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Facial expressions and autonomous nervous system responses elicited by tasting different juices

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Abstract

The aim of this study was to get a better understanding of reactions elicited by the taste of foods using the example of different juices. The reactions investigated were the rating behavior of self-reported spontaneous liking, various autonomous nervous system (ANS) responses and implicit as well as explicit facial expressions. Therefore, following four hypotheses were tested: 1) Different sensory stimuli of juices elicit different ANS responses. 2) Differences in facial expressions elicited by sensory stimuli of juices used in an implicit and explicit measurement approach can be detected by using FaceReader 5. 3) Self-reported liking is correlated with the measured ANS parameters and the elicited facial expressions. 4) The measured ANS parameters, facial expressions and self-reported liking allow identical differentiations between samples.

Skin conductance level (SCL), skin temperature (ST), heart rate (HR), pulse volume amplitude (PVA) and the facial expressions of 81 participants were analyzed during and shortly after tasting juice samples (implicit measurement approach). Additionally, participants were asked to show how much they liked the tasted sample with an intentional facial expression (explicit measurement approach). Banana, grapefruit, mixed vegetable, orange and sauerkraut juices were used as sensory stimuli.

The juices elicited significant differences in SCL and PVA responses and intensities of several facial expressions. For these parameters a moderate correlation with self-reported liking was found, allowing a differentiation between liked, disliked and neutral rated samples. The results show that self-reported liking cannot simply be explained by the measured ANS and implicit facial expression parameters, instead providing different information. Significant differences in facial expressions between the implicit and explicit approach were observed. In the implicit approach participants showed hardly any positive emotions when tasting samples they liked, whereas in the explicit approach they displayed a high degree of positive emotions. In both cases negative emotions were shown more intensely for disliked samples.

Keywords: Autonomous nervous system responses; Skin conductance; Facial expressions; FaceReader; Self-reported liking; Implicit measurement

1 Introduction

Since its inception, sensory and consumer science has mainly focused on methods based on self-report to characterize perceptions and the food samples that elicit these perceptions. To study further aspects in the control chain of nutritional behavior – besides perceptions – such as emotions, expectations or memories, introspective methods have been developed and applied in the last ten years (Adriaanse, de Ridder, & Evers, 2011; Arnow, Kenardy, & Agras, 1995; King & Meiselman, 2010). Yet, all these introspective methods suffer from the fundamental problem of conscious and rational processing to be able to answer the questions, consequently biasing the results (Koster, 2003).

Therefore, implicit physiological and behavioral measurements are in development to get a more complete and deeper understanding of consumers' reactions towards culinary stimuli

(Köster, 2009). De Houwer (2007) defined an implicit measure as "a measurement outcome that reflects the to-be-measured construct by virtue of processes that have the features of automatic processes", which are characterized as unconscious, unintentional, uncontrollable, effortless and fast". Investigating these reactions might considerably contribute to the understanding of consumers' nutritional behavior (Canetti, Bachar, & Berry, 2002; Garcia-Burgos & Zamora, 2013).

1.1 Measuring autonomous nervous system reactions

As a part of the peripheral nervous system, the autonomic nervous system (ANS) acts as a control system, functioning largely below the level of consciousness. Autonomic control of several organs aims to maintain homoeostasis in health (Dorland, 2011). The measured physiological parameters skin conductance, heart rate, pulse volume and skin temperature are to a high extend under control of the autonomous nervous system. They are often related to stress, arousal and emotions (Kreibig, 2010). General arousal leads to an increase of sympathetic-driven responses of the autonomous nervous system, i.e. increased heart rate, blood pressure and tonic electrodermal activity (Boucsein & Backs, 2008).

Many studies investigated ANS parameters in the context of stress situations, psychological disorders like anxiety or schizophrenia, but only a few focused on ANS reactions in the context of food. Most of the studies focusing on food used pictures (Drobes et al., 2001; Overduin, Jansen, & Eilkes, 1997) or olfactory food stimuli (Alaoui-Ismaïli, Vernet-Maury, Dittmar, Delhomme, & Chanel, 1997; Robin, Alaoui-Ismaïli, Dittmar, & Vernet-Maury, 1998, 1999), but only a few studies examined the actual tasting situation (Nederkoorn, Smulders, & Jansen, 2000; Rousmans, Robin, Dittmar, & Vernet-Maury, 2000).

Among ANS measurements, tonic electrodermal activity (EDA) parameters have been used as an indicator for arousal in psychophysiological research for a long time. EDA describes changes in the skin's ability to conduct electricity. It is also known as the galvanic skin response, which is the combination of the changes in the galvanic skin resistance and galvanic skin potential, reflecting the eccrine sweat gland activity, especially those on the palms and soles of the feet, which are involved in emotion-evoked sweating (Dawson, Schell, & Filion, 2000). It is regarded as a sensitive and valid indicator for the lower arousal range and reflects small variations in arousal state. Heart rate (HR; number of heartbeats per unit of time) is suggested to be an indicator for the higher arousal range and for somatically determined arousal processes (Epstein, Boudreau, & Kling, 1975; Miezejeski, 1978).

Rousmans et al. (2000) stated that skin resistance and cardiac responses were the most relevant ANS parameters to distinguish among different taste solutions and that these differences could be associated with the hedonic valence. Pleasant tastes induced the weakest ANS responses, whereas the unpleasant ones induced stronger ANS responses. This also matches the findings of De Wijk et al. (2012). Evidence was found by Delplanque and colleagues (2009) for the temporal priority of stimulus novelty processing over pleasantness processing on cardiac activity. Nederkoorn et al. (2004) showed that pulse volume amplitude (PVA, as a measure for changes in blood volume in arteries and capillaries) is related to the urge to eat favorable food. De Wijk et al. (2012) demonstrated that skin temperature was higher for liked foods than for disliked foods irrespective of age group, whereas Rousmans et al. (2000) found the opposite effect in an earlier work.

1.2 Measuring emotions

Many scientists, amongst them Charles Darwin (1872), have investigated the linkage between facial expressions and emotions. Facial expressions have been studied as indicators for emotional states and tools for communicating emotions. A very influential work in this field has been published by Ekman and Friesen (1971), linking basic emotions and facial expressions. In a later work, they introduced the Facial Action Coding System (FACS) (Ekman & Friesen, 1977) as a method to visually encode facial muscle movements. Due to the nature of this method, analyses are very time-consuming, specially trained coders are needed and real time detection of emotions is not possible, whereas automated facial recognition systems have the advantage of being faster and easier to apply. Some novel methods using self-reports of emotional states like EsSense Profile™ (King & Meiselman, 2010) or visual self-reports like PrEmo (SusaGroup BV, Nijbroek, The Netherlands) are quick to apply and user friendly, but have two major limitations, namely “cognitively biased” and to some degree retrospective.

Non-intrusive and fast ways to measure facial expressions are automated facial expression recognition systems like Nviso (nViso SA, Lausanne, Switzerland), Affdex (Affectiva Inc., Waltham, USA) and FaceReader (Noldus Information Technology, Wageningen, The Netherlands). These methods are not as sensitive as electromyography (EMG) and highly reliant on good quality video recordings of the observed face. They are sensitive to anything that partially obstructs the view of the face, like haircuts with fringes or thick-rimmed/reflective glasses. Suboptimal lighting and camera angles might lead to misinterpretations of the emotional state of the face, at least for the level of technology at the time of this writing. However, the large improvements of these programs over the past few years, combined with more affordable computing power for real-time analysis or higher throughput in batch analysis, make these methods increasingly interesting. For this study FaceReader 5 (Noldus Information Technology, Wageningen, The Netherlands) was used.

It has been discussed that rating perceptions on a scale requires significant cognitive processing resulting in cognitive and scaling biases (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Schwarz & Sudman, 1996). To reduce these biases it might be a promising strategy to use explicit, intentional facial expressions. Despite the intentionality they are a very intuitive means of communication in everyday life, which human beings start using early after birth (Boyatzis & Satyaprasad, 1994; Josephs, 1994; Schmidt & Cohn, 2001). Facial expressions are permanently used intentionally as well as unintentionally in human interactions to convey valence information rapidly (Blair, 2003). Using the intuitive means of showing intentional facial expressions might make it easier for test persons to communicate the nature and intensity of their hedonic perceptions, at least easier than using rationale scales with numbers or lines on paper with pens or on a computer using input devices.

To our knowledge, there is only one study by De Wijk et al. (2012) investigating the combination of the analysis of facial expressions and ANS responses in a food context. In De Wijk's study the effects on facial expressions and ANS responses elicited by the first look at a product and by different instructions to look at, smell or taste liked as well as disliked samples were investigated.

