects on the motivational state for both females and males (see Figure 1). This fact becomes even stronger in light of the finding that chocolate and yoghurt elicited large variations in motivational states between females and males because none of them seems to be associated with similar associations. Although this is all very speculative (in fact no data about associations with summer, seashore, and friends were collected), we consider it a possible interpretation.

Whatever interpretation seems most realistic, startle response modulation can be considered a reliable method for evaluating the motivational state during food consumption in humans. In fact, startle response modulation might be an excellent candidate for product evaluation in general. It may provide reliable quantifications of emotional and motivational impacts related to all sorts of consumer products.

EEG Experiment

The EEG data analyzed in our study by means of source localization revealed no significant differences between food conditions, neither across gender nor in a female-to-male comparison. However, all food conditions consistently evoked brain activities in the orbitofrontal area as defined by sLORETA (see Method section) (see also Table 1 and Figure 3). Both the negative outcome (no significant differences between food conditions) as well as the consistent orbitofrontal brain activity across all conditions must be treated with great caution, however, because of methodological drawbacks. We should mention a few suggestions. As mentioned in the Introduction, the orbitofrontal cortex has been associated with taste, flavor, and reward. The orbitofrontal cortex (Brodmann areas 11 and 12) receives input (reciprocal connection) from the medial part of the mediodorsal nucleus of the thalamus. In addition, input comes from the ventral visual stream and from olfactory, taste, and somatosensory information processing systems (Fuster, 1997). Previous research indicates that one function of the human orbitofrontal cortex is to code the magnitude of rewards and punishments (O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). Specifically, neural networks of the orbitofrontal cortex related to olfactory and gustatory information processing are suggested as being involved in the ability to determine the so-called reward value of food (Rolls, Sienkiewicz, & Yaxley, 1989). Furthermore, the representation of flavor has also been ascribed to the orbitofrontal cortex, where taste and olfactory inputs converge (Rolls, 2004).

O'Doherty et al. (2001) reported their findings from a functional magnet resonance imaging study and concluded that the lateral area of the orbitofrontal cortex is activated following a punishing outcome related to a given stimulus, whereas the medial orbitofrontal cortex is activated following a rewarding outcome. Although not clearly apparent, our neurophysiological findings could possibly be linked to brain functions related to reward. Assuming that the bilateral orbitofrontal brain activity that occurred in our study in association with all conditions of food was rather medial, one could venture the interpretation that the consumption of all provided foods resulted in rewarding situations. Yet this is only a vague interpretation. Since we in fact did not find significant differences between the food conditions we provided, we do not want to go into further details. Finally, it was also shown that the orbitofrontal cortex receives inputs from various oral texture channels leading to a total representation of whatever is in the mouth (Rolls, Critchley, Browning, Hernardi, & Lenard, 1999; Verhagen, Rolls, & Kadohisa, 2003). Since we did not find any significant differences between our food conditions, we believe that all provided foods elicited similar sensations with respect to texture.

In summary, our study provides evidence that startle response modulation can be used reliably to quantify human motivational states related to the intake of different kinds of food, while EEG recordings seem to be less selective. It is suggested to consider startle response modulation to provide a so called emotion scope (emoscope) of any product on the market.

Acknowledgments

Our thanks to Florian Fischmeister for his help with data processing including statistical analysis. This study was financially supported by Eskimo/Unilever Austria GmbH. Special thanks to Karin Anninger, Barbara Fuchs-Puchner, and Teresa Mischek-Moritz.

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Accepted for publication: October 5, 2009

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