Assessing the effects of social pressure on implicit and explicit measures of food experience

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by

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Cover Image: Dutch and Japanese food exemplified by stamppot [1] and sushi [2]

Abstract

Food-evoked emotions are essential for consumers' food choice prediction and market success. These food-evoked emotions are predominantly measured by explicit self-reports. Yet in certain situations such as social desirability, explicit measures might not reflect one's true emotional experience. The additional use of implicit measures can be beneficial.

The present study investigated whether social pressure truly changes food experience by means of explicit and implicit measures of food liking. Explicit ratings were EmojiGrid valence and arousal ratings in response to familiar and unfamiliar food images and soups. Implicit measures consisted of frontal alpha asymmetry during pre-selected scenes of a movie about Japanese soy sauce as well as sip size of the soup. Explicit and implicit measures were compared to assess the effect of social pressure on Japanese and Dutch food liking.

No differences between the social pressure (n = 19) and control group (n = 23) emerged in any of the measures. Explicit ratings and the implicit measure sip size, but not frontal alpha asymmetry during watching the movie, showed differences between participants with high and low food neophobia. The insensitivity of frontal alpha asymmetry to food neophobia groups could be explained by the movie scenes showing rather familiar foods. BMI grouping similarly showed no effect on frontal alpha asymmetry during watching the movie, but also explicit measures were unaffected.

It was concluded that the social pressure intervention itself was not effective in inducing increased liking of Japanese food, since there was no increase in neither reported liking nor 'true' liking. Additional ways to induce social pressure, e.g. observation during rating, are advisable if the study was repeated. Furthermore, the use of stronger stimuli to induce approach or avoidance motivation as measured by frontal alpha asymmetry, is recommended. It cannot be concluded whether social pressure truly affects food experience.

Acknowledgements

This thesis marks the end of my Master's degree in Biomedical Engineering, completed at the Technical University of Delft. Writing a Master's thesis in the middle of a pandemic is certainly challenging. It requires a lot of self-discipline, perseverance and resilience. Therefore, I would like to take this opportunity to thank those people without whose support I would not have been able to complete this degree.

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Priya Sabu

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Contents

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Introduction

Positive emotions toward food products are essential for market success in the food industry [3]. With increasing globalization, cross-cultural emotion measurement is particularly relevant for international food marketers [4]–[8]. As a part of the product experience, emotional responses to food play an important role in predicting consumer choice [9]–[12]. Simple liking scores, that have been the main measure for predicting food choice behaviour and preference, are imprecise [13]–[15]. In [10] it was suggested that food-evoked emotions can be more accurate predictors of a person's food preference than liking scores. Hence, the emotional assessment of responses towards food might disclose valuable information for product development and marketing beyond traditional measures [16], [17].

A recent review revealed that food-evoked emotions are predominantly measured by explicit ratings [17]. Explicit measures are verbal or visual self-reported measurements, that request participants to report their emotions upon smelling, seeing or consuming food products [18]. This does not allow for continuous measurement which is required to understand how the emotional experience changes. Furthermore, in certain situations people might not be willing or able to give an accurate description of their mental state. Social desirability might influence participants to asses a product more positively or negatively, while this does not correspond to their true experience. In a study by Dell et al. [2] respondents were about 2.5 times more likely to favour a technology believed to be developed by the interviewer compared to an exactly identical alternative which was not developed by the interviewer [19]. Similarly in food evaluation, Robinson et al. [20] found that exposing participants to negative compared to neutral social information about a certain food or drink led to reduced reported liking. Furthermore, Kim et al. [21] using videos of remote peers making healthy food choices showed that preschoolers were susceptible to social pressure. For 29% of the trials the preschoolers changed their initially unhealthy food choice to match that of remote peers. Similarly, in [22] participants (young adolescents and young adults) conformed their food desirability rating to that of their respective peers. From this it is clear that social aspects affect how people rate food. However, based on existing literature, it is uncertain whether participants' true and unconscious food experience changes as well in cases of social pressure or whether it stays unaffected. In the case of the latter, explicit ratings would indicate an increased positive assessment, while implicit measures would remain unchanged.

The additional use of (neuro-) physiological measures, such as brain activity, skin conductance and heart activity can provide a deeper understanding in implicit food experience. Implicit measures are unbiased, in so far that they circumvent conscious thought processing [23]. They also allow for evaluation of the temporal dynamics of an individual's cognitive or affective state [24].

Neurophysiological measurements can provide insight into the arousal and valence dimensions of emotion, as described in the circumplex model of affect [25]. According to this model, valence describes the degree of positive or negative affect, whereas arousal refers to the intensity of the affective response with regard to the stimulus [25], [26]. The arousal dimension of the model aligns well with physiological arousal that is consistently linked to measures such as skin conductance and pupil dilation [27], [28]. Valence, on the other hand, is more complicated to assess using physiological measures.

In this regard, frontal alpha asymmetry is of particular interest for emotion processing [29]–[32]. Frontal alpha asymmetry describes the difference in alpha band (8-13 Hz) activity between the left and right frontal electrode sites of the electroencephalogram (EEG) [33]. Initial research focused on affective manipulations, where increased left-hemispheric activation was reported for positively valenced stimuli and increased right-hemispheric activation for negatively valenced stimuli. Hence it was interpreted as a feeling of positive or negative affect respectively [34]. Alongside this, the motivational direction model was explored, describing greater left frontal activation as a tendency of approach and greater right frontal activation as a tendency to avoid or withdraw from a certain stimulus. The cortical activation pattern caused by anger allowed for differentiation of the valence and the motivational direction models. The lateralization of anger as a negatively valenced emotion was found in the left frontal cortex just as happiness [35]. Further evidence for the support of the motivational direction model was found in transcranial magnetic stimulation experiments [36]. Applying transcranial magnetic stimulation to one hemisphere led to transient brain activity shifts to the contralateral side. When the stimulation was applied over the right prefrontal cortex, motivational shifts toward approach-related behaviours were observed [37]–[39]. Stimulating the left prefrontal cortex induced motivational shifts to avoidance-related behavior [40]. For instance, in [41] low frequency magnetic stimulation over the left prefrontal cortex caused increased avoidance, whereas stimulating the right prefrontal cortex led to increased approach toward angry faces.

A previously conducted literature review (added as supplementary materials, in Appendix G) on the role of stimuli in event-related frontal alpha asymmetry has shown that video stimuli can effectively induce an approach-avoidance effect. In the reviewed studies rather strong emotional stimuli targeted to evoke approach or avoidance were used. The current study investigates whether frontal alpha asymmetry can also be an indicative marker of differentiating between groups of individuals in different social pressure conditions. All participants are shown pictures of familiar (Dutch) and unfamiliar (Japanese) foods that they are asked to rate. After half of the food pictures, each participant is presented with a movie about Japanese soy sauce and food culture. While one group of individuals is told that the movie is just for calibration purpose (control group), the other group is put under social pressure by the experiment leader who advocates Japanese food (socially pressured group).
To investigate whether social pressure truly changes food experience or only changes people's reports on food experience, alpha asymmetry as an implicit measure of food liking is compared to explicit measures of food liking. If social pressure would truly change food experience, next to higher ratings in self-reports, increased approach motivation indicated by greater left frontal activation would be present for the socially pressured group while watching the movie compared to the control group. As multiple studies have emphasized that individual differences potentiate frontal alpha asymmetry [42]–[44], correlation analyses between individual characteristics such as Body Mass Index (BMI) or food neophobia, and frontal alpha asymmetry were included. The following was hypothesized:

1. Frontal alpha asymmetry during pre-selected video scenes of approach are significantly different than pre-selected avoidance and neutral video scenes.
2. Socially pressured individuals show increased relative left frontal activation (i.e., approach) compared to controls for pre-selected approach and neutral scenes.

3. Individuals that a priori can be expected to show stronger approach tendencies towards (unfamiliar) food (lower food neophobia score or higher BMI) show greater relative left frontal activation during approach and neutral scenes.

2

Methods

2.1. Participants

Participants were required to be of Dutch nationality, between 18 and 65 years of age, free of any food allergy and not following any type of diet. The recruitment notice can be viewed in Appendix A. The experiment sample consisted of 53 participants. At the beginning of the experiment a problem with the presentation of the movie occurred, such that sound and video were played at inconsistent speeds. This led to a final sample of 42 participants (19 female, 23 male). Their age ranged from 19 to 64 years (M= 46.6, SD= 15.3) and Body Mass Index from 18.4 to 46.4 (M= 25.6, SD= 5.2). Most of the participants reported eating Asian food weekly ($n = 16$) and monthly ($n = 14$). Six participants expressed eating Asian food daily, one every other day and the remaining participants less than once a month ($n = 5$). The study was approved by the TNO Institutional Review Board under reference 2020-091. Prior to the experiment participants signed an informed consent. Upon completion of the experiment, participants received a monetary reimbursement for their time and travel expenses.

2.2. Stimulus material and Design

First participants were randomly assigned to the social pressure ($n = 18$) or control group ($n = 24$). To explore the effect of social pressure on food experience by means of implicit and explicit measures, the experiment paradigm consisted of three phases, namely 1. initial rating,

2. movie, and 3. post-social pressure rating, as depicted in Figure 2.3. In the first phase and in the last phase, all participants were shown images of food from the CROCUFID (Cross Cultural Food Images Database [45]) on a computer screen. The images were of four different categories: Japanese food, Dutch food, palatable food (universal food, such as fruits) and unpalatable food (molded food and food beleaguered by insects or snails). For easier recognition a symbol in the right bottom corner of the image displayed whether the food was of Dutch, Japanese or universal nature (palatable and unpalatable). Since palatable and unpalatable image categories are not relevant for the research questions, their results are attached in Appendix Section E.2.2 only. Image examples of each of the four categories with symbols are displayed in Figure 2.1.

Figure 2.1: Example of the food images from each category

For this study two sets (subset A and B), each consisting of 20 images were selected for every category (Dutch, Japanese, palatable and unpalatable food). A detailed list of the food images used in this experiment is given in Appendix C. The order of the subset presentation in the initial and post-social pressure rating phases was counterbalanced (A-B or B-A). In both phase one and phase three, 80 unique images (20 from each category) were presented in a randomized order, for two seconds each, preceded by a fixation cross displayed for 0.5 seconds to the participants irrespective of their assigned group (social pressure or control). Immediately after viewing each image, participants were prompted to rate their emotion using the EmojiGrid (Figure 2.2). The EmojiGrid is a graphical and language-independent self-reporting tool to measure the emotional dimensions of valence (x-axis) and arousal (y-axis) in a food-related context [26].

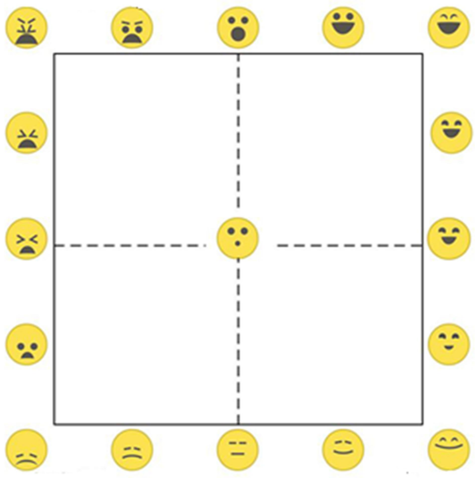

Figure 2.2: EmojiGrid: a graphical self-reporting tool measuring valence (x-axis) and arousal (y-axis) [26]

After viewing and rating the images in phase 1 and phase 3, one Dutch (Vegetable or Tomato) and one Japanese (Miso or Sumashi) soup were presented to the participant (irrespective of social pressure or control group) in a randomized order to taste and rate using the EmojiGrid. Note that soups as well as images were different for the initial and post-social pressure rating phase, such that no image or soup would be presented more than once. The amount of soup consumed, also referred to as the sip size, was recorded as an implicit measure of liking. Then to keep the promise of getting to taste food, popcorn or chips were served to the participants, depending on which of those was displayed in the preceded picture viewing and rating phase.

After phase 1 (initial rating), the movie phase started. The stimulus for this phase was a 15-minute-long movie about the production and origin of Kikkoman soy sauce. Just prior to the movie, participants who were in the social pressure group were attempted to be socially pressured to increase their liking for Japanese food. For this, one of the experiment leaders (DK, who looks Japanese and is a Kikkoman employee) told the participants anecdotes and his favourable opinion of Japanese food.
The control group was visited by a different (non-Japanese) experiment leader and was only told that the EEG sensors would be calibrated and meanwhile they could watch a movie. All participants were reminded to keep their head still and avoid any unnecessary movement during the movie. After watching the movie participants went through 12 multiple choice questions, as listed in Appendix Section B.4, to check whether the subjects paid attention to the movie.

Following the attention questionnaire, the experiment leader entered the room and again intended to apply social pressure for the social pressure group by referring to the movie and stimulating appetite for Japanese food. With the control group, the other experiment leader conducted basic small talk without mentioning anything about the movie's content. The experiment leaders' text for the social pressure group, as well as the control group, pre- and post-movie, are stated in Appendix Section B.3.