Our study not only examined the effects of the actual tasting of food samples on facial reactions and selected ANS responses for the first time, but also highlighted their correlations to self-reported liking ratings. Previous studies examining the correlation between ANS parameters, facial expressions and self-reported liking showed moderate correlations (Alaoui-Ismaïli et al., 1997; R. A. de Wijk et al., 2012; Wendin, Allesen-Holm, & Bredie, 2011) indicating that these parameters deliver different information to a certain extent.

The first research question was to investigate whether juice samples are able to elicit significantly different ANS responses and facial reactions. The second question was whether these parameters are able to differentiate samples rated as liked, disliked and neutral rated samples. Liquid products were chosen as stimuli, because chewing and eating movements would potentially disturb the measurement of facial expressions. Additionally, the use of liquids made our results comparable to previous studies (Danner, Sidorkina, Joechl, & Duerrschmid, 2014; Wendin et al., 2011; Zeinstra, Koelen, Colindres, Kok, & de Graaf, 2009). By using juice samples available on the market we wanted to have a broad spectrum of tastes easily distinguishable for the consumers and significantly varying in liking, therefore allowing a good comparison between liked and disliked samples. After a preliminary test with 41 participants tasting a wide range of different juices sold in Austrian supermarkets, five juice samples that fulfill these requirements best and showing similar familiarity ratings were selected for this study.

To answer the research questions, the following four hypotheses were tested:

H1: Different sensory stimuli of juices elicit different ANS responses.

H2: Differences in facial expressions elicited by sensory stimuli of juices used in an implicit and explicit measurement approach can be detected by using FaceReader 5.

Furthermore, differences between implicit and explicit measurements of facial expressions were investigated.

Moreover, if H1 and H2 are not falsified then correlations of ANS and facial expressions with liking ratings should be examined and following hypotheses should be tested:

H3 a: There are negative correlations between liking and ANS responses.

H3 b: There are negative correlations between liking and emotionally "negative" facial expressions.

H3 c: There are positive correlations between liking and emotionally "positive" facial expressions.

H4: The measured ANS parameters, facial expressions and self-reported liking allow identical differentiations between samples.

2 Material and methods

2.1 Samples and sample preparation

To select suitable samples a preliminary test with 41 participants in the age group between 20 and 29 years (46% female) not participating in the main study was performed, assessing hedonic acceptance, familiarity and flavor perception. Five different fruit and vegetable juices available on the Austrian market, including banana, grapefruit, mixed vegetable, orange and sauerkraut, were used as test stimuli in this study. These samples were chosen to cover a wide hedonic range, including liked and disliked samples, with similar familiarity. The familiarity rating ranged from 3.5 for grapefruit to 4.1 for banana and orange juice on a 5 point familiarity scale (ranging from 1 completely unfamiliar to 5 very familiar). For a detailed sample description see table 1. As a warm-up sample orange juice was used, which was always presented as first sample to familiarize the participants with exact testing procedure, reduce their excitement and giving them the possibility to ask questions during the procedure without interfering the measurement. Using five samples plus one warm-up sample allowed a good compromise between the number of tasted samples and time needed for the test. With this setup, including attaching electrodes, introduction and letting the participant settle, the test took about 25 to 30 minutes. All samples were presented randomized and coded in a sequential monadic way at room temperature (21°C). Water was provided to rinse the mouth between tasting the samples.

--Table 1 about here--

2.2 Participants

In total, 99 subjects participated in this study. All participants drink juices on a regular basis and confirmed that they do not have any food allergies or food intolerances. Due to various reasons, the results of 18 participants could not be used for statistical analysis. Ten participants were wearing glasses with frames covering the eyebrows which compromised the FaceReader analysis; five presented too much movement in the electrode-equipped hand to guarantee accurate measurements and further three failed to comply with the instructions. In the end, 81 participants, with an average age of 22.9 years (SD = 4.1 years), 43.2% of which were female.

The study was performed in accordance with the ethical guidelines for scientific research of the University of Natural Resources and Life Sciences. Before the test, all participants were informed about the procedure and that they would be video-recorded during the task. All participants gave written informed consent concerning the use of their video footage and questionnaire data for further analysis. Additionally, they were informed that they could withdraw themselves and their data from the study without giving an explanation at any time. All participants agreed to these conditions. As a reward, the participants could choose(apple, pear) or a chocolate bar.

2.3 Measurement of ANS parameters

A Biofeedback 2000$^{x\text{-}pert}$ device with radio module MULTI (Schuhfried GmbH, Mödling, Austria), capable of measuring skin conductance level (SCL) in µS, skin temperature (ST) in degrees Celsius, heart rate (HR) in beats per minute (pbm) and pulse volume amplitude (PVA) as % of the maximum value was used. SCL was recorded with an EDA1 gold electrode using current-voltage measurement at a sampling rate of 2 kHz. The use of alternating voltage prevents polarization. The measurement resolution for the SCL measurement using Biofeedback 2000$^{x\text{-}pert}$ is 1 nS. ST was measured using a digital sensor at a sampling rate of 4 Hz allowing a measurement resolution of .01 °C. HR and PVA were measured by infrared absorption principle with a sampling rate of 500 Hz. Measurement resolutions for these parameters are .004 bpm and .25 %, respectively. Moreover, the mobility of the non-dominant hand was monitored with an accelerometer in m/s^2 integrated into the sender unit to ensure that recordings were not compromised by movements of the hand.

All sensors were combined in one unit which was attached to the volar surface of the middle section of the forefinger of the non-dominant hand.

2.4 Measurement of facial expressions

FaceReader 5 (Noldus Information Technology, Wageningen, The Netherlands) was used in this study allowing an offline frame-by-frame facial expression analysis of video recordings. This software works in three steps:

1.) Finding the position of the face in an image using a Viola-Jones cascaded classifier algorithm (Viola & Jones, 2004),

2.) face modeling using an Active Appearance Model (Cootes, Edwards, & Taylor, 2001) and

3.) face classification as “angry”, “disgusted”, “happy”, “sad”, “scared”, “surprised” and “neutral” state and scaling these emotions from 0 (not present at all) to 1 (maximum intensity), *whereas 0.2 are slightly visible and 0.5 clearly visible expressions (Kuilenburg, Wiering, & Uyl, 2005).*

Robustness and reliability were tested in different studies, including studies by Den Uyl & Van Kuilenburg (2005) and Terzis, Moridis, & Economides (2010) showing that FaceReader matches with the judgments of trained observers in up to 89% of all cases.

2.5 Self-reported liking

Self-reported liking was assessed using a 9-point-hedonic scale in the German language (Lill & Köhn, 2007). Throughout the experiment, Compusense® five 5.2.19 (Compusense Inc., Guelph, Canada) software was used to present the questionnaire and to guide the participants through the testing procedure.

2.6 Testing procedure

The experiments took place in a testing booth of the sensory lab at the University of Natural Resources and Life Sciences, Vienna. The whole testing session was video recorded continuously with a resolution of 640 x 480 @ 25fps using a Logitech HD Pro C910 webcam mounted on the screen of the presenting Laptop using Media Recorder 2 (Noldus Information Technology. Before the electrodes of the Biofeedback 2000$^{x\text{-}pert}$ module MULTI (Schuhfried GmbH, Mödling, Austria) were attached on the middle section of the forefinger of the non-dominant hand, the participants were orally instructed regarding the procedure by the experimental leader. The sender unit was strapped on the participant’s forearm and transmitted the signals via Bluetooth to the analyzing computer. Special care was taken to ensure good illumination of the participant’s face, which is an important requirement for FaceReader 5 software to produce reliable results. In figure 1 and 2 the procedure of the study is outlined. After the start of the video recording and ANS measurement, a period of five minutes was given for habituation of the participants, to allow them to relax and to let the ANS measurements stabilize. During this time, the instruction text was shown on the screen. After that, the participants were instructed to drink 2 cl of the first sample, presented in 4 cl shot cups, in the way they normally drink juice. Two cl represents the average volume of a swallow (Jones & Work, 1961; Oman, Pelletier, Bender, & Lawless, 2003) and therefore, allows natural drinking of the whole volume. The volume was fixed because previous experiments showed that when participants were allowed to drink as much as they desired, some drank only very little of the samples they suspected to dislike or change their drinking behavior over the period of the test. Amounts of more than 2 cl could also result in other reactions like quenching thirst, which were not intended to be tested in this study. Standardizing the sample volume and limiting it to one swallow is also substantial to control motor artifacts resulting from oral processing of the sample.

After drinking the sample the participants should think about how the sample appealed to them. After 20 seconds they were able to continue on the questionnaire screen.