Subsequently phase 3 took place, which was essentially the same as phase 1. The entire procedure took about one hour (about 20 minutes electrode fitting and 40 minutes for the experiment) to complete.

2.3. Self-report measures

Before the presentation of food pictures, participants answered general questions and filled out the food neophobia questionnaire, as detailed in Appendix Section B.1 and B.2 respectively. The general questionnaire was used to get a basic description of the participant sample and to obtain factors that were expected to be important in this experiment (such as frequency of consuming Asian food). Furthermore, the food neophobia scale [46] was used to evaluate willingness to try novel foods. This questionnaire consists of ten statements, for which a rating on a 7-point Likert scale, ranging from 'strongly disagree' to 'strongly agree', can be given. High scores indicate high food neophobia, meaning unwillingness to try new foods, while low scores indicate enthusiasm to try novel food. At the end of the experiment participants filled out a questionnaire (see Appendix Section B.5) to find out how socially pressured they felt and whether they suspected the true intent of the experiment leader applying social pressure to increase their liking for Japanese food.

2.4. Procedure

The experiment was conducted during weekdays' mornings (9–12 a.m.) and afternoons (1.30–5 p.m.). All COVID-related protocols at that time (Q1 2021) were followed, such as wearing a mouth mask when interacting with the subjects. Note, that participants performed the experiment one at a time. Participants were accompanied to the experiment rooms, where they read information about the experiment and signed the informed consent form (both attached in Appendix A). Next, the experiment leader attached the EEG sensors. The experimental setup is shown in Figure 2.4.

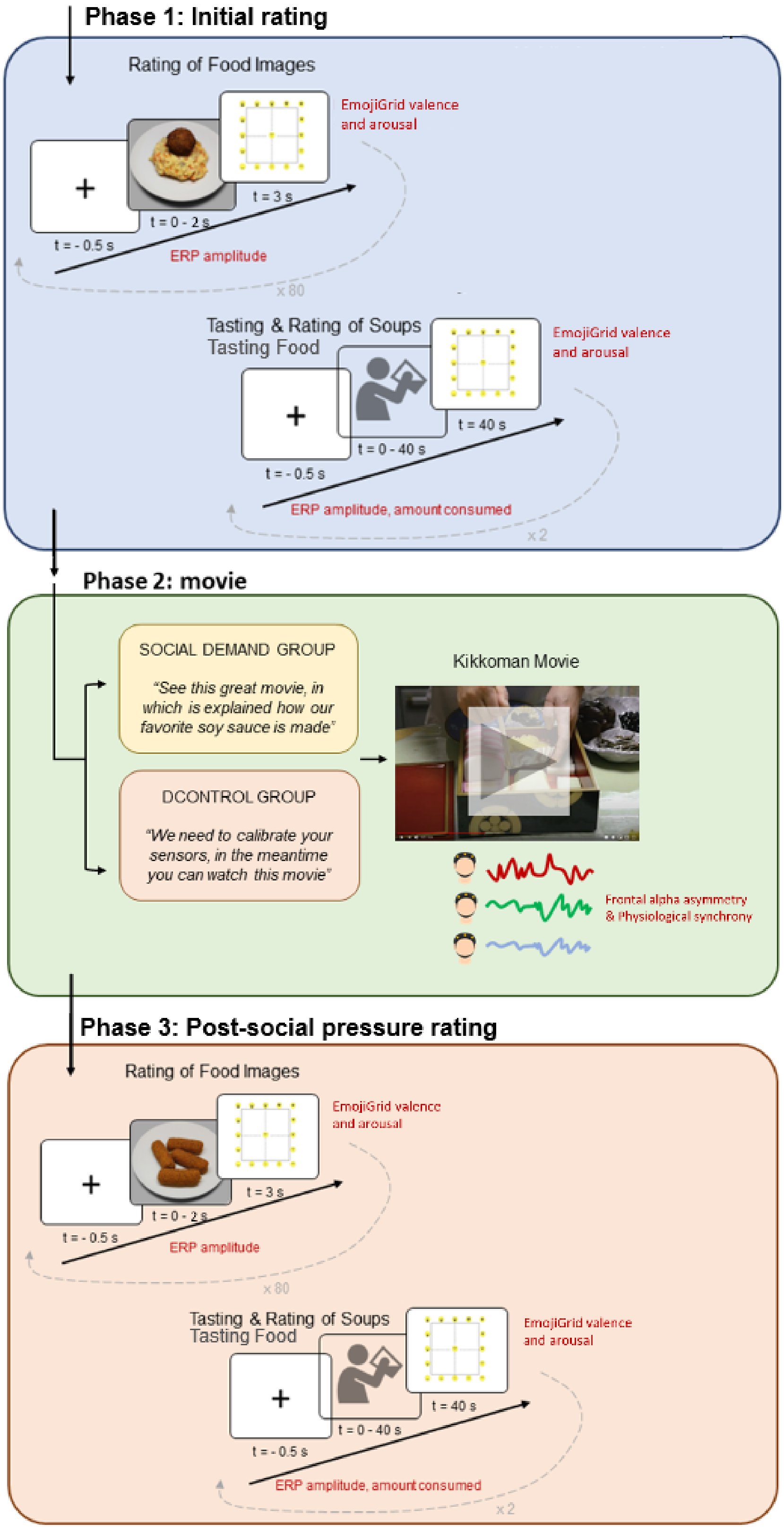

Figure 2.3: Experimental paradigm visualizing the three phases: 1. initial rating, 2. movie and 3. post-social pressure rating

Before the start of the experiment participants were shown their real-time brain activity to emphasize the importance of minimizing any type of movement. In order to increase participants' engagement with food pictures, they were told that they would get to taste some of the food items displayed. Subsequently the experiment was started.

Figure 2.4: Experimental setup: participant seated in front of computer screen, wearing a 32-channel EEG-cap with electrodes placed according to the 10-20 system

2.5. EEG recording and pre-processing

EEG was recorded continuously throughout the experiment using a 32 active electrodes BioSemi ActiveTwo system (BioSemi, Amsterdam, the Netherlands). For all electrodes impedances were kept below 5 kΩ. Since former literature review concluded that video stimuli are superior to pictures in evoking an approach-avoidance effect as measured by frontal alpha asymmetry, the following analysis was conducted on the 15-minute movie shown in the movie phase.

EEG pre-processing was performed offline with the free MATLAB-based EEGLAB version 2021.0 [47]. First the EEG data was downsampled from 1024 Hz to 512 Hz to reduce computational effort. Next, using EEGLAB's finite impulse response filter (*pop_eegfiltnew*) the data was high-pass filtered at 1 Hz to remove the baseline drift, and notch filtered at 50 Hz, to remove main current interference. Furthermore, with EEGLAB's *clean_rawdata* function bad channels were rejected and continuous data using Artifact Subspace Reconstruction was corrected. With *pop_interp* the rejected electrode channels were interpolated, since for proper average referencing sphericity is required. Channels were then re-referenced to average channel values. In the following step an independent component analysis based on principal component analysis was conducted to separate artifacts from EEG data. Then the Multiple Artifact Rejection Algorithm [48] was implemented to classify and remove artifactual components, i.e., components that have a high probability to be artifacts from different sources, such as eye movement or muscular activity.

2.6. Frontal alpha asymmetry computation

Frontal alpha asymmetry is defined as the difference in alpha activity between the left and right frontal electrode sites and is typically calculated by a natural log-transformed difference score of homologous electrodes: $\ln R - \ln L$, where R indicates the mean alpha power (in $\mu V^2/Hz$) of the respective right electrode site and L that of the left [33], [49]. Correlated to the previous metric, sometimes in literature the laterality coefficient (LC) is used, indicating relative right versus left activation. It separates the variance in asymmetry and variance in magnitude [3], [50] and is calculated as $LC = \frac{R-L}{R+L} \cdot 100$. This index allows for simpler comparison of data from various experiments, frequency bands and locations [51]. Alpha power is inversely related to brain activity, hence lower values in the alpha frequency range of 8-13 Hz indicate higher activation [33]. Based on this, higher values for the alpha asymmetry metrics correspond to increased left hemispheric activity. This brain activity is typically investigated at mid frontal (corresponding to $F4 - F3$ in the International 10–20 system) and lateral frontal ($F6 - F5$, $F8 - F7$) sites [52].

The power spectra of an individual's EEG data at electrode locations F34 and F78 were computed over the 15-minute-long movie. For this, EEGLAB's *spectopo*-function with a Hamming-window of 1s epoch length and 50% overlap was used, similar to Papousek et al. [50]. The window length of 1s was chosen, because relatively short epochs (1-2s) better match the stationarity assumption of the Fourier transform. It assumes that every signal that is periodic (repeating at a uniform distance), can be decomposed in a number of sine and cosines. Note that EEG signals are strictly speaking not periodic, yet short epochs consist of data features that repeat in a highly similar way. Applying a window however, attenuates signals at the distal regions of the window due to its weighting functions. This can be dealt with by overlapping windows, such that all portions of the signal in a particular epoch are highly weighted [53]. Next, alpha power in the frequency range of 8 to 13 Hz was extracted and the laterality coefficients were calculated.

Six colleagues independently watched the movie and marked times of scenes they observed as inducing a sense of approach or avoidance (for details see Appendix D). From this analysis the nine most-rated approach (average length of 15 seconds, SD = 8s) and nine most-rated avoidance (average length of 13 seconds, SD = 4s) were selected from the 15-minute-long movie to maximize differences in cortical responding. More details about the exact timing and content of the approach and avoidance scenes, are given in Table 2.1 and 2.2, respectively. Furthermore, a longer scene of 52 seconds (see details in Table 2.3) was included, that was marked by the raters as neutral. A possibly increased approach effect purely due to social pressure might be more apparent during the neutral scene. This is because during a neutral scene it is expected that every participant would display similar brain activity, unless there had been some sort of predisposition or inclination, like in this case social pressure intended to increase liking. The laterality coefficients during these approach, avoidance and neutral scenes for each individual were extracted from the overall laterality coefficients of the entire movie. Then laterality coefficients for the nine approach and avoidance scenes were averaged respectively and used for further analysis.

Table 2.1: Nine selected approach scenes from the 15-minute long movie

Start	**End**	**Duration**	**Description**	**Type**
00:19	00:35	00:16	Pouring soy sauce over Asian foods	APP
01:49	02:00	00:11	Grilling meat with soy sauce	APP
06:20	06:37	00:17	Cooking of foods with sizzling soy sauce	APP
08:23	08:41	00:18	Soy sauce dripping along the sheets	APP
09:20	09:30	00:10	Soy sauce dripping along the sheets	APP
10:24	10:55	00:31	Display how soy sauce is used in different food	APP
11:27	11:50	00:23	Pouring soy sauce over foods	APP
12:37	12:50	00:13	Funny old advertisement	APP
13:53	14:07	00:14	Soy sauce used in restaurant food preparation	APP
Average:		**00:15**		

2.7. Analysis

For the calculation of BMI, weight and height data of two participants were missing. Based on visual investigation one participant was classified as an outlier and thus excluded. Hence, BMI-related analyses were conducted with 39 participants.

Table 2.2: Nine selected avoidance scenes from the 15-minute long movie

Start	End	Duration	Description	Type
02:44	02:57	00:13	Taking a sample that looks like mold	AVO
02:57	03:20	00:23	Reveal of Aspergillus	AVO
03:50	03:58	00:08	Shoyu koji	AVO
04:27	04:37	00:10	Mold growing	AVO
04:56	05:04	00:08	Shoyu Koji transported into tanks	AVO
05:05	05:15	00:10	Shoyu Koji chunks falling into tanks	AVO
06:47	07:01	00:14	Moromi bubbling	AVO
07:12	07:29	00:17	Microorganisms at work	AVO
11:07	11:22	00:15	Raw food	AVO
Average:		**00:13**		

Table 2.3: Selected neutral scene with duration of 52 seconds from the 15-minute long movie

Start	End	Duration	Description	Type
13:00	13:52	0:52	market expansion and factory locations	NEU

2.7.1. The effect of scenes

To test the general sensitivity of frontal alpha asymmetry for pre-selected approach, avoidance and neutral scenes, a one-way analysis of variance (ANOVA) was conducted. For this, the frontal alpha asymmetry laterality coefficient served as the dependent variable and the scene types (approach, avoidance and neutral) as independent variables.

To explore the sensitivity of frontal alpha asymmetry for different scene types within groups (social pressure and control), one-way analysis of variance was conducted. Here the mean frontal alpha asymmetry laterality coefficient of the respective group served as the dependent variable and scene types (approach, avoidance and neutral) as independent variables.

2.7.2. The effect of social pressure

The effect of social pressure on frontal alpha asymmetry at electrode pairs F34 and F78 during approach and neutral scenes of the movie was analysed using a one-way ANOVA with groups (social pressure and control) as the independent variable.

In order to examine whether there was an effect of social pressure on the EmojiGrid ratings (valence and arousal) of images and soups, two-way mixed ANOVAs were conducted. Here, valence and arousal served as dependent variables. Independent variables were groups (social

pressure and control) as a between-subject factor, the image/soup types (Dutch and Japanese) and the social pressure intervention (pre and post) as within-subject factors.
Furthermore, the amount of soup consumed also known as sip size was analysed. For this, a two-way mixed ANOVA was conducted where groups (social pressure and control) were the between-subject factor, and soup types (Dutch and Japanese) and the social pressure intervention (pre and post) served as within-subject factors.
The self-reported social pressure was analysed with an independent-samples t test between the social pressure and control group.

2.7.3. The effect of food neophobia

To investigate the role of individual differences, due to a priori approach tendencies towards unfamiliar food, first based on the median of all food neophobia scores, participants were grouped into those with high ($n = 21$) and low food neophobia ($n = 21$).
To examine the effect of food neophobia on frontal alpha asymmetry at electrode pairs F34 and F78 during approach and neutral scenes of the movie, a one-way ANOVA was conducted with food neophobia groups (high and low food neophobia) as the independent variable.
Moreover, the Pearson Product-Moment Correlation Coefficient was calculated to explore the linear relationship between food neophobia and frontal alpha asymmetry during approach and neutral scenes.
To examine the effect of food neophobia on EmojiGrid ratings of images and soups, two-way mixed ANOVAs were performed. For this, valence and arousal served as dependent variables. Independent variables were groups (high and low food neophobia) as the between subject-factor and image/soup types (Dutch and Japanese) as the within-subject factor.
Similarly, the effect of food neophobia on sip size was analysed using food neophobia as the dependent variable. Independent variables were groups (high and low food neophobia) as the between subject-factor and soup types (Dutch and Japanese) as the within-subject factor.

2.7.4. The effect of BMI

To investigate the effect of BMI on implicit and explicit ratings, first participants were divided based on the median of all BMIs into those with low ($n = 20$) and high BMI ($n = 19$).
To explore the effect of individual differences in terms of BMI on frontal alpha asymmetry at electrodes F34 and F78 during approach and neutral scenes, a one-way ANOVA was utilized with BMI groups (high and low BMI) as the independent variable.

Furthermore, the Pearson Product-Moment Correlation Coefficient was calculated to explore the linear relationship between BMI and frontal alpha asymmetry during approach and neutral scenes.

To examine the effect of BMI on EmojiGrid ratings of images and soups, two-way mixed ANOVAs were performed. For this, valence and arousal respectively were the dependent variables. Independent variables included BMI groups (high and low BMI) as a between-subject factor and image/soup types (Dutch and Japanese) as a within-subject factor.

For the analysis of sip size, two-way mixed ANOVAs were performed. Independent variables were BMI groups (high and low BMI) as the between-subject factor and soup types (Dutch and Japanese) as the within-subject factor.

Two-way mixed ANOVAs were performed using SPSS Statistics 25 (IBM, Armonk, NY, USA). Frontal alpha asymmetry related one-way ANOVAs, Pearson correlations and the self-reported social pressure analysis were performed using MATLAB R2020a (The MathWorks Inc., Natick, MA, USA). For all statistical tests, a significance level of .05 was used.

3

Results

3.1. The effect of scenes

3.1.1. General approach-avoidance-neutral scenes

To see whether approach, avoidance and neutral scenes are generally distinctive by means of frontal alpha asymmetry, a one-way analysis of variance was conducted. Figure 3.1 shows the mean frontal alpha asymmetry (laterality coefficient) of all participants during approach, avoidance and neutral scenes for electrode locations F34 (left) and F78 (right) respectively. As already suggested by the figures, ANOVAs indicated that alpha asymmetry was not significantly different between scene types (F34: $F(2, 123) = 0.11$, $p = .892$ and F78: $F(2, 123) = 0.02$, $p = .981$).

3.1.2. Approach-avoidance-neutral scenes within groups

To explore whether frontal alpha asymmetry was different for approach, avoidance and neutral scenes within social pressure and control group, one-way ANOVAs were conducted. As Figure 3.2 suggests these analyses showed no difference for scene types neither for the social pressure (F34: $F(2, 51) = 0.05$, $p = .954$ and F78: $F(2, 51) < 0.01$, $p = .999$), nor the control group (F34: $F(2, 69) = 0.08$, $p = .920$ and F78: $F(2, 69) = 0.04$, $p = .959$).

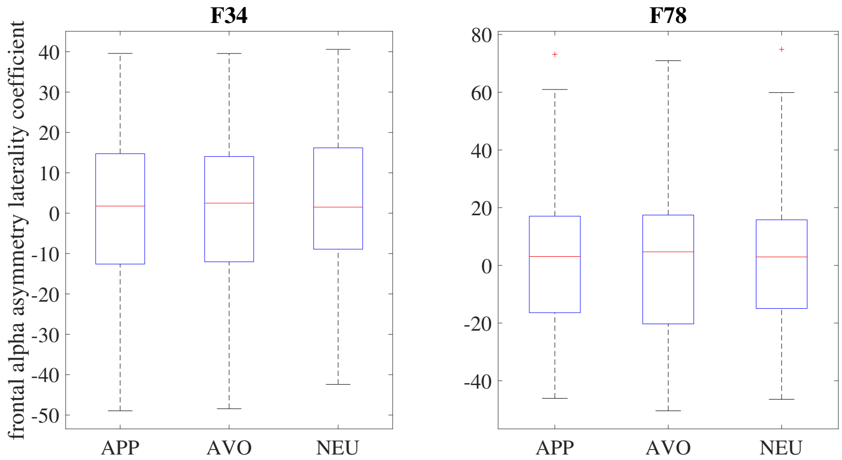

Figure 3.1: frontal alpha asymmetry laterality coefficient for approach (APP), avoidance (AVO) and neutral (NEU) scenes at electrode locations F34 (left) and F78 (right), the red horizontal line represents the median value, and the whiskers extend to the most extreme values, i.e., the minimum and maximum value, not considered as outliers; the lower blue horizontal line represents the 25th percentile and the upper the 75th percentile, outliers are shown as red pluses ('+')

3.2. The effect of social pressure

3.2.1. Frontal alpha asymmetry between groups

To explore the effect of social pressure on frontal alpha asymmetry, analyses between social pressure and control group were performed. These one-way ANOVAs of the frontal alpha asymmetry laterality coefficient during approach and neutral scenes showed no significant group effect (approach scenes: F34: $F(1, 40) = 0.64$, $p = .428$ and F78: $F(1, 40) = 0.38$, $p = .543$, neutral scene: F34: $F(1, 40) = 0.56$, $p = .459$ and F78: $F(1, 40) = 0.19$, $p = .663$). Figure 3.3 shows the mean frontal alpha asymmetry (laterality coefficient) during approach (top row) and neutral scenes (bottom row) for electrode locations F34 (left column) and F78 (right column) between the social pressure and control group.

3.2.2. EmojiGrid ratings for images

Figure 3.4 shows the EmojiGrid valence (left) and arousal (right) ratings for Dutch and Japanese food images between the social pressure and control group before and after the social pressure intervention. As indicated by the left figure, for valence no significant group effect ($F(1, 40) = 2.45$, $p = .125$) and no effect for the social pressure intervention were found ($F(1, 40) = 1.24$, $p = .273$). There was an effect for image types ($F(1, 40) = 15.63$, $p < .001$), showing that Japanese food images were overall rated lower in valence than Dutch food im-

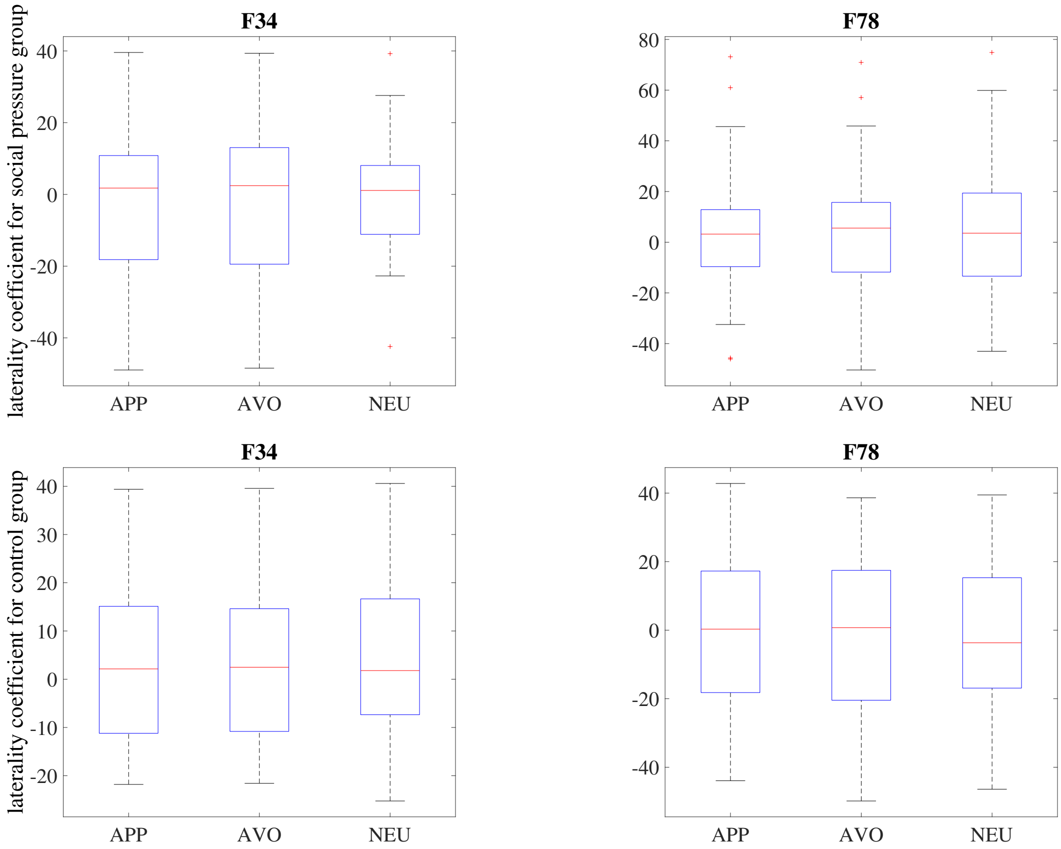

Figure 3.2: frontal alpha asymmetry laterality coefficient of approach (APP),avoidance (AVO) and neutral (NEU) scenes at electrodes F34 (left column) and F78 (right column) for social pressure (top row) and control group (bottom row), boxplot parts as described in Figure 3.1

ages. There were no interaction effects for the valence ratings between image types and groups ($F(1,40) = 0.01$, $p = .933$), the social pressure intervention and groups ($F(1,40) = 0.46$, $p = .501$), the social pressure intervention and image types ($F(1,40) = 0.68$, $p = .415$) and image types, the social pressure intervention and groups ($F(1,40) = 0.17$, $p = .679$).

For arousal no significant effects for groups ($F(1,40) = 1.33$, $p = .255$), social pressure intervention ($F(1,40) = 0.01$, $p = .924$) or image types ($F(1,40) = 0.15$, $p = .700$) were found, as suggested by Figure 3.4 on the right side. There were no interaction effects for the arousal ratings between image types and groups ($F(1,40) = 0.10$, $p = .751$), the social pressure intervention and groups ($F(1,40) = 2.98$, $p = .092$), the social pressure intervention and image types ($F(1,40) = 2.94$, $p = .094$) and image types, the social pressure intervention and groups ($F(1,40) = 0.69$, $p = .411$).