--Figure 1 about here--------------------------------------

Emotions and the corresponding facial expressions have a quick onset; changes in ANS parameters are generally slightly slower. Facial expressions can begin in a matter of milliseconds after an emotion-provoking stimulus, and are usually brief in duration (several seconds; (Ekman, 1992)); the measured ANS parameter have a slower onset in the range of a few seconds (Dawson et al., 2000; Venables & Mitchell, 1996). Preliminary tests showed that allowing the participants 20 s to consider the taste, offered a good compromise, giving the participants enough time to make up their minds regarding the taste and ensuring that the ANS measurement is not interfered by other tasks.

Following, the participants were asked to show how much they liked the sample with an intentional facial expression. To allow offline analyzing and unmistakable identification of the period when participants showed the intentional facial expressions, they were asked to raise the hand without the attached electrode as a signal, as long as they showed the intentional facial expressions. Afterwards, the self-reported liking was assessed using a 9-point hedonic scale, followed by 70 s break between samples allowing the participants to rinse their mouths with water and to normalize the ANS parameters after tasting the samples and answering the questionnaire. The duration of the breaks was standardized using the presenting software. At the end, after tasting all samples, some demographic and consumer behavior related questions were asked.

2.7 Data processing

The video recordings (recorded with 25 frames per second, saved as AVI files) were analyzed frame by frame using FaceReader 5 (Noldus Information Technology, Wageningen, The

Netherlands), scaling the 6 basic emotions ("angry", "disgusted", "happy", "sad", "scared" and "surprised") and neutral from 0 (not present at all) to 1 (maximum intensity of the fitted model). The results of the FaceReader analysis, the ANS responses (continuously recorded with Biofeedback 2000$^{x\text{-}pert}$ device) and the videos of the participants were imported to Observer XT 11 (Noldus Information Technology, Wageningen, The Netherlands). After synchronization of all measured variables, the three sections of interest (baseline, spontaneous/implicit response and intentional/explicit facial expressions) for each sample were selected by hand (see figure 2). The duration of the baseline section was 20 seconds. It started at the end of the neutralization phase of the previous sample (in case of the first sample after the neutralization of warm-up sample) and ended shortly before the participant started handling the next sample. The implicit section (duration of 15 seconds) started exactly when the participants swallowed the samples and it ended when they continued with the questionnaire. The explicit section started after the implicit session at the exact moment when the participant gave the "raise hand" signal and stopped when they lowered the hand again. The duration of the implicit and explicit sections varied slightly between the participants, depending how quick they handled the sample and how long they showed their intentional facial expressions. We refrained from timing this duration exactly (e.g. by giving the participants a light or sound signal) not to compromise the implicit character of the experiment, to allow a more "natural" sample handling and posing of facial expressions.

--(Figure 2) about here--------------------------------------

2.8 Statistical analyses

For the statistical analyses, the differences of the mean values of SCL, HR, PVA and skin temperature between baseline and implicit section were used. To correct the interindividual variance, Lykken and colleagues (1966) suggested expressing SCL as a proportion of one person's individualized range. Therefore, relative SCL values were calculated by dividing each baseline corrected mean value per sample by the highest baseline corrected mean value out of all samples presented for each participant.

In the case of the facial expressions, the difference in the maximum values of the facial expression patterns ("angry", "disgusted", "happy", "neutral", "sad", "scared", "surprised", and "neutral") of the implicit and baseline section as well as explicit section and baseline were used. Due to the shorter duration of the facial reactions compared to ANS responses, the use of the maximum values seems more appropriate. Preliminary experiments showed that using the baseline corrected maximal values resulted in a slightly better differentiation between samples than using mean values. Additionally, two cumulative parameters were included in the statistical analyses: a) the baseline corrected “valence” and b) the baseline corrected “sum of all negative” emotions. Valence in this context is defined as the ratio between positive and negative facial expressions and can give valuable insights into the emotional status of the test persons (Noldus Information Technology, 2012). Since participants often show a mixture of several emotions at the same, cumulative parameters of emotions using the sum of all negative emotions or valence might uncover effects better.

To test H1 and H2, a Repeated Measures MANOVA was conducted with the presented samples as within-subject factors and the facial expression and ANS parameters as measures. Greenhouse-Geisser correction was used in case of violation of the assumption of Sphericity. For the post-hoc comparisons between samples, Bonferroni alpha correction was performed.

To Test H3 and examine the correlations between ANS parameters, facial expressions and self-reported liking, Spearman correlation was used.

Experiment condition was added as additional factor to the Repeated Measures MANOVA to test H4. Additionally, the individual liking ratings were classified as liked (rating 9-7 on 9-point-hedonic scale), neutral (rating 6-4) and disliked (rating 3-1) and an ANVOA was performed, to test if the different measures allow a differentiation between liked, disliked and neutral rated samples.

All analyses were performed with IBM SPSS Statistics 21 (IBM Corporation, Armonk, USA).

3 Results

3.1 Self-reported spontaneous liking

Significant differences in self-reported spontaneous liking were observed between samples ($F(4,76) = 80.791$, $p<.001$). The five samples could be clustered in three groups (for detailed results see table 2). Banana juice ($\bar{x} = 7.41$) was rated significantly higher than all other samples. Orange juice ($\bar{x}$ = 6.43) was rated significantly lower than banana, but better than the other samples. No significant differences between sauerkraut ($\bar{x}$ = 2.62), mixed vegetable ($\bar{x}$ = 3.32) and grapefruit juice ($\bar{x}$ = 3.19) were observed.

-----------------------------Table 2 about here--

3.2 Hypothesis 1: Different sensory stimuli of juices elicit different ANS responses

The Repeated Measures MANOVA showed a significant effect ($F(16,64) = 3.756$, $p<.001$) of samples on the ANS responses and therefore supports H1. The univariate tests (table 3) identified significant influence of the presented samples on the relative SCL change ($F(4,316) = 12.180$, $p<.001$) and PVA ($F(3.52,278.08) = 2.726$, $p = .036$). The change in SCL allowed a good differentiation between samples with sauerkraut juice causing the highest and orange juice the lowest increase. The post-hoc comparison for PVA was not significant ($p = .086$), but indicated that mixed vegetable juice elicited a slightly lower decrease in the PVA than the other samples. No significant differences of skin temperature and heart rate were found.

3.3 Hypothesis 2a: Differences in facial expressions elicited by sensory stimuli of juices used in an implicit approach can be detected by using FaceReader 5.

The Repeated Measures MANOVA showed significant differences in the intensity of the elicited facial expressions between the samples ($F(32,48) = 2.327$, $p = .004$), supporting H2. The univariate tests (table 3) showed significant differences for “disgusted” ($F(2.51,197.98) = 12.420$, $p<.001$), “happy” ($F(3.27,257.98) = 13.349$, $p<.001$), “neutral” ($F(2.44,192.60) = 17.461$, $p<.001$), “sad” ($F(4,316) = 3.969$, $p=.004$) and the cumulative parameter “sum of negative emotions” ($F(3.16,249.88) = 10.712$, $p<.001$). Sauerkraut, grapefruit and mixed vegetable juice elicited significantly more intense facial expressions of “disgusted” and “sum of negative emotions” than banana and orange juice. Also “neutral” allowed a significant differentiation between the samples. Sauerkraut juice caused the highest decline of “neutral” compared to the baseline, followed by grapefruit juice. Furthermore, sauerkraut juice elicited the most intense facial expression of “happy”. This interesting behavior will be further elucidated in the discussion section. The means, SE and the results of the post-hoc comparison are displayed in table 3.

3.4 Hypothesis 2b: Differences in facial expressions elicited by sensory stimuli of juices used in an explicit approach can be detected by using FaceReader 5

Significant differences ($F(8,48) = 2.344$, $p = .004$) in intentional facial expressions between tested samples were observed using Repeated Measures MANOVA, supporting the second part of H2. The univariate test (table 3) showed significant effects on “angry” ($F(2.95,233.13) = 4.028$, $p = .008$), “disgusted” ($F(3.17,250.56) = 5.840$, $p<.001$), “happy” ($F(4,316) = 4.196$, $p = .003$), “neutral” ($F(2.45,206.82) = 18.044$, $p<.001$), “sad” ($F(4,316) = 3.426$, $p = .009$), “valence” ($F(4,316) = 9.124$, $p<.001$) and “negative emotions” ($F(3.46,273.11) = 11.063$, $p<.001$) (see table 3). In the implicit case, the sauerkraut, grapefruit and mixed vegetable sample elicited significantly more intense facial expressions of “disgusted” and “sum of negative emotions”. “Neutral” allowed the differentiation in three homogeneous groups: sauerkraut with the highest decline in “neutral” facial expression followed by the grapefruit and mixed vegetable samples, forming the second group, and banana and orange with the lowest decrease in “neutral” forming the third group. “Happy” and “valence” showed that orange and banana significantly differed from sauerkraut, grapefruit and mixed vegetable.