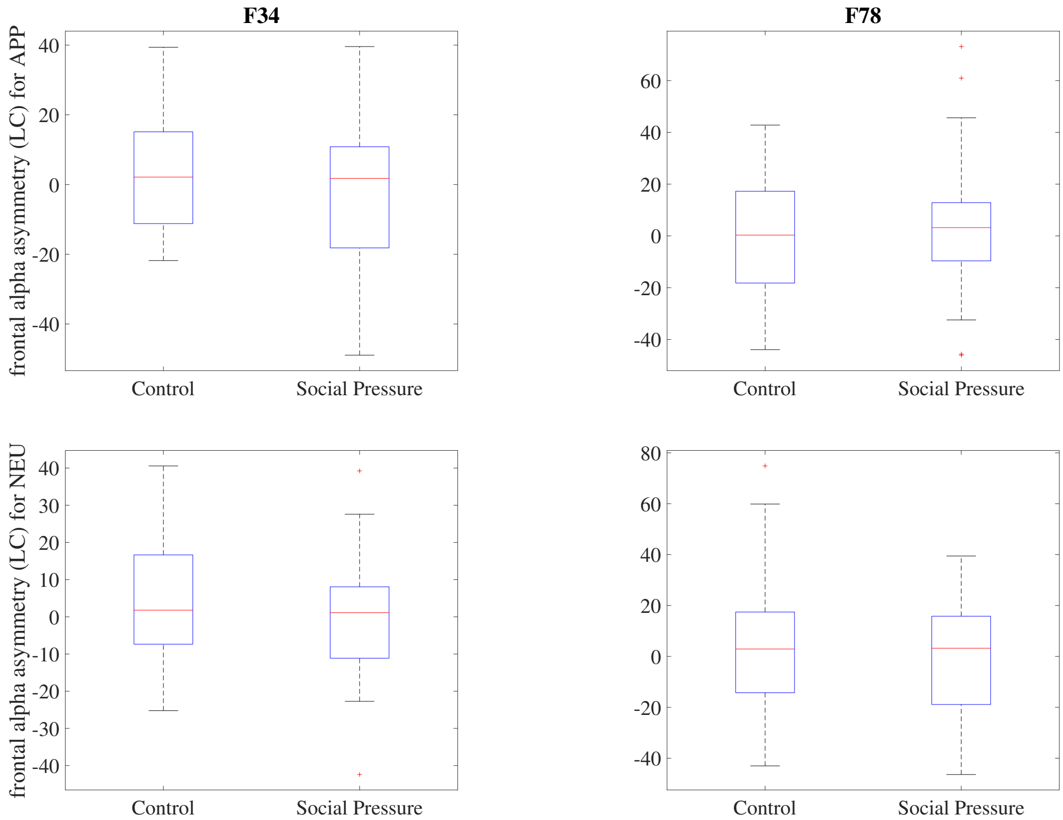

Figure 3.3: frontal alpha asymmetry laterality coefficient between social pressure and control group at electrodes F34 (left column) and F78 (right column) during approach (top row) and neutral (bottom row) scenes, boxplot parts as described in Figure 3.1

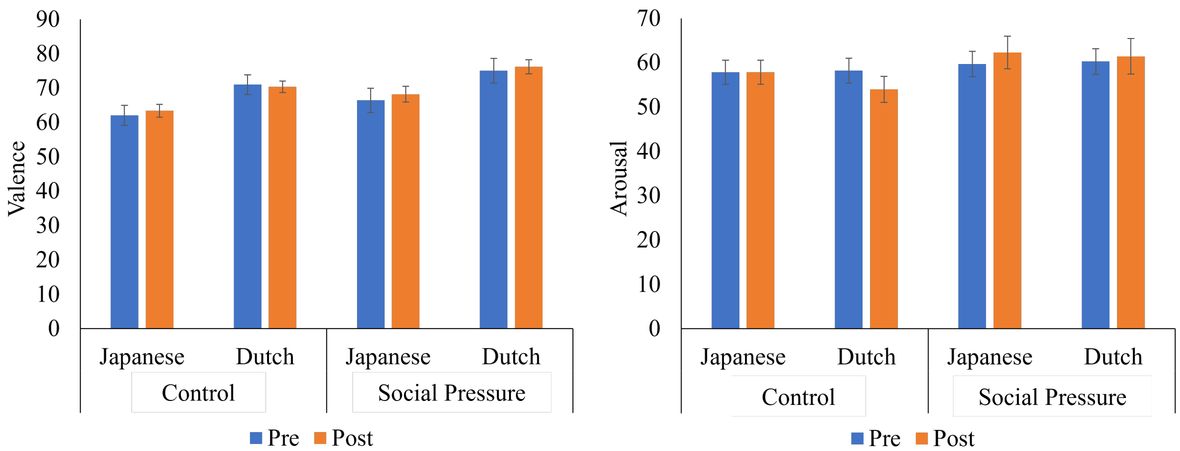

Figure 3.4: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese food images, pre- and post social pressure intervention; error bars indicate the standard error of the mean

3.2.3. EmojiGrid ratings for soups

Figure 3.5 shows the mean EmojiGrid ratings of valence (left) and arousal (right) of Dutch and Japanese soups before and after the social pressure intervention. For the valence ratings no significant effects of group ($F(1,40) = 0.29$, $p = .591$), social pressure intervention ($F(1,40) = 0.02$, $p = .880$) and soup types ($F(1,40) = 1.88$, $p = .178$) were obtained. There were no interaction effects for the valence ratings between soup types and groups ($F(1,40) = 0.50$, $p = .591$), the social pressure intervention and groups ($F(1,40) = 0.78$, $p = .383$), the social pressure intervention and soup types ($F(1,40) = 2.21$, $p = .145$) and soup types, the social pressure intervention and groups ($F(1,40) = 0.05$, $p = .826$).

The graph on the right shows the arousal ratings of Dutch and Japanese soups. ANOVAs revealed no effects for groups ($F(1,40) = 0.95$, $p = .335$), social pressure intervention ($F(1,40) = 0.03$, $p = .876$), and soup types ($F(1,40) = 0.21$, $p = .650$). Furthermore, there were no interaction effects for the arousal ratings between soup types and groups ($F(1,40) = 0.43$, $p = .518$), the social pressure intervention and groups ($F(1,40) = 3.11$, $p = .086$), the social pressure intervention and soup types ($F(1,40) = 0.26$, $p = .614$) and soup types, the social pressure intervention and groups ($F(1,40) = 1.51$, $p = .226$).

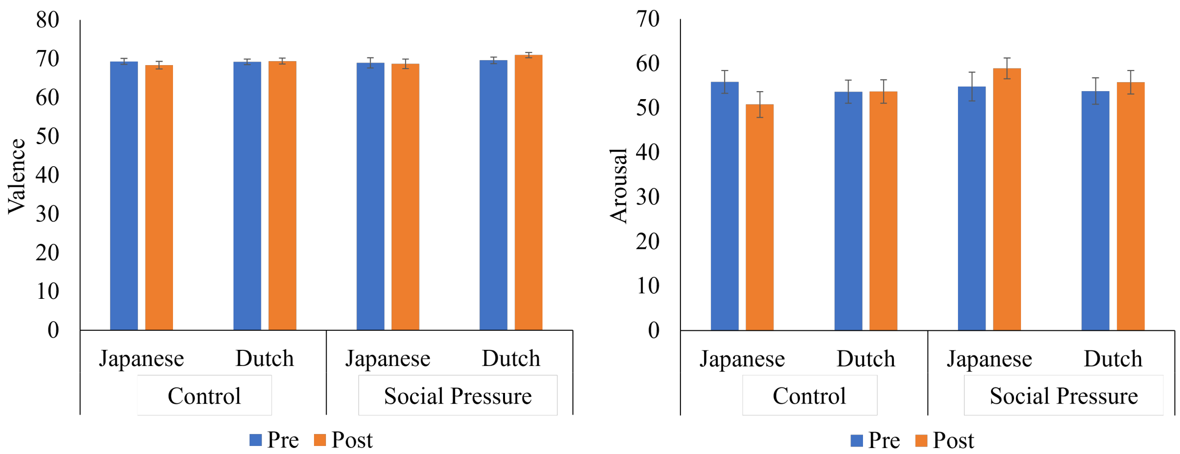

Figure 3.5: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese soups, pre- and post social pressure intervention; error bars indicate the standard error of the mean

3.2.4. Sip size

Figure 3.6 shows the amount of soup consumed (in grams) for the social pressure and control group. The two-way mixed ANOVA did not show any significant effect for groups ($F(1,40) = 0.77$, $p = .386$), soup types ($F(1,40) = 0.92$, $p = .343$) or social pressure intervention ($F(1, 40) < 0.01$, $p = .969$).

Moreover, no interaction effects between soup types and groups ($F(1, 40) = 2.64$, $p = .112$), social pressure intervention and groups ($F(1, 40) = 1.41$, $p = .242$), the social pressure intervention and soup types ($F(1, 40) = 0.08$, $p = .778$) and soup types, social pressure intervention and groups ($F(1, 40) = 0.41$, $p = .524$) were found.

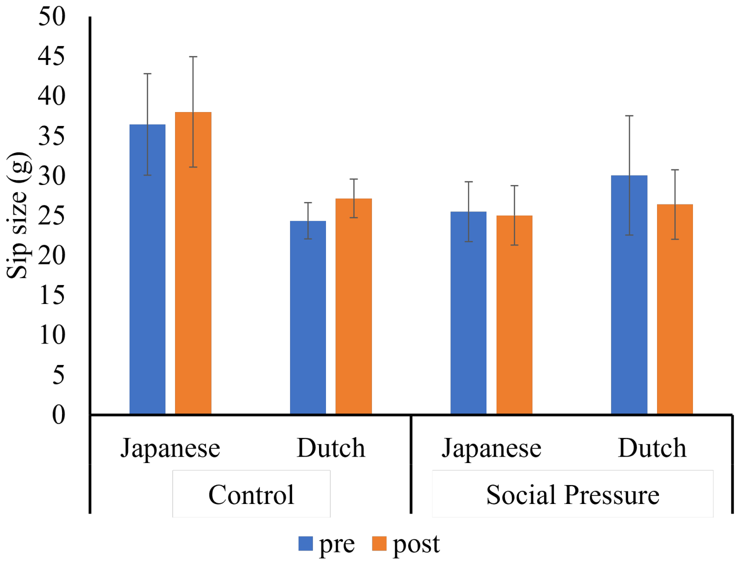

Figure 3.6: Average sip size (in grams) between social pressure and control group; error bars indicate the standard error of the mean

3.2.5. Self-reported social pressure

Below in Figure 3.7 the distribution of the self-reported social pressure between the social pressure and control group is visualized. The scale went from -1 (did not feel socially pressured at all) to 1 (felt very socially pressured). Although a slightly increased median for the social pressured group is visible, no statistically significant differences ($t(51) = 1.06$, $p = .294$) in self-reported social pressure between the groups were found.

For the open question on the goal of the experiment, almost all participants did not suspect the social pressure intervention per se. Participants thought the experiment's goal was to promote Japanese food, or explore cultural food perception, look at the reaction to molded food and fermentation, or to investigate the influence of visual perception of food on the taste experience.

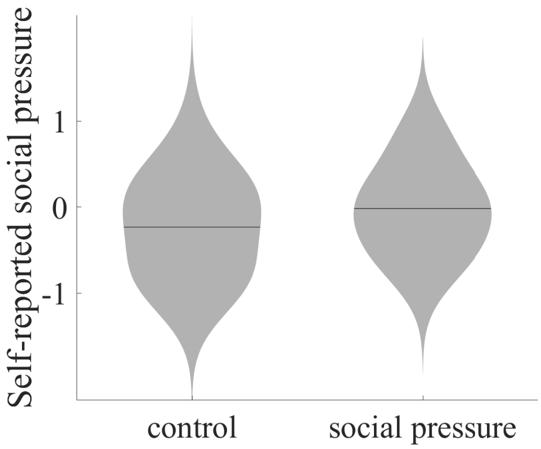

Figure 3.7: Distribution of self-reported social pressure between social pressure and control group

3.3. The effect of food neophobia

3.3.1. Frontal alpha asymmetry during the movie

One-way ANOVA results of frontal alpha asymmetry at electrodes F34 and F78 during approach and neutral scenes showed no group effect between participants with high and low food neophobia (approach scenes: F34: $F(1, 40) = 0.8$, $p = .377$ and F78: $F(1, 40) = 0.12$, $p = .728$, neutral scene: F34: $F(1, 40) = 0.29$, $p = .592$ and F78: $F(1, 40) = 0.14$, $p = .706$). The mean frontal alpha asymmetry laterality coefficient during approach (top row) and neutral scenes (bottom row) for electrode locations F34 (left column) and F78 (right column) between individuals with high and low food neophobia can be viewed in Figure 3.8.

3.3.2. Frontal alpha asymmetry and food neophobia correlation

Correlation analyses between the food neophobia score and the frontal alpha asymmetry laterality coefficient at electrode positions F34 and F78 during approach (F34: $r(40) = .06$ and $p = .723$, F78: $r(40) = -.21$ and $p = .172$) and neutral scenes (F34: $r(40) = -.01$ and $p = .955$, F78: $r(40) = -.24$ and $p = .127$) revealed no significant results. This is visualised in Figure 3.9 with frontal alpha asymmetry at F34 (left column) and F78 (right column) for approach scenes in the top row and the neutral scene in the bottom row.

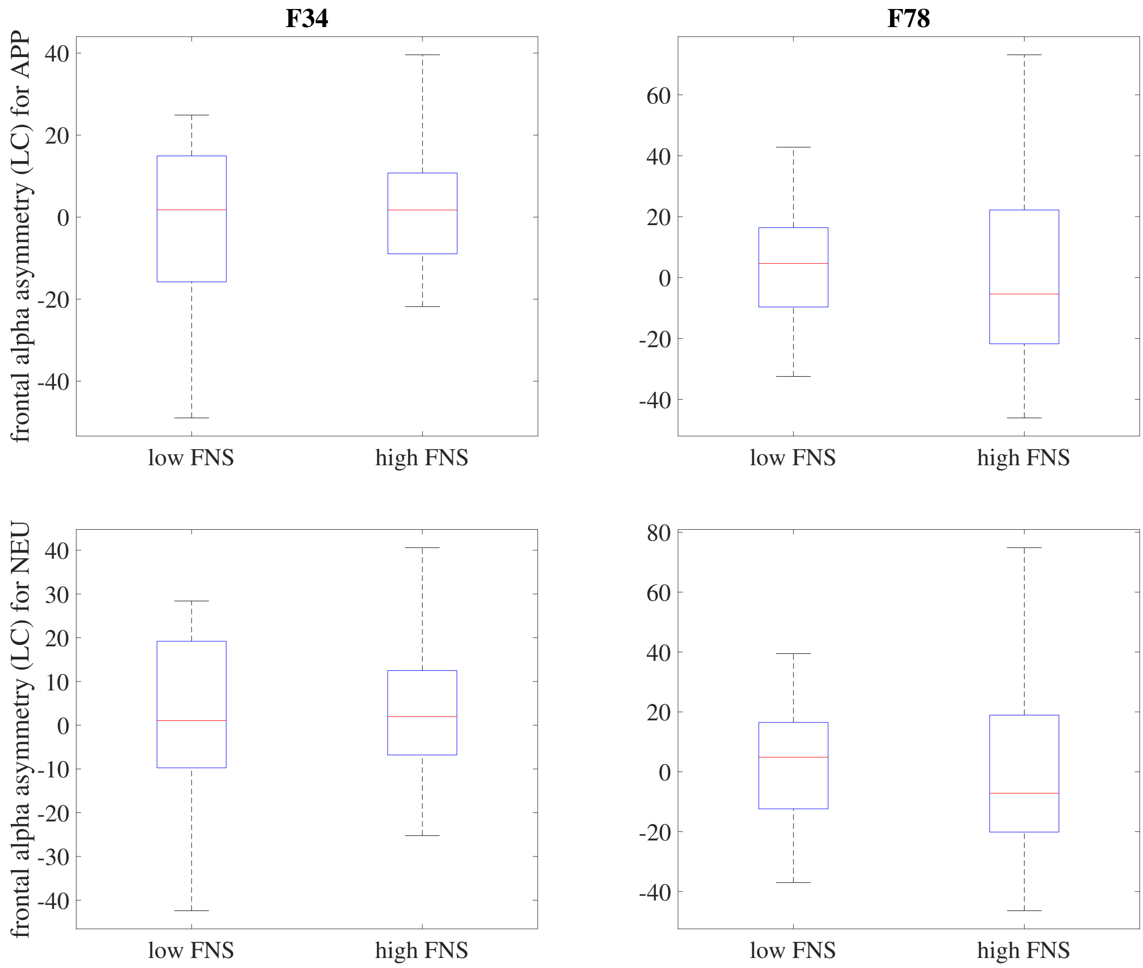

Figure 3.8: frontal alpha asymmetry laterality coefficient between participants with high and low food neophobia at electrodes F34 (left column) and F78 (right column) during approach (top row) and neutral (bottom row) scenes, boxplot parts as described in Figure 3.1

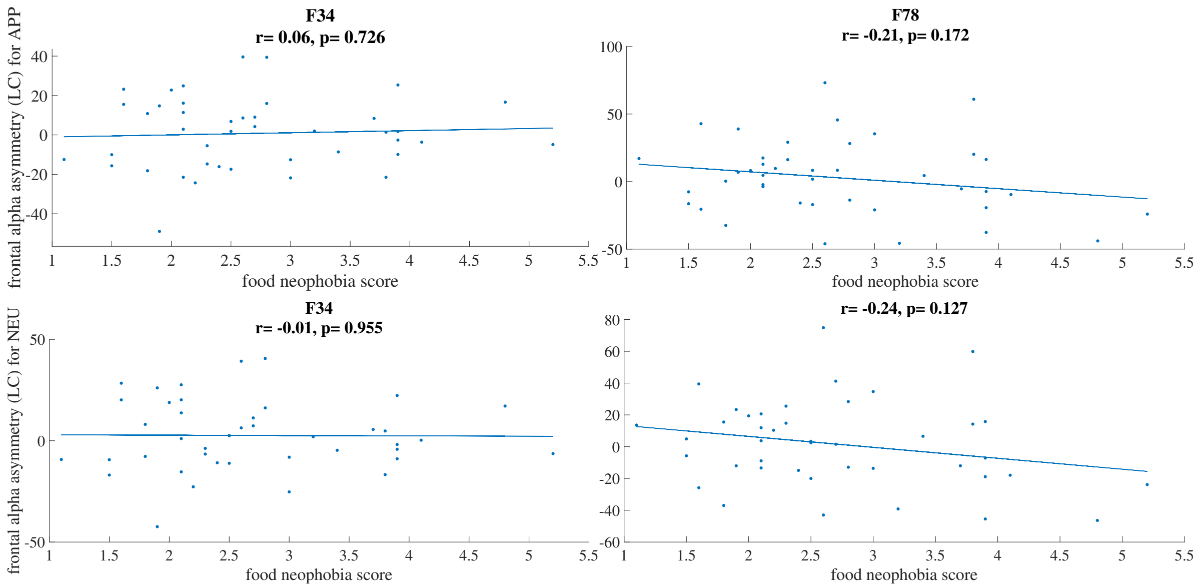

Figure 3.9: Correlation of food neophobia score and frontal alpha asymmetry laterality coefficient at electrode positions F34 (left column) and F78 (right column) during approach scenes (top row) and the neutral scene (bottom row), where each data point depicts one participant

3.3.3. EmojiGrid ratings for images

Figure 3.10 shows the mean EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese food images between individuals with high and low food neophobia. As suggested by the left graph, ANOVAs for the dependent variable valence revealed an effect for image types ($F(1, 40) = 15.63$, $p < .001$) and food neophobia groups ($F(1, 40) = 7.24$, $p = .010$). Additionally, a marginal interaction effect between image types and food neophobia groups was found ($F(1, 40) = 3.41$, $p = .072$).

For arousal (displayed on the right), no effect for image types ($F(1, 40) = 0.32$, $p = .578$), food neophobia groups ($F(1, 40) = 2.49$, $p = .123$) and no interaction effect between the two variables were found ($F(1, 40) = 1.51$, $p = .226$).

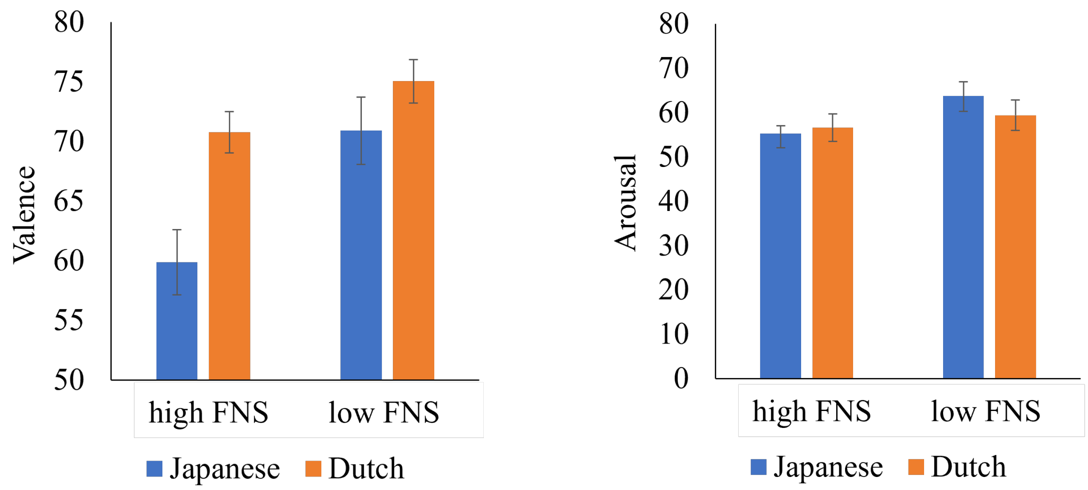

Figure 3.10: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese food images between individuals with high and low food neophobia scores (FNS); error bars indicate the standard error of the mean

3.3.4. EmojiGrid ratings for soups

Figure 3.11 displays the mean EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese soups between individuals with high and low food neophobia. ANOVAs for the dependent variable valence showed no effects for soup types ($F(1, 40) = 1.56$, $p = .220$), food neophobia groups ($F(1, 40) = 0.94$, $p = .337$) and no interaction effect between those two ($F(1, 40) = 0.06$, $p = .801$).

Arousal ratings showed no effects for food neophobia groups ($F(1, 40) = 0.09$, $p = .772$) and soup types ($F(1, 40) = 0.34$, $p = .562$). However an interaction effect was found between soup types and food neophobia groups ($F(1, 40) = 4.44$, $p = .041$), as the graph on the right visualises. Individuals with high food neophobia scores rated the Dutch soup with greater arousal than the Japanese soup. Participants with low food neophobia scores on the other hand, found the Dutch soup less arousing than the Japanese soup.

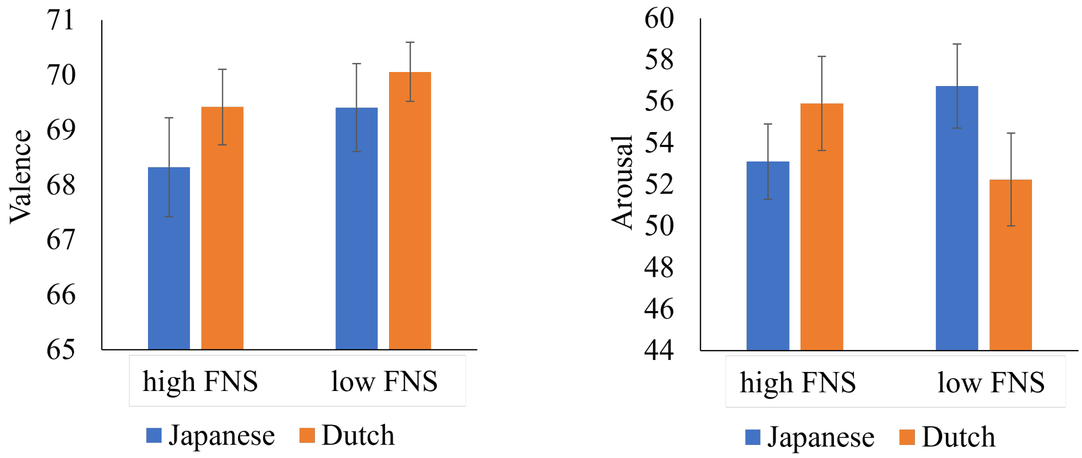

Figure 3.11: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese soups between individuals with high and low food neophobia scores (FNS); error bars indicate the standard error of the mean

3.3.5. Sip size

Figure 3.12 shows the amount of soup consumed (in grams) of individuals with high and low food neophobia. As visible in the Figure, two-way mixed ANOVA showed an effect for food neophobia groups ($F(1,40) = 13.31$, $p = .001$), but no effects for soup types ($F(1,40) = 1.73$, $p = .196$) and no interaction between groups and soup types ($F(1,40) = 1.82$, $p = .184$).

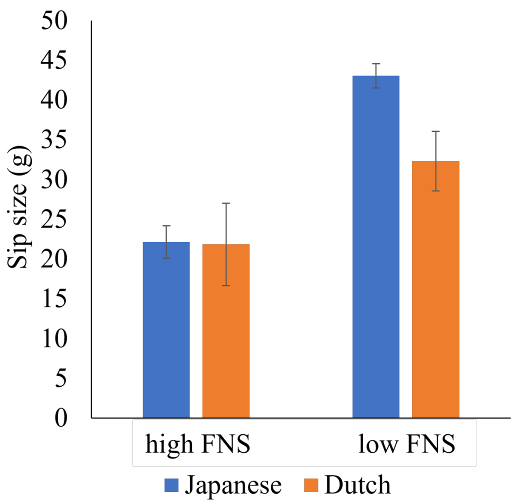

Figure 3.12: Average sip size (in grams) between individuals with high and low food neophobia scores (FNS); error bars indicate the standard error of the mean

3.4. The effect of BMI

3.4.1. Frontal alpha asymmetry during the movie

Figure 3.13 shows the mean frontal alpha asymmetry (laterality coefficient) during approach (top row) and neutral scenes (bottom row) for electrode locations F34 (left column) and F78 (right column) between participants with high and low BMI. The results of the one-way ANOVA revealed no group effects at electrodes F34 and F78 during approach (F34: $F(1,37) = 1.02$, $p = .320$ and F78: $F(1,37) = 0.41$, $p = .528$) and neutral scenes (F34: $F(1,37) = 0.59$, $p = .447$ and F78: $F(1,37) = 0.47$, $p = .496$).