--Table 3 about here--------------------------------------

3.5 Hypothesis 3a: There are negative correlations between liking and ANS responses

SCL was found to be the only ANS parameter that correlated significantly with liking ($p < .001$), supporting H3a. The correlation coefficient of -.222 indicates a weak negative correlation meaning that SCL increases with disliking. Skin temperature, heart rate and pulse volume amplitude did not show a significant correlation (all $p>0.05$). The detailed results of the correlation analyses are displayed in table 4.

Additionally, it was tested, whether it was possible to differentiate between liked, disliked and neutral samples (based on the individual self-reported liking rating) using ANS parameters. Therefore, individual liking ratings were classified as liked (rating 9-7 on 9-point-hedonic scale), neutral (rating 6-4) and disliked (rating 3-1) and an ANVOA was performed. This ANOVA allowed a significant differentiation ($p<.001$) between liked and disliked samples using SCL.

3.6 H3 b: There are negative correlations between liking and emotionally "negative" facial expressions

For the implicit measurement, significant correlations were found for "disgusted", "sad" and "sum of negative emotions", all p<.01 (see table 4), with "disgusted" showing the strongest correlation (r = -.413), supporting H3b. Similar results were observed for the intentional facial expressions where significant negative correlations were found for "angry", "disgusted", "sad" and "sum of negative emotions", also supporting H3b. "Disgusted" showed the strongest correlation with an correlation coefficient of r = -.510.

--- Table 4 about here-----------------------------------

3.7 H3 c: There are positive correlations between liking and emotionally positive facial expressions.

The correlation analyses (table 4) indicated a significant negative correlation (p<0.001, r = -.256) between "happy" and self-reported liking, showing the opposite effect as expected, falsifying H3c. On the contrary, a significant positive correlation was observed for intended facial expressions (p<.001, r = .281), supporting H3c.

The means of the unintentional facial expressions (see figure 3) indicated that disliked samples elicited more intense facial expressions of most negative emotions and less intense facial expressions of "neutral" than liked or neutral rated samples. Neutral rated and liked samples showed no significant difference. This assumption was strengthened for "disgusted" and "sad" as well as for "neutral" by an ANOVA (all p<.001) with the samples classified as liked (rating 7 - 9 on 9-point-hedonic scale), neutral (rating 4 - 6) and disliked (rating 1 -3).

-- Figure 3 about here-----------------------------------

Similar to the implicit case, a linear or monotone model was not fully able to describe the relations between facial expressions and hedonic acceptance (see figure 4). Facial expressions of negative emotions, as for example "disgusted" and "angry", were elicited only by disliked samples but not by neutral rated or liked samples. Whereas, an increase in "happy" and in "valence" were elicited by liked but not by disliked or neutral rated samples. This was tested with an ANOVA with the samples classified as liked (rating 9-7 on 9-point-hedonic scale), neutral (rating 6-4) and disliked (rating 3-1). It showed that disliked samples elicited significantly more intense expressions of “angry” ($p = .024$) and “disgusted” ($p<.001$) and less intense “neutral” ($p<.001$) than neutral rated and liked samples. No significant differences between neutral rated and liked samples were observed. “Happy” and “valence” showed the opposite effect, significantly differentiating between liked and neutral rated samples, as well as between liked and disliked samples, but not between neutral and disliked samples.

-- Figure 4 about here-----------------------------------

3.8 Hypothesis 4: The measured ANS parameters, facial expressions and self-reported liking allow identical differentiations between samples

Comparing the grouping resulting from the Repeated Measures MANOVA, significant differences could be observed between ANS parameters, facial expressions and self-reported liking: 1) Significant differences in liking between banana and orange juice were found, but no parameter of facial expressions or ANS reactions showed significant differences between these samples. 2) On the contrary, significant differences between sauerkraut and grapefruit and between sauerkraut and mixed vegetable juice were found for the “neutral” facial expressions and SCL, whereas no significant differences were found in liking.

To compare intentional and unintentional facial expressions, the factor experimental condition was included in the Repeated Measures MANOVA. The results revealed significant differences in elicited facial expressions ($F(8,72) = 29.798$, $p<.001$). In the implicit case, the emotions “angry”, “neutral”, “sad”, “surprised” and “sum of negative emotions” were elicited more intensely and “valence” less intensely. These differences were all significant at $p<.001$. Significant interaction effects between sample and experimental condition ($F(32,48) = 3.190$, $p<.001$) were shown for “happy” and “valence”. These differences are shown in figure 5. “Happy” was elicited more intensely in the implicit case for the samples grapefruit and sauerkraut and less for the other samples ($p = .008$). Therefore, H4 was falsified.

-- Figure 5 about here----------------------------------

4 Discussion & Conclusions

Results of this work are discussed along the four hypotheses. Hypothesis 1 (Different sensory stimuli of juices elicit different ANS responses) could not be falsified by this study. Tasting different juice samples provoked significantly different ANS responses (SCL and PVA). Disliked samples elicited more intense galvanic skin responses than liked samples. This is in accordance with the findings of Robin et al. (1998) and Rousmans et al. (2000) who found that disliked odors elicited more intense skin resistance responses. Our results do not support the findings of De Wijk (2012) who showed that the liked samples induced higher finger temperatures than disliked samples. However, the temperature differences observed by De Wijk (2012) were very small (in the range of .001°C). Sauerkraut as the least liked sample provoked the highest decrease in skin temperature within all the tested samples, although this result was not significant. Findings of Rousmans et al. (2000) showed a similar trend.

Hypothesis 2 (Differences in facial expressions elicited by sensory stimuli of juices used in an implicit and explicit measurement approach can be detected by using FaceReader 5) was not falsified by our experiments. Spontaneous facial expressions (especially “disgusted” and “neutral”) allowed a clear differentiation between liked and disliked samples (in terms of self-reported liking rating). Disliked samples (sauerkraut, grapefruit and mixed vegetable) elicited significantly more intense negative facial expressions and less neutral ones than liked samples. Liked samples provoked only minor changes in spontaneous facial expressions (see figure 5). This is in accordance with the findings of Zeinstra et al. (2009) and Wendin et al. (2011) who found that facial expressions are a good indication for disliking but not for liking. Also Horio et al. (2003) found that chewing muscles of adult humans show greater responses to disliked than to preferred tastes. Interestingly, in the implicit measurement the facial expression of “happy” was expressed more intensely for disliked samples, especially for sauerkraut juice, than for the liked samples. Asking the participants why they smiled or even laughed when tasting these samples, they answered that they were surprised or did not expect that taste. This is an indication of display rules coming into effect; instead of showing the typical facial expression of surprise participants mask it with smiling.

Contrary to the implicit approach results, in the explicit experimental approach (intentional facial expressions) “happy” was expressed more intensely for liked samples than for disliked samples. The explicit experimental approach allowed a better discrimination between "liked", "neutral" and "disliked" rated samples, whereas in the implicit measurement only samples rated as "disliked" could be discriminated significantly from "liked" and "neutral" rated samples, but no differentiation between "liked" and "neutral" rated samples was possible. These results are corroborated by the findings of a previous study of our group (Danner et al., 2014), in which we observed considerable differences in the way participants showed facial expressions. Also in the present study about 15% of the participants showed hardly any facial reaction to the presented stimuli, whereas the other 85% showed measurable facial expressions. This may partially be attributed to the sensory laboratory test setup, where the participants are facing an unfamiliar environment and therefore feel stressed or are very focused on the task. Also personality traits of the participants may cause these response differences. Outgoing personalities show more intense facial expressions, whereas introverted people tend to show less intense facial expressions. Jaencke (1993) hypothesizes that introverts actively inhibit their facial expression of positive emotions. These findings support the importance of a within-subject design in this context.

Hypothesis 3a (There are negative correlations between liking and ANS responses): The results of the correlation analyses indicate a significant but weak negative correlation of SCL with self-reported liking. This supports our hypothesis as well as the findings of Alaoui-Ismaïli et al. (1997) and Bensafi et al. (2002), who also found moderate correlations between SCL and self-reported liking. No significant correlation between the other measured ANS parameters (ST, heart rate and PVA) and liking were found.