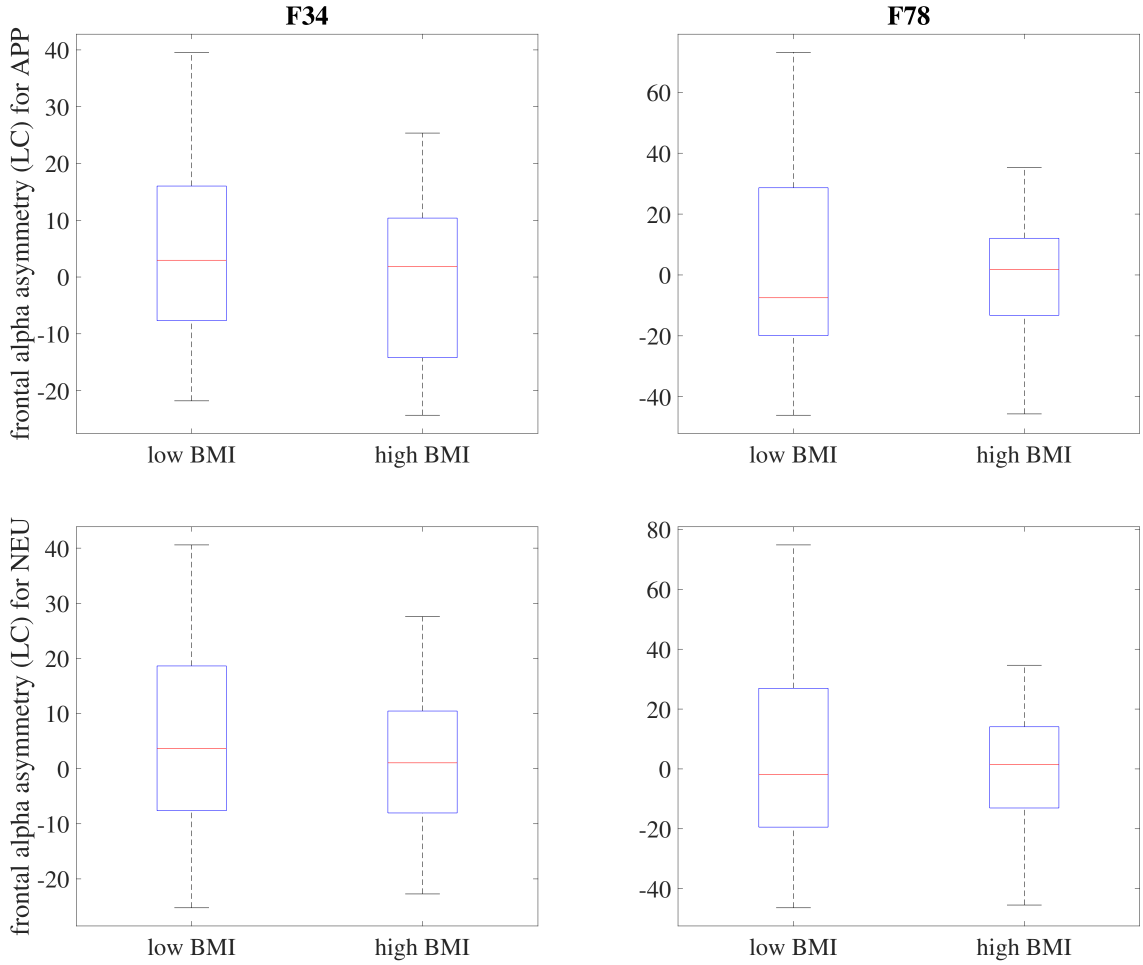

Figure 3.13: frontal alpha asymmetry laterality coefficient between participants with high and low BMI at electrodes F34 (left column) and F78 (right column) during approach (top row) and neutral (bottom row) scenes, boxplot parts as described in Figure 3.1

3.4.2. Frontal alpha asymmetry and BMI correlation

Figure 3.14 shows the correlation between BMI and frontal alpha asymmetry at F34 (left) and F78 (right) during approach (top row) and neutral (bottom row) of the movie. Above each graph, the respective Pearson Product-Moment correlation coefficient is indicated. As can be seen in the top left graph, a moderate correlation was found between BMI and frontal alpha asymmetry at F34 during the approach scenes ($r(38) = -.40$ and $p = .010$). Additionally a weak correlation was found between BMI and frontal alpha asymmetry at F34 during the neutral scene ($r(38) = -.35$ and $p = .026$). Both correlations indicate that participants with higher BMI had lower frontal alpha asymmetry indicating avoidance, opposite to the expected correlation.

Correlation analyses between BMI and frontal alpha asymmetry at F78 for approach ($r(38) = .19$ and $p = .247$) and neutral scenes ($r(38) = .12$ and $p = .459$) were in the expected positive direction, but not significant.

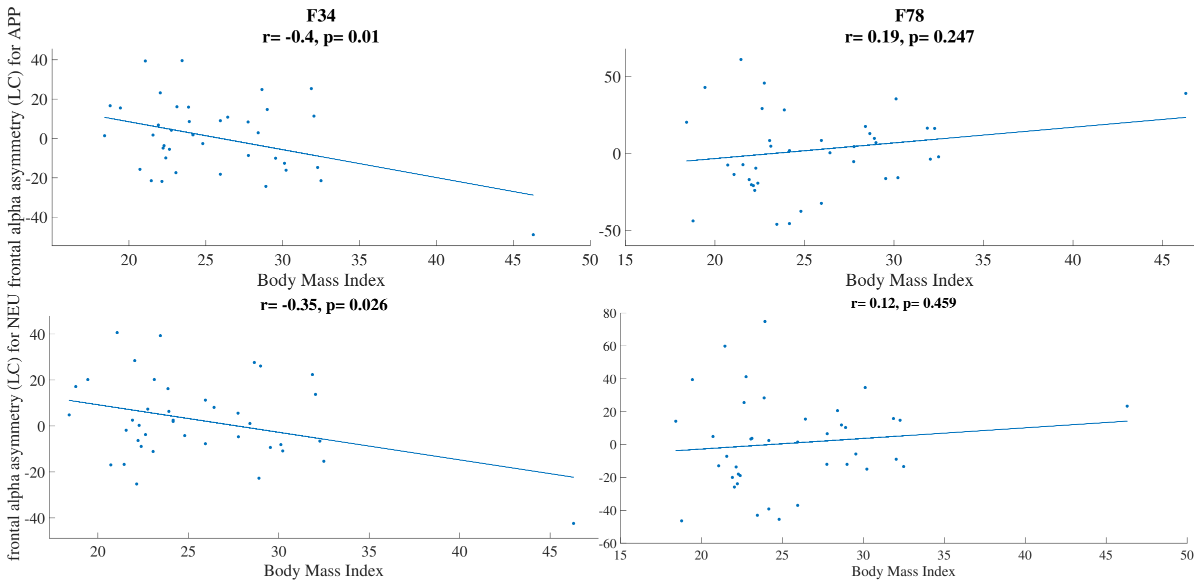

Figure 3.14: Correlation of BMI and frontal alpha asymmetry laterality coefficient at electrode positions F34 (first column) and F78 (second column) during approach scenes (first row) and the neutral scene (second row), where each data point depicts one participant

Based on visual inspection an outlier (participant with BMI value of 46.3) was identified and removed. The graphs excluding the outlier are shown in Figure 3.15. With the removal of the outlier, Pearson correlations for approach (F34: $r(37) = -.17$ and $p = .305$, F78: $r(37) = -.12$ and $p = .470$) and neutral scenes (F34: $r(37) = .07$ and $p = .689$, F78: $r(37) = .05$ and $p = .782$) show no significant linear correlations.

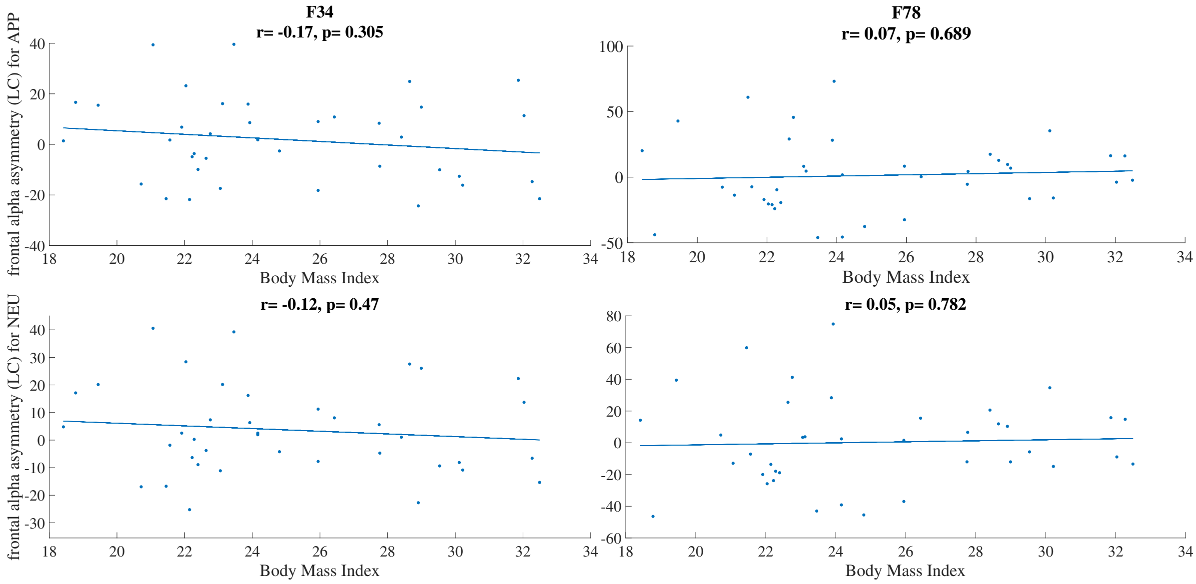

Figure 3.15: Correlation of BMI and frontal alpha asymmetry laterality coefficient at electrode positions F34 (first column) and F78 (second column) during approach scenes (first row) and the neutral scene (second row), where each data point depicts one participant and an outlier was removed

3.4.3. EmojiGrid ratings for images

Figure 3.16 shows the mean EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese food images between individuals with high and low BMI. As visible in the left graph, for valence there was an effect for image types ($F(1, 37) = 18.18$, $p < .001$), which indicated that Japanese food images were rated lower in valence. There was no effect for BMI groups ($F(1, 37) = 0.41$, $p = .528$) and no interaction effect between groups and image types ($F(1, 37) = 0.81$, $p = .806$).

Analyses for arousal in reaction to images (displayed in the right graph) showed no effects for image types ($F(1, 37) = 0.01$, $p = .914$), BMI groups ($F(1, 37) = 1, 77$, $p = .191$) and no interaction effect between the two variables ($F(1, 37) = 0.52$, $p = .477$).

3.4.4. EmojiGrid ratings for soups

Figure 3.17 demonstrates the mean EmojiGrid valence (left graph) and arousal (right graph) ratings of Dutch and Japanese soups between individuals with high and low BMI. The two-way mixed ANOVA for valence showed no effect for soup types ($F(1, 37) = 1.44$, $p = .237$), BMI groups ($F(1, 37) = 3.21$, $p = .081$) and no interaction effect between BMI groups and soup types ($F(1, 37) = 0.18$, $p = .678$).

The analyses of the reported arousal in response to soups showed an effect for BMI groups

($F(1, 37) = 8.20$, $p = .007$). Individuals in the high relative to the low BMI group rated the soups as less arousing. There was no effect for soup types ($F(1, 37) = 0.01$, $p = .981$), and no interaction effect between soup types and BMI groups ($F(1, 37) = 0.72$, $p = .401$).