Hypothesis 3b (There are negative correlations between liking and emotionally "negative" facial expressions) & c (There are positive correlations between liking and emotionally positive facial expressions.): The correlations between facial expressions and self-reported liking were moderate with the highest Spearman correlation coefficients of about 0.5 in the explicit measurement and 0.4 in the implicit experiment, which are comparable with a study of de Wijk and colleagues (2014), supporting the stated hypotheses H3 b and H3 c. Looking at the data of the explicit measurement in detail (see figure 3), "happy" exhibited a linear increase with liking in the well-liked half of the scale (5 to 9) but flattens out below 5. "Disgusted" showed an inverse relationship to liking compared to the aforementioned. For both, the explicit as well as for the implicit measurements, these findings are in accordance with the findings of Wendin et al. (2011) and Greimel et al. (2006). This resulted in a U-shaped relation between facial expression and liking: liked samples elicited “happy” facial expressions, neutral rated samples provoked only little facial expressions, whereas “disliked” samples provoked mainly negative facial expressions of “disgusted”.

Hypothesis 4 (The measured ANS parameters, facial expressions and self-reported liking allow identical differentiations between samples) has been falsified by our experiments. Facial reactions and ANS parameters allowed a differentiation between most samples similar to the differentiation using self-reported liking rating, but there were two striking exceptions: 1) Significant differences in liking between banana and orange juice were found, but no parameter of facial expressions or ANS reactions showed significant differences between these samples. 2) On the contrary, significant differences between sauerkraut and grapefruit and between sauerkraut and mixed vegetable juice were found for the “neutral” facial expressions and SCL, whereas no significant differences were found in liking.

The weak to moderate correlations between measured ANS parameters, facial expressions and self-reported liking, as well as the differences in the distinction between samples, indicate that these parameters give information different to self-reported liking. Therefore they might be meaningful in future studies for a better explanation of market performance of food products, food preferences and learning of nutritional behaviors.

In this study, facial expressions of six basic emotions (“angry”, “disgusted”, “happy”, “sad”, “scared” and “surprised”) and neutral were analyzed. Studying more different shades of positive emotions might be beneficial, as several studies (e.g. *(Desmet & Schifferstein, 2008)*) showed that pleasant emotions were reported to be experienced more often than unpleasant emotions in response to food. However, identifying foods that elicit negative emotions, for example for not matching the expectations of consumers, could be of interest in many cases.

4.1 Limitations

The current study has some limitations that deserve addressing in further research. Due to the use of intense stimuli, strongly differing in sensory properties as well as consumer acceptance, a clear differentiation between the effects of sensory properties and valence on ANS responses and facial expressions is not possible. This study tested if different sensory stimuli from complex juices elicit different facial expressions and ANS responses, and how these responses differ. Further research is necessary to assess the independent influence of each factor and to examine if a discrimination between samples with more subtle differences in sensory properties as well as hedonic acceptance is possible.

Motor artifacts are easily misinterpreted by FaceReader software. In this study, liquid samples were used to minimize motor artifacts. They need less oral processing efforts than solid food. The tasting instructions, “taste the sample like you normally drink juice and taste only once”, should prevent the participants to taste in a professional way with a lot of oral processing. For the data analysis of facial expressions, a time slot immediately after swallowing the sample was defined. This procedure was able to reduce artifacts as well. During this time period, artifacts of oral processing were in fact negligible and facial expressions could be observed unbiasedly. Due to the aforementioned test setup, good lighting conditions and specific arranged testing conditions in the sensory booth (positioning of samples, laptop, cameras and application of the electrodes), we had no problems with missing data.

Numerous studies (e.g. by McIntosh (1996) and Soussignan (2002)) have shown that asking participants to pose a certain facial expression may modify subjective self-reports. However, in this study the participants were not forced to a specific facial expression instead they were free to show the facial expression they wanted, best matching their hedonic experience. Furthermore, preliminary examinations gave no indications that showing explicit facial expressions are influencing the hedonic rating behavior to a relevant extent.

This work has dealt with spontaneous short time reactions, but it is already known that liking shows a temporal dynamic development. Therefore, a further research focus should be laid on the dynamics of facial reactions and ANS responses.

4.2 Conclusion & Outlook

This work, for the first time, combines and compares the measurement of ANS responses and facial expressions elicited by the actual tasting of samples, and shows that tasting small amounts of different juices elicit different unintentional reactions. Facial expressions, ANS responses and liking ratings do not give the same information, meaning that they are only weakly to moderately correlated. Future research projects should deal with the question what responses of these parameters mean in terms of food experience and food related behavior.

References

Adriaanse, M. a, de Ridder, D. T. D., & Evers, C. (2011). Emotional eating: eating when emotional or emotional about eating? *Psychology & health*, *26*(1), 23–39. doi:10.1080/08870440903207627

Alaoui-Ismaïli, O., Vernet-Maury, E., Dittmar, A., Delhomme, G., & Chanel, J. (1997). Odor hedonics: connection with emotional response estimated by autonomic parameters. *Chemical senses*, *22*(3), 237–248.

Arnow, B., Kenardy, J., & Agras, W. S. (1995). The Emotional Eating Scale: the development of a measure to assess coping with negative affect by eating. *The International journal of eating disorders*, *18*(1), 79–90.

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., & Holley, a. (2002). Autonomic nervous system responses to odours: the role of pleasantness and arousal. *Chemical senses*, *27*(8), 703–9.

Blair, R. J. R. (2003). Facial expressions, their communicatory functions and neuro-cognitive substrates. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *358*(1431), 561–72. doi:10.1098/rstb.2002.1220

Boucsein, W., & Backs, R. (2008). The psychophysiology of emotion, arousal, and personality: Methodes and Models. In B. G. Duffy (Ed.), *Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering*, Human Factors and Ergonomics (1st ed., p. 35: 1–18). Boca Raton: CRC Press. doi:10.1201/9781420063523.ch35

Boyatzis, C. J., & Satyaprasad, C. (1994). Children's facial and gestural decoding and encoding: Relations between skills and with popularity. *Journal of Nonverbal Behavior*, *18*(1), 37–55. doi:10.1007/BF02169078

Canetti, L., Bachar, E., & Berry, E. M. (2002). Food and emotion. *Behavioural processes*, *60*(2), 157–164.

Cootes, T. F., Edwards, G. J., & Taylor, C. J. (2001). Active appearance models. *Pattern Analysis and Machine Intelligence*, *23*(6), 681–685.

Danner, L., Sidorkina, L., Joechl, M., & Duerrschmid, K. (2014). Make a face! Implicit and explicit measurement of facial expressions elicited by orange juices using face reading technology. *Food Quality and Preference*, *32*, 167–172. doi:10.1016/j.foodqual.2013.01.004

Darwin, C. (1872). *The expression of the emotions in man and animal*. London: J. Murray.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Bertson (Eds.), *Handbook of Psychopyhsiology* (2nd ed., pp. 200–223). Cambridge: Cambridge University Press.

De Houwer, J., & Moors, A. (2007). How to define and examine the implicitness of implicit measures. In B. Wittenbrink & N. Schwarz (Eds.), *Implicit Measures of Attitudes* (pp. 179–194). New York: The Guilford Press.

De Wijk, R. a, He, W., Mensink, M. G. J., Verhoeven, R. H. G., & de Graaf, C. (2014). ANS Responses and Facial Expressions Differentiate between the Taste of Commercial Breakfast Drinks. *PloS one*, *9*(4), e93823. doi:10.1371/journal.pone.0093823

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

Delplanque, S., Grandjean, D., Chrea, C., Coppin, G., Aymard, L., Cayeux, I., Margot, C., et al. (2009). Sequential unfolding of novelty and pleasantness appraisals of odors: evidence from facial electromyography and autonomic reactions. *Emotion*, *9*(3), 316–28. doi:10.1037/a0015369

Den Uyl, M. J., & Van Kuilenburg, H. (2005). The FaceReader: Online facial expression recognition. In L. P. J. J. Noldus, F. Grieco, L. W. S. Loijens, & P. H. Zimmerman (Eds.), *Proceedings of Measuring Behavior* (Vol. 2005, pp. 589–590). Wageningen, The Netherlands.

Desmet, P. M. a, & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite*, *50*(2-3), 290–301. doi:10.1016/j.appet.2007.08.003

Dorland, W. A. N. (2011). *Illustrated medical dictionary* (32nd ed.). WB Saunders Company.

Drobes, D. J., Miller, E. J., Hillman, C. H., Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (2001). Food deprivation and emotional reactions to food cues: implications for eating disorders. *Biological psychology*, *57*(1-3), 153–177.

Ekman, P. (1992). An argument for basic emotions. *Cognition & Emotion*, *6*(3-4), 169–200.

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, *17*(2), 124–129. doi:10.1037/h0030377

Ekman, P., & Friesen, W. V. (1977). *Facial Action Coding System*. Consulting Psychologists Press, Stanford University, Palo Alto.

Epstein, S., Boudreau, L., & Kling, S. (1975). Magnitude of the heart rate and electrodermal response as a function of stimulus input, motor output, and their interaction. *Psychophysiology*, *12*(1), 15–24. doi:10.1111/j.1469-8986.1975.tb03053.x

Garcia-Burgos, D., & Zamora, M. C. (2013). Facial affective reactions to bitter-tasting foods and body mass index in adults. *Appetite*, *71*, 178–86. doi:10.1016/j.appet.2013.08.013

Greimel, E., Macht, M., Krumhuber, E., & Ellgring, H. (2006). Facial and affective reactions to tastes and their modulation by sadness and joy. *Physiology & Behavior*, *89*(2), 261–269. doi:10.1016/j.physbeh.2006.06.002

Horio, T. (2003). EMG activities of facial and chewing muscles of human adults in response to taste stimuli. *Perceptual and Motor Skills*, *97*(1), 289–298.

Jäncke, L. (1993). Different facial EMG-reactions of extraverts and introverts to pictures with positive, negative and neutral valence. *Personality and Individual Differences*, *14*(1), 113–118. doi:http://dx.doi.org/10.1016/0191-8869(93)90180-B

Jones, D. V, & Work, C. E. (1961). Volume of swallow. *Archives of Pediatrics & Adolescent Medicine*, *102*(3), 427.

Josephs, I. (1994). Display rule behavior and understanding in preschool children. *Journal of Nonverbal Behavior*, *18*(March 1993), 301–326.

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

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

Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, *20*(2), 70–82. doi:10.1016/j.foodqual.2007.11.002

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: a review. *Biological psychology*, *84*(3), 394–421. doi:10.1016/j.biopsycho.2010.03.010

Kuilenburg, H. Van, Wiering, M., & Uyl, M. Den. (2005). A model based method for automatic facial expression recognition. In J. Gama, R. Camacho, P. Brazdil, A. M. Jorge, & L. Torgo (Eds.), *16th European Conference on Machine Learning* (pp. 194–205). Berlin: Springer-Verlag.

Lill, F., & Köhn, E. (2007). Methoden, Anwendungen und Analysen. In M. Busch-Stockfisch (Ed.), *Praxishandbuch Sensorik in der Produktentwicklung und Qualitätssicherung* (17th ed., pp. 1–56). Hamburg: B. Behr's Verlag GmbH & Co.KG.

Lykken, D. T., Rose, R. J., Luther, B., & Maley, M. (1966). Correcting psychophysiological measures for individual differences in range. *Psychological Bulletin*, *66*(6), 481–484.

McIntosh, D. N. (1996). Facial feedback hypotheses: evidence, implications, and directions. *Motivation and Emotion*, *20*(2), 121–147.

Miezejeski, C. M. (1978). Relationships between behavioral arousal and some components of autonomic arousal. *Psychophysiology*, *15*(5), 417–421. doi:10.1111/j.1469-8986.1978.tb01408.x

Nederkoorn, C., Smulders, F., Havermans, R., & Jansen, A. (2004). Exposure to binge food in bulimia nervosa: finger pulse amplitude as a potential measure of urge to eat and predictor of food intake. *Appetite*, *42*(2), 125–130. doi:10.1016/j.appet.2003.11.001

Nederkoorn, C., Smulders, F. T., & Jansen, A. (2000). Cephalic phase responses, craving and food intake in normal subjects. *Appetite*, *35*(1), 45–55. doi:10.1006/appe.2000.0328

Noldus Information Technology. (2012). FaceReader 5 ™ Reference Manual. Noldus Information Technology.

Oman, C., Pelletier, C., Bender, S., & Lawless, H. T. (2003). Gender, Age, Vessel Size, Cup vs. Straw Sipping, and Sequence Effects on Sip Volume. *Dysphagia*, *18*(3), 196–202. doi:10.1007/s00455-002-0105-0

Overduin, J., Jansen, A., & Eilkes, H. (1997). Cue reactivity to food- and body-relates stimuli in restrained and unrestrained eaters. *Addictive Behaviours*, *22*(3), 395–404.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *The Journal of applied psychology*, *88*(5), 879–903. doi:10.1037/0021-9010.88.5.879

Robin, O., Alaoui-Ismaïli, O., Dittmar, A., & Vernet-Maury, E. (1998). Emotional responses evoked by dental odors: an evaluation from autonomic parameters. *Journal of Dental Research*, *77*(8), 1638–1646.

Robin, O., Alaoui-Ismaïli, O., Dittmar, A., & Vernet-Maury, E. (1999). Basic emotions evoked by eugenol odor differ according to the dental experience. A neurovegetative analysis. *Chemical senses*, *24*(3), 327–335.

Rousmans, S., Robin, O., Dittmar, A., & Vernet-Maury, E. (2000). Autonomic nervous system responses associated with primary tastes. *Chemical senses*, *25*(6), 709–718.

Schmidt, K. L., & Cohn, J. F. (2001). Human facial expressions as adaptations: evolutionary questions in facial expression research. *American journal of physical …*, *116*(33), 3–24.

Schwarz, N., & Sudman, S. (Eds.). (1996). *Answering questions: Methodology for determining cognitive and communicative processes in survey research* (p. 469). San Francisco: Jossey-Bass.

Soussignan, R. (2002). Duchenne smile, emotional experience, and autonomic reactivity: a test of the facial feedback hypothesis. *Emotion*, *2*(1), 52–74. doi:10.1037//1528-3542.2.1.52

Terzis, V., Moridis, C., & Economides, A. A. (2010). Measuring instant emotions during a self-assessment test: the use of FaceReader. In A. J. Spink, F. Gieco, O. . E. Krips, L. W. S. Loijens, L. P. J. J. Noldus, & P. H. Zimmerman (Eds.), *Proceedings of Measuring Behavior* (Vol. 2010, pp. 192–195). Eindhoven, The Netherlands.

Venables, P. H., & Mitchell, D. a. (1996). The effects of age, sex and time of testing on skin conductance activity. *Biological psychology*, *43*(2), 87–101.

Viola, P., & Jones, M. (2004). Robust real-time face detection. *International journal of computer vision*, *57*(2), 137–154.

Wendin, K., Allesen-Holm, B. H., & Bredie, W. L. P. (2011). Do facial reactions add new dimensions to measuring sensory responses to basic tastes? *Food Quality and Preference*, *22*(4), 346–354. doi:10.1016/j.foodqual.2011.01.002

Zeinstra, G. G., Koelen, M. A., Colindres, D., Kok, F. J., & de Graaf, C. (2009). Facial expressions in school-aged children are a good indicator of “dislikes”, but not of “likes.” *Food Quality and Preference*, *20*(8), 620–624. doi:10.1016/j.foodqual.2009.07.002

Table 1: Sample description

Code	Producer	Description
Banana	Producer A	Nectar min. 30% banana
Grapefruit	Producer A	100% juice
Mixed vegetable	Producer B	55% red beet, 18% carrot, 18% celery, 7% potato, 2% radish
Orange	Producer C	100% orange juice
Warm-up	Producer A	100% orange juice
Sauerkraut	Producer B	100% salted sauerkraut juice

Table 2: Self-reported liking ratings and ANS responses; significant differences are indicated with * p<.05 ** p<.01 *** p<.001. For post-hoc comparison Bonferroni correction and significance level of p=.05 was used.

Sample	Self-reported liking ***			HR (bpm)			PVA * (%)			SCL ***			Skin temperature (°C)		
	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.
Banana	7.41	.18	C	12.611	2.092	ns	-4.407	.809	ns	.373	.047	AB	-.015	.009	ns
Grapefruit	3.19	.24	A	12.036	1.937	ns	-6.032	1.255	ns	.468	.050	BC	-.011	.012	ns
Mixed vegetable	3.32	.26	A	10.622	1.804	ns	-2.769	.814	ns	.574	.046	CD	-.009	.015	ns
Orange	6.43	.20	B	11.851	2.096	ns	-5.826	1.081	ns	.303	.053	A	-.011	.011	ns
Sauerkraut	2.62	.24	A	14.127	1.924	ns	-5.910	1.164	ns	.671	.042	D	-.017	.009	ns

Table 3: Intensity of facial expressions elicited by juices. Significant differences are indicated with * p<.05 ** p<.01 *** p<.001. For post-hoc comparison Bonferroni correction and significance level of p=.05 was used