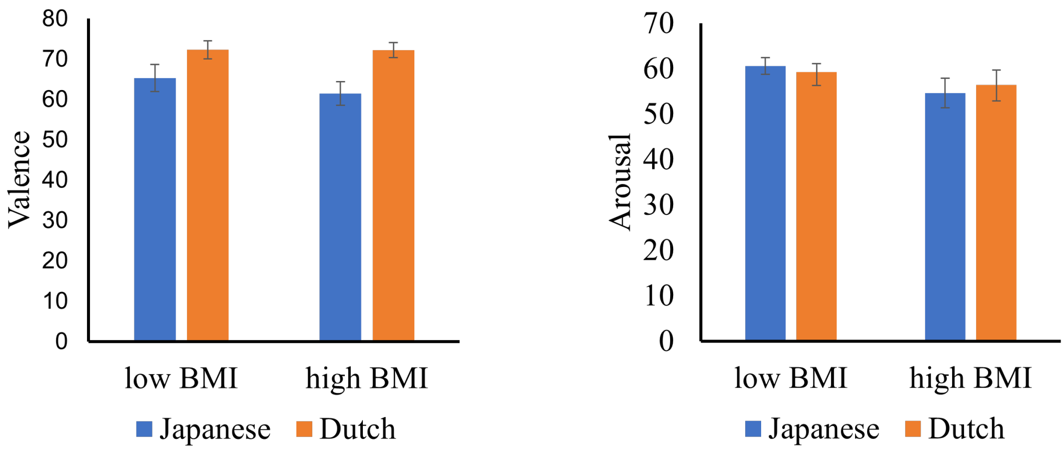

Figure 3.16: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese food images between individuals with high and low BMI; error bars indicate the standard error of the mean

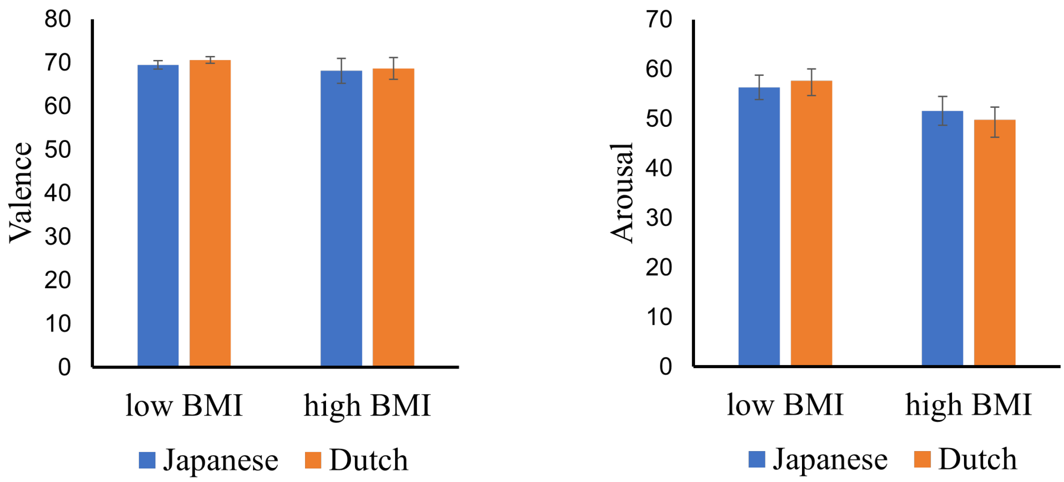

Figure 3.17: EmojiGrid valence (left) and arousal (right) ratings of Dutch and Japanese soups between individuals with high and low BMI; error bars indicate the standard error of the mean

3.4.5. Sip size

Figure 3.18 shows the mean sip size (in grams) of individuals with high and low BMI. Analyses exhibited a marginal effect for BMI groups ($F(1, 37) = 3.65$, $p = .064$), but no effect for soup types ($F(1, 37) = 0.86$, $p = .359$) and no interaction between soup types and BMI groups ($F(1, 37) = 0.13$, $p = .720$). The marginal group effect indicates that the high BMI group consumed more soup than the low BMI group.

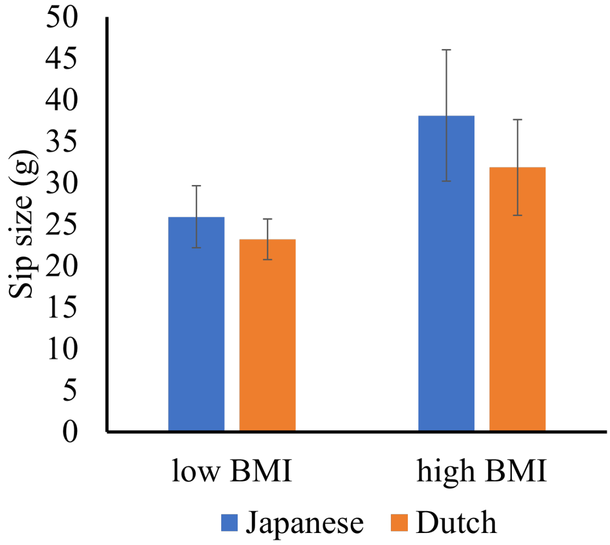

Figure 3.18: Average sip size (in grams) between individuals with high and low BMI; error bars indicate the standard error of the mean

4

Discussion and Conclusion

The aim of this study was to explore differences in food liking between socially pressured participants ($n = 18$) and control participants ($n = 24$) by means of frontal alpha asymmetry, as an implicit measure. No effects involving social pressure were found for frontal alpha asymmetry or any other measure (explicit measures of food liking, i.e. EmojiGrid valence and arousal ratings for images and soups; sip size). When participants were divided into high and low food neophobia groups, differences in the explicit EmojiGrid ratings were observed. However, implicit frontal alpha asymmetry between neophobia groups was not significantly different either. Similarly, frontal alpha asymmetry was unaffected by BMI grouping. Also explicit ratings to images were not affected by BMI, but effects were marginal for sip size and significant for arousal ratings to soups.

4.1. The effect of scenes

The intention of this study was to investigate whether approach-avoidance as measured by frontal alpha asymmetry while watching a natural movie about Japanese soy sauce is affected by social pressure to like Japanese food. The first step in the research was to investigate whether frontal alpha asymmetry was different between approach, avoidance and neutral scenes of the movie so that the sensitivity of the measure in this context could be estimated. Frontal alpha asymmetry results however did not significantly differ between approach, avoidance and neutral scenes. Also no differences between the scenes were found within social pressure and control groups. Although the approach scenes mainly consisted of appetizing food, and thus might be salient for inducing approach, avoidance scenes were comparably weak. Colleagues who rated the scenes reported to have found it difficult to find avoidance scenes. Thus, the scenes may not have been strong enough in inducing their target motivation, resulting in frontal alpha asymmetry that was not significantly different between approach, avoidance and neutral scenes.

4.2. The effect of social pressure

Second, it was investigated whether socially pressured individuals showed different frontal alpha asymmetry than control individuals. However, the social pressure intervention did not increase approach motivation as measured by frontal alpha asymmetry for the social pressure group relative to the control group. Also the EmojiGrid results – being the self-reported, explicit measure of evoked emotion in response to the food images and soups watched or drank before and after the social pressure intervention - did not show any significant effect involving social pressure. Social contexts can influence food preference and liking [20], [54]. Since no changes in implicit and particularly explicit measures were observed, we infer that the social pressure intervention itself was not successful in our study. Self-reported social pressure results confirm this conclusion. To explore effects of social pressure on food experience, additional ways to induce social demand are required. The challenge is to not make it too obvious so participants do not get aware of the intervention. For future experiments, including Japanese food or soy sauce samples that are told to have been highly rated by others, might be a possibility to increase (rated) liking for Japanese food. Additionally, asking participants to rate in the presence and observation of the person that induced social pressure, may result in an effect of social pressure on explicit ratings.

Independent of social pressure groups, Japanese compared to Dutch food images were rated lower in valence, as it was regarded as novel and unfamiliar food by the Dutch participants.

Furthermore, past studies have shown that interpersonal differences influence frontal alpha asymmetry [42]–[44], [55]. The participant sample of 42 individuals is a sound number for EEG studies. They varied in age, food neophobia scores, BMI and had an almost even gender distribution ($n_m = 23$, $n_f = 19$). These factors make the sample on the one hand a good representative for the population. But on the other hand there is more interpersonal variability between the participants, which weakens possible approach-avoidance effects as measured by frontal alpha asymmetry. Hence, it is of importance to isolate these stimulus-independent individual differences [44].

4.3. The effect of food neophobia

For the same reason of considering interpersonal differences, participants were split based on the median of all food neophobia scores. Yet food neophobia did not affect frontal alpha asymmetry, as the selected movie scenes were not strong in inducing their target emotion. Moreover, approach scenes mainly consisted of Western food not foreign food. Thus insensitivity to food neophobia differences is reasonable.

EmojiGrid ratings however were sensitive to food neophobia groups. Valence for food images was lower for high compared to low food neophobic people, which is reasonable. This was also reflected in the sip sizes, as individuals with high compared to low food neophobia generally consumed less soup.

4.4. The effect of BMI

Next to food neophobia, the final research question deals with the influence of BMI on frontal alpha asymmetry.

Frontal alpha asymmetry during approach and neutral scenes was not sensitive to BMI grouping. This is not surprising since frontal alpha asymmetry was not sensitive to any scene type as discussed above.

Interestingly the correlation of BMI and frontal alpha asymmetry at F34 initially showed that with higher BMI frontal alpha asymmetry decreased indicating avoidance motivation. This was opposite to our expectation and what was found in previous studies. For instance, in [56] frontal alpha asymmetry while participants watched a video of a confederate consuming potato chips, was significantly positively correlated with BMI. By removing the outlier with a BMI value of 46.3, the correlation effects vanished. Thus the correlation coefficient was affected by an outlier. It is well documented, that the Pearson correlation is non robust hence sensitive to outliers [57], [58]. Therefore it is important in addition to considering interpersonal differences, to exclude outliers interfering with the correlation coefficients. Another possibility is to use the Spearman rank correlation coefficient, since it is more robust to outliers and variability between the data [57]. In the absence of outliers and when the data are normally distributed, Spearman and Pearson correlations provide almost the same results [59].

Similarly BMI grouping showed no effect on the explicit ratings, except for the arousal ratings of soups. The high BMI group rated the soups overall lower in arousal than the low BMI groups. Contrary to that sip size, as an implicit measure was marginally affected by BMI groups, showing that the high BMI group consumed relatively more soup. This indicates the added value of implicit measures, as they can assess information beyond our conscious awareness.

4.5. Limitations and future work

A limitation of this study is that an EEG baseline measurement prior to the experiment was omitted. The inclusion of an EEG baseline (e.g. two minutes of eyes open, eyes closed or looking at a neutral image or video for a minute) could have had implications for the results. It could have reduced outliers [59], and removed brain activity that was present before the stimulus was presented, such that only stimulus-related activity would have been analysed. Thus it is recommended for future studies to include a baseline measurement prior to the stimulus presentation.

Moreover, time (in hours) since the participants' last meal was registered in the general questionnaire at the beginning of the experiment. Due to ambiguity, since some responses were entered as the time of the day, analyses on the time since last meal could not be conducted. It is important to prevent ambiguities like this in future.

Furthermore, it was noticed that more individuals with high food neophobia were in the control group than in the social pressure group ($n_{SP} = 8$ and $n_C = 13$). Future studies could first assess food neophobia and then assign participants into social pressure and control group. This would produce an even distribution of high and low food neophobic people into experiment groups.

4.6. Conclusion

To conclude, the social pressure intervention of this experiment was not successful, as reflected in the implicit and explicit measures. Thus it cannot be concluded whether social pressure truly changes food experience. The question of whether frontal alpha asymmetry would be a suitable marker to distinguish between socially pressured and control individuals also remains open. Approach, avoidance and neutral scene analyses for all participants, as well as within social pressure and control group, revealed no significant differences in frontal alpha asymmetry between the scene types. This implies that motivationally stronger and more salient stimuli are required to strengthen approach-avoidance effects. Inclusion of individual differences by means of food neophobia and BMI were also not sensitive to frontal alpha asymmetry during movie scenes. However, explicit measures and sip size were sensitive to food neophobia and partially BMI. This suggests that frontal alpha asymmetry while watching a movie about soy sauce is not sensitive in reflecting food experience.

More research is required to explore effects of social pressure on food experience and replicate these findings. This can contribute to the understanding of underlying psychological mechanisms of dietary choices. Moreover comparing explicit and implicit measures under social pressure aspects provides additional knowledge on whether these assess similar information. If differences between implicit and explicit measures emerge, it would indicate to expand current traditional measuring toolboxes of explicit only measures to adding implicit ones.

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Nomenclature

Abbreviations

Abbreviation	Definition
APP	approach
AVO	avoidance
BMI	body mass index
C	control
EEG	electroencephalogram
e.g.	exempli gratia, for example
FNS	food neophobia score
i.e.	id est, that is
LC	laterality coefficient
M	mean
NEU	neutral
n_f	number of female individuals
n_m	number of male individuals
Q1	quarter one
s	second(s)
SD	standard deviation
SP	social pressure
VAS	visual analogue scale

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A

Information for participants

This appendix presents the documents 'recruitment text' (Hersensignalen tijdens het zien en proeven van voedsel), 'information for participants' (Informatie voor deelnemers aan het onderzoek) and 'informed consent' (toestemmingsverklaring). They were provided to the participants before participating in this experiment. To ensure good understanding these forms are in Dutch.

Titel: “Hersensignalen tijdens het zien en proeven van voedsel”

Aantal deelnemers: 50

Vergoeding:

- € 25
- Reiskosten per bezoek (0.19 c/km tot een max van 15€)

In deze studie onderzoeken wij de reacties in hersensignalen op het zien en het proeven van voedsel. Dit kan bijvoorbeeld handig zijn om voedselbeleving te meten over culturen heen, waarbij er geen effect is van cultuurafhankelijke bias zoals die er wel is bij het beantwoorden van vragen.

Het onderzoek bestaat uit twee keer vier delen met een pauze ertussen:
- Het bekijken en beoordelen van voedselplaatjes
- Het proeven en beoordelen van twee soepen
- Het proeven van een van de typen voedsel zoals afgebeeld in de plaatjes

We zullen u ook vragen een vragenlijst over demografische gegevens (zoals lengte en gewicht) en voedselvoorkeur in te vullen.

Gedurende het hele onderzoek meten we EEG-hersenactiviteit via een mutsje waarin sensoren verwerkt zitten. Daarbij wordt een speciale gel gebruikt.

Het onderzoek zal plaatsvinden bij TNO te Soesterberg aan de Kampweg 55 en zal ongeveer twee uur duren. De (bruto)vergoeding bedraagt € 25,-. Reiskosten worden vergoed op basis van 19 cent/km gerekend vanaf uw woonadres tot een maximum van 15 euro per bezoek.