Sample	ANGRY			DISGUSTED***			HAPPY***			NEUTRAL***			SAD**			SCARED			SURPRISED			NEGATIVE EMOTIONS***			VALENCE		
	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.
Implicit facial expressions																											
Banana	.039	.009	ns	.003	.002	A	.003	.021	B	.013	.008	C	.100	.028	A	-.005	.006	ns	.014	.015	ns	.136	.034	A	-.009	.015	ns
Grapefruit	.066	.013	ns	.066	.022	B	.079	.026	B	-.029	.012	B	.174	.022	AB	.010	.003	ns	.021	.015	ns	.315	.038	C	-.023	.014	ns
Mixed vegetable	.053	.014	ns	.081	.021	B	.061	.026	B	-.019	.016	BC	.151	.027	AB	.005	.003	ns	.014	.014	ns	.300	.040	BC	-.023	.019	ns
Orange	.053	.011	ns	.002	.004	A	.014	.016	B	.006	.007	BC	.116	.022	AB	.003	.007	ns	.009	.019	ns	.174	.024	AB	-.017	.010	ns
Sauerkraut	.061	.015	ns	.131	.028	B	.219	.036	A	-.133	.021	A	.208	.026	B	.011	.004	ns	-.006	.017	ns	.411	.048	C	.014	.021	ns

Sample	ANGRY***			DISGUSTED***			HAPPY**			NEUTRAL***			SAD*			SCARED			SURPRISED			NEGATIVE EMOTIONS***			VALENCE***		
	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.	mean	SE	sig. diff.
Explicit facial expressions																											
Banana	-.023	.008	A	-.004	.001	A	.220	.380	B	-.077	.016	A	-.079	.024	ns	-.006	.006	ns	-.052	.019	ns	-.112	.030	A	.199	.034	C
Grapefruit	.023	.015	B	.055	.019	BC	.069	.025	A	-.147	.024	B	-.003	.022	ns	.006	.003	ns	-.018	.019	ns	.081	.030	CD	.007	.024	A
Mixed vegetable	.002	.012	AB	.054	.018	BC	.090	.033	A	-.150	.025	B	-.058	.027	ns	-.003	.002	ns	-.040	.018	ns	-.004	.031	BCD	.044	.030	AB
Orange	-.007	.008	AB	.008	.011	AB	.146	.030	AB	-.054	.013	A	-.072	.021	ns	-.005	.005	ns	-.047	.015	ns	-.076	.029	AB	.124	.025	BC
Sauerkraut	.024	.015	B	.079	.022	C	.116	.031	AB	-.277	.036	C	.002	.023	ns	.008	.004	ns	-.048	.017	ns	.114	.036	D	.016	.029	AB

Table 4: Spearman correlation between self-reported liking ratings and facial expressions as well as between self-reported liking and ANS parameters (n = 405)

	implicit		**explicit**	
parameter	**r**	**p-value**	**r**	**p-value**
angry	-.067	.177	-.182	<.001
disgusted	-.413	<.001	-.510	<.001
happy	-.256	<.001	. 281	<.001
negative	-.306	<.001	-.359	<.001
neutral	.399	<.001	.323	<.001
sad	-.215	<.001	-.174	<.001
scared	-.151	.002	-.035	.484
surprised	.105	.034	.057	.250
valence	.009	.857	.412	<.001
ST	.013	.799		
heart rate	-.009	.854		
PVA	-.013	.794		
SCL	-.222	<.001		

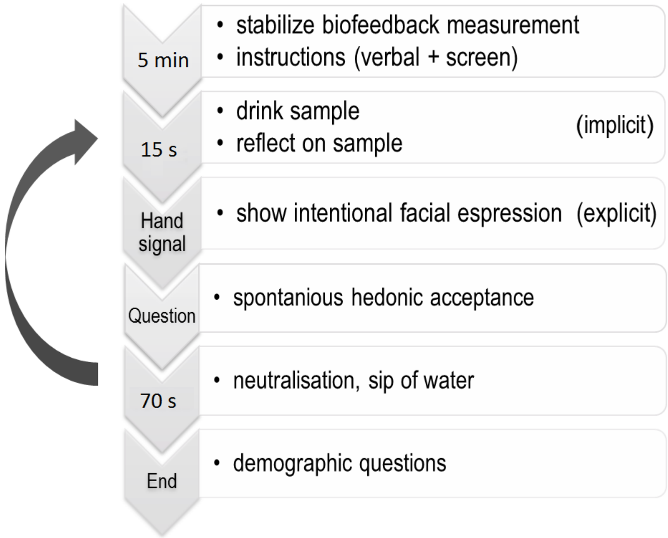

Figure 1: Scheme of the testing procedure

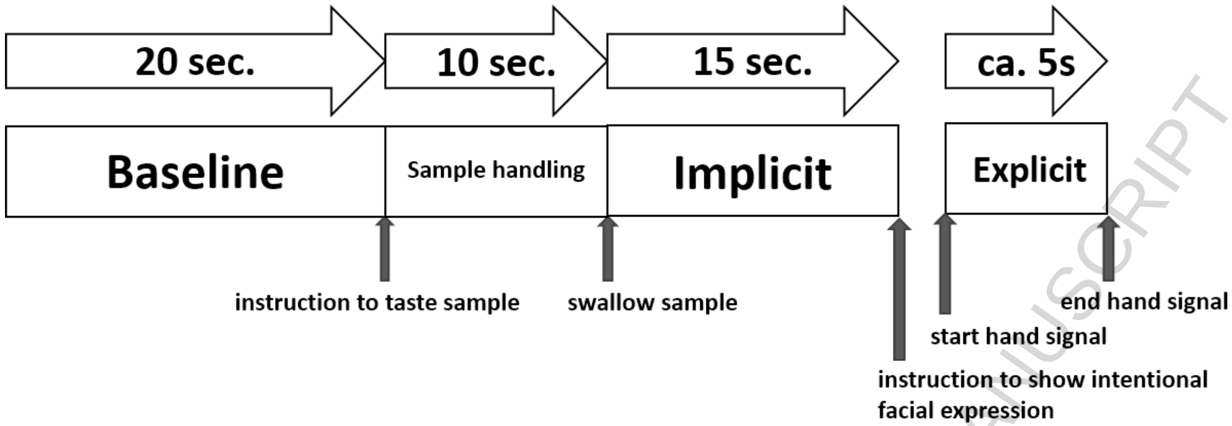

Figure 2: Phases of the experiment and sections selected for data analysis

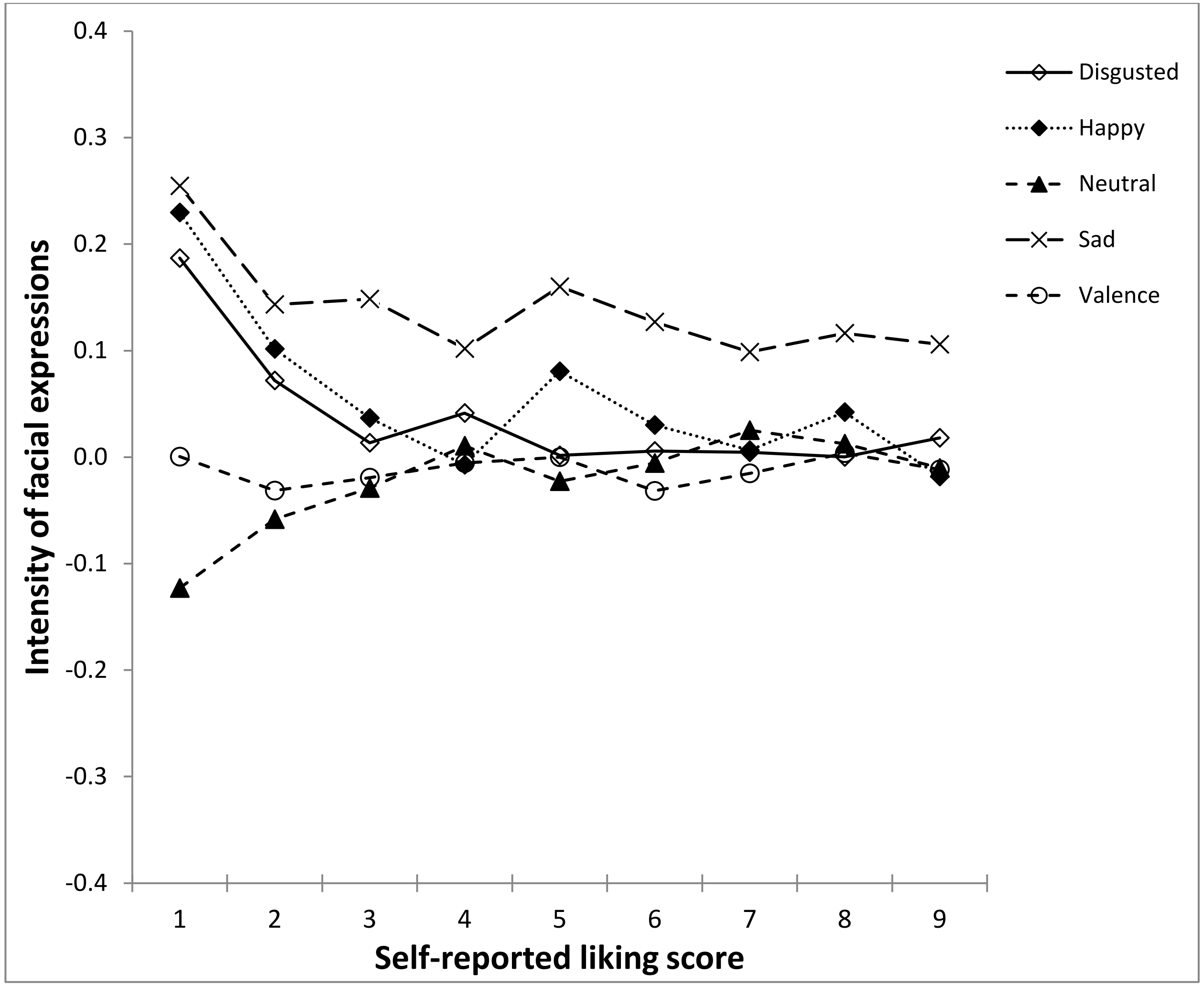

Figure 3: Relations between the means of the implicit/spontaneous facial expressions and self-reported liking ratings

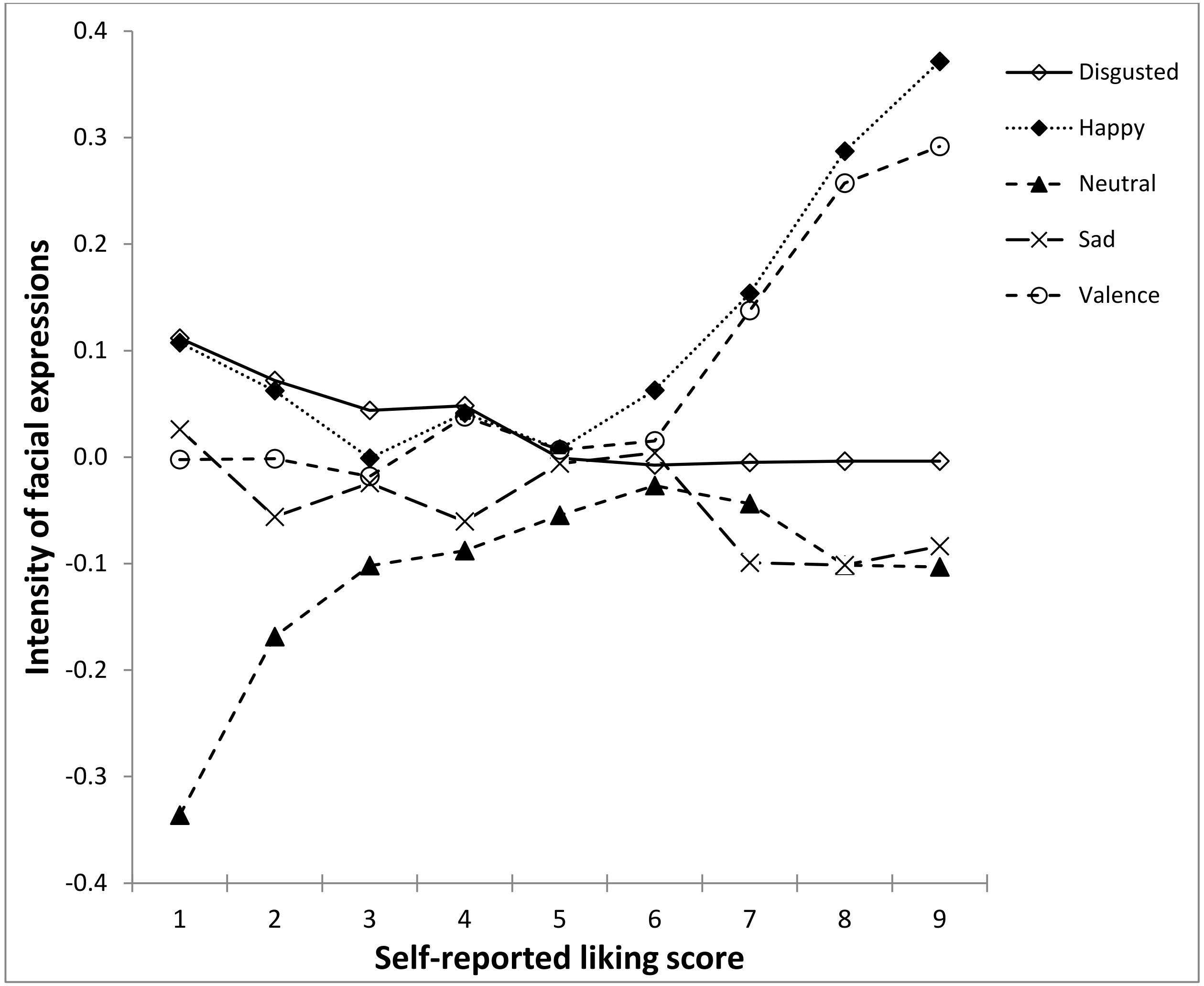

Figure 4: Relations between the means of the explicit/intentional facial expressions and self-reported liking ratings

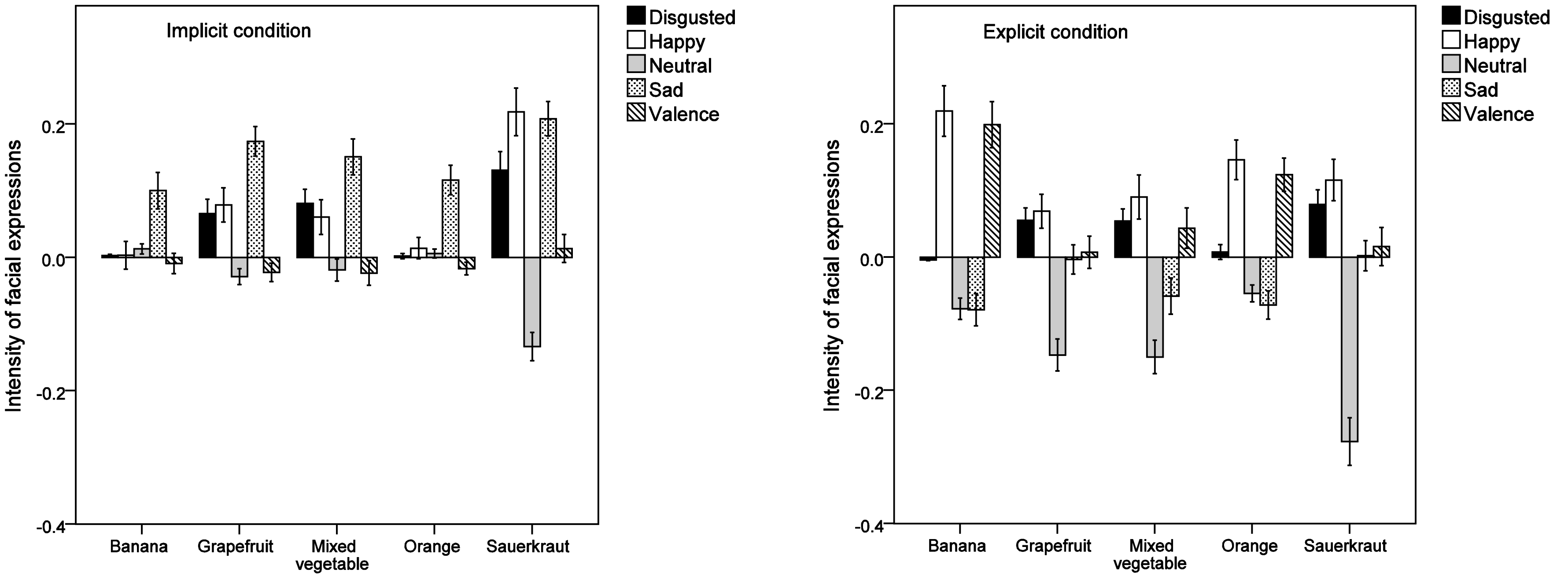

Figure 5: Intensities of elicited facial expressions for the implicit and explicit condition. Error bars indicate SE

Highlights

- Tasting of various juices elicited different ANS responses and facial expressions
- Facial expressions and self-reported liking correlate moderately
- Skin conductance and self-reported liking correlate moderately
- ANS responses and facial expressions do not fully explain self-reported liking
- Implicit and explicit facial expressions differ mainly in positive emotions