Wie kan meedoen aan het onderzoek?
Je kunt deelnemen aan dit onderzoek als je voldoet aan de volgende kenmerken:

- tussen de 25 en 65 jaar oud
- Nederlandse nationaliteit
- *geen* voedselallergieën
- *geen* strikte dieet voorkeuren (zoals vegetarisch, of een religieuze voedselvoorschriften)
- je neemt vrijwillig deel aan het onderzoek
- je geeft schriftelijk toestemming voor deelname
- je bent bereid je te houden aan de regels van het onderzoek
- je accepteert dat de verzamelde gegevens anoniem worden gebruikt en mogelijk gepubliceerd

FEITEN

Naam experimentleider: Ivo Stuldreher & Priya Sabu

E-mail adres: ivo.stuldreher@tno.nl

Aantal proefpersonen werven: 50

Aantal onderzoeksdagen: 20

Selectiecriteria:

Zie het informatiedocument voor de volledige criteria.

Locatie onderzoeksdag: Soesterberg, Kampweg 55

Tijdsduur experiment: 90 min.

Te ontvangen vergoeding in EUR: €25

Reiskostenvergoeding: Ja (€ 0,19/km - max. € 15,00)

Informatie voor deelnemers aan het onderzoek

Titel:	Implicite maten van voedsel ervaring
Projectnummer:	060.44750/01.66
Onderzoeksleider:	Ivo Stuldreher +31 6 29367802 ivo.stuldreher@tno.nl
Onderzoekslocatie:	TNO Kampweg 55 3769 DE Soesterberg
Adres:	TNO Postbus 23 3769 ZG Soesterberg 088 866 15 00

1 Wat is het doel van het onderzoek?

In deze studie onderzoeken wij de reacties in hersensignalen op het zien en het proeven van verschillende typen voedsel. Dit kan bijvoorbeeld handig zijn om voedselbeleving te meten over culturen heen, waarbij er geen effect is van cultuurafhankelijke bias zoals die er wel is bij het beantwoorden van vragen.

2 Over TNO

De letters TNO staan voor Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek. TNO ontwikkelt kennis gericht op praktische toepassing en richt zich hierbij op de volgende aandachtsgebieden: Bouw, Infra & Maritiem; Circulaire Economie & Omgeving; Defensie & Veiligheid, Energie; Industrie; Gezond Leven; Strategische Analyses & Beleid; Mobiliteit & Logistiek; Informatie & Communicatie Technologie.

3 Deelname aan onderzoek

Via dit document willen wij u informeren over het onderzoek waaraan u wordt gevraagd deel te nemen. Het onderzoek zal plaatsvinden bij TNO in Soesterberg, waarvan het bezoekadres op de voorpagina is vermeld. Het onderzoek zal inclusief instructie ongeveer 1.5 uur in beslag nemen. In totaal zullen we ongeveer 50 deelnemers onderzoeken.

4 Wie kan meedoen aan het onderzoek?

Deelnemers aan dit onderzoek moeten tussen de 25 – 65 jaar oud zijn. Aangezien dit onderzoek reacties meet op het zien en proeven van (Aziatisch) voedsel kunnen mensen met de volgende kenmerken *niet* deelnemen aan het dit onderzoek:

- Voedselallergieën
- Strikte dieetvoorkeuren (vegetariërs, veganisten, religieuze voedselvoorschriften)
- Niet-Nederlandse nationaliteit

5 Hoe wordt het onderzoek uitgevoerd?

Het onderzoek start met een vragenlijst over demografische gegevens (zoals lengte en gewicht) wat van belang is om het onderzoek met uitkomsten van ander onderzoek te vergelijken, en voedselvoorkeur. Daarna volgen twee identieke blokken, met tussendoor een calibratie pauze. Een blok bestaat uit de volgende onderdelen:

- Het bekijken en beoordelen van voedselplaatjes
- Het proeven en beoordelen van twee soepen
- Het proeven van een van de typen voedsel zoals afgebeeld in de plaatjes

Gedurende het hele onderzoek meten we uw EEG-hersenactiviteit via een mutsje waarin sensoren verwerkt zitten.

6 Wat wordt er van u verwacht?

We vragen u de instructies te volgen zoals aangegeven in dit document en vragen u om instructies van de proefleider goed op te volgen.

7 Wat zijn mogelijk voor- en nadelen van deelname aan dit onderzoek?

Voor het meten van de hersenactiviteit wordt gebruik gemaakt van gel die in het haar kan achterblijven. Er wordt de mogelijkheid geboden om na het onderzoek de haren te wassen. U kunt gevraagd worden iets te proeven dat u niet lekker vindt.

Door deel te nemen aan dit onderzoek helpt u mee met de ontwikkeling van kennis over het meten van voedselbeleving over culturen heen. Daarbij krijgt u een financiële vergoeding van 25 euro en worden uw reiskosten vergoed tot een maximum van 15 euro.

Er zijn geen risico's verbonden aan uw deelname.

8 Wat gebeurt er als u niet (meer) wenst deel te nemen aan dit onderzoek?
Deelname is geheel vrijwillig en u kunt op elk moment stoppen met het onderzoek zonder opgave van reden en verdere consequenties. Indien van toepassing kan het onderzoek ook op elke moment gestaakt kunnen worden door de onderzoeker.

9 Wat gebeurt er met uw gegevens?
Tijdens dit onderzoek verzamelen we uw hersenactiviteit en vragenlijst data. Uw persoonsgegevens worden gepseudonimiseerd. Dat houdt in dat uw data wordt gekoppeld aan een proefpersoonnummer en niet naar u als persoon is terug te herleiden. Uw contactgegevens (naam, adres, e-mail en telefoonnummer) en bankgegevens zijn bekend bij het secretariaat om contact en betaling mogelijk te maken. Uw leeftijd en geslacht zijn bij de onderzoekers bekend voor onderzoeksdoeleinden. Het 'sleutelbestand', dat uw naam koppelt aan de gepseudoniemiseerde data wordt na afloop van het experiment verwijderd.

Onderzoeksdata worden opgeslagen en bewaard om eventueel in de toekomst hergebruikt te worden om nieuwe onderzoeksvragen te beantwoorden. Door het hergebruiken van deze data wordt voorkomen dat proefpersonen opnieuw moeten worden bemeten. In dat geval zullen data geanonimiseerd worden. De onderzoeksdata zullen na maximaal 10 jaar na het afsluiten van het onderzoek verwijderd worden. Deze bewaartermijn is gebaseerd op de TNO Selectielijst. Zie voor meer informatie https://www.nationaalarchief.nl/archiveren/kennisbank/selectielijst-nederlandse-organisatie-voor-toegepast-natuurwetenschappelijk. Zoals genoemd zal de koppeling tussen jouw persoonlijke informatie en het gebruikte pseudoniem zal worden verwijderd wanneer het onderzoek is afgesloten. Daarna is het niet meer mogelijk uw gegevens te verwijderen omdat deze dan geanonimiseerd zijn.

Om uw privacy te waarborgen, worden uw naam en contactgegevens zoveel mogelijk gescheiden van uw onderzoeksgegevens bewaard. TNO garandeert dat uw gegevens alleen voor onderzoeksdoeleinden worden gebruikt. Uw gegevens zijn slechts toegankelijk voor daartoe bevoegde leden van het onderzoeksteam. Derden hebben geen toegang tot de verzamelde gegevens. Inzage door bevoegde inspecteurs kan nodig zijn om de betrouwbaarheid en kwaliteit van het onderzoek na te gaan. In publicaties over het onderzoek zijn (de antwoorden van) individuele deelnemers op geen enkele wijze herkenbaar. U heeft op basis van de privacywetgeving rechten zoals het recht van inzage, verwijdering van uw gegevens of correctie op uw persoonsgegevens. Meer informatie over welke rechten van toepassing zijn en hoe u deze kunt uitoefenen, kunt u vinden in het privacy statement (https://www.tno.nl/nl/over-tno/contact/corporate-legal/privacystatement/) van TNO. U kunt hierover ook een e-mail sturen aan privacy@tno.nl.>

10 Is er een vergoeding wanneer u besluit aan dit onderzoek mee te doen?
Als dank voor deelname aan dit onderzoek krijgt u een financiele compensatie van 25 euro en een vergoeding van uw reiskosten tot maximaal 15 euro (19 cent per kilometer).

11 Ethische aspecten
TNO gaat zorgvuldig met u om. U doet vrijwillig mee en u krijgt precies te horen wat u moet doen. Als u het daar mee eens bent en u bent geschikt om mee te doen dan begint u aan het onderzoek. U kunt ook stoppen gedurende het onderzoek als het u niet (meer) bevalt. U hoeft

daarbij geen reden op te geven. Het onderzoek wordt uitgevoerd volgens alle van toepassing zijnde nationale en internationale wetgeving en richtlijnen die gericht zijn op het bewaken van uw gezondheid en veiligheid. Het onderzoek is vooraf getoetst door de interne toetsingscommissie voor mensgebonden onderzoek van TNO.

12 Verzekering

Voor iedereen die meedoet aan dit onderzoek heeft TNO een verzekering afgesloten. De verzekering dekt schade door deelname aan het onderzoek. Schade moet u zo snel mogelijk aan TNO melden.

13 Wilt u verder nog iets weten?

Voor vragen kunt u terecht bij Ivo Stuldreher via ivo.stuldreher@tno.nl

14 Ondertekening toestemmingsformulier

In de bijlage vindt u de toestemmingsverklaring. Wanneer u geen vragen meer heeft en deel wilt nemen aan dit onderzoek, vragen we u deze te ondertekenen.

Informed consent / toestemmingsverklaring

Ondergetekende,

Naam . ______________________________

Geboortedatum ______________________________

verklaart op vrijwillige basis deel te nemen aan het onderzoek, getiteld

Impliciete maten van voedsel ervaring

bij TNO.

Ik bevestig dat ik de informatie over bovengenoemd onderzoek heb gelezen.
Ik begrijp de informatie.

De bedoelingen van het onderzoek en de daarbij gevolgde aanpak zijn tot mijn tevredenheid uitgelegd.

Ik heb de gelegenheid gehad om aanvullende vragen te stellen en deze vragen zijn naar tevredenheid beantwoord.

Ik heb voldoende tijd gehad om over deelname na te denken.

Ik weet dat mijn deelname aan het onderzoek geheel vrijwillig is en dat ik mijn toestemming op ieder moment kan intrekken zonder dat ik daarvoor een reden hoef op te geven.

Ik geef toestemming om mijn persoonsgegevens (zoals leeftijd, lengte en gewicht) te verwerken voor de doelen zoals beschreven in de informatie.

Ik geef toestemming om mijn onderzoeksgegevens te hergebruiken voor toekomstig onderzoek op het beschreven onderzoeksgebied op voorwaarde dat deze zo gecodeerd zijn, dat ze niet meer naar mij als persoon terug te leiden zijn.

Ik geef toestemming voor het bewaren van de gegevens en dat bevoegde leden van het onderzoeksteam en bevoegde inspecteurs hier inzage in hebben.

Voorts verklaar ik geen mij bekende belemmeringen te hebben om aan het onderzoek deel te nemen.

Plaats, datum ______________________________

Handtekening proefpersoon: ______________________________

TOELATING
Ik heb me ervan vergewist dat ik deze proefpersoon goed geïnformeerd heb over het onderzoek waaraan hij/zij gaat deelnemen. Ik heb mij ervan overtuigd dat deze proefpersoon voldoet aan de selectiecriteria om aan bovengenoemd onderzoek deel te mogen nemen.

Naam, handtekening en datum ondertekening proefleider:

Naam proefleider:	
Datum en plaats:	

Handtekening	

B

Questionnaires & Social Pressure Intervention

B.1. General questions

- What is your age (years)?
- What is your gender? (Male/Female)
- What is your height (cm)?
- What is your weight (kg)?
- How much time did pass since your last food consumption (hours)?
- How often do you eat Asian food? (Daily/ Every other day/ Weekly/ Monthly/ Less than once a month
- Are you on a diet? [free answer]
- How hungry are you right now? (Not hungry at all - Very hungry [VAS])
- How thirsty are you right now? (Not thirsty at all - Very thirsty [VAS])
- How full do you feel right now? (Not full at all - Very full [VAS])
- How familiar are you with Asian food? (Not familiar at all – Very familiar [VAS])

B.2. Food Neophobia Scale

The Food Neophobia Scale was used to evaluate willingness to try novel foods. This questionnaire consists of ten statements, for which a rating on a 7-point Likert scale (Strongly Disagree, Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Agree, Strongly Agree) can be given. Following are the statements in order:

- I am constantly sampling new and different foods.
- I don't trust new foods.
- If I don't know what is in a food, I won't try it.
- I like foods from different countries.
- Ethnic food looks too weird to eat.
- At dinner parties, I will try new food.
- I am afraid to eat things that I have never had before.
- I am very particular about the foods I will eat.
- I will eat almost anything.
- I like to try new ethnic restaurants.

B.3. Social pressure and control narrative

Social Pressure

Before the movie (right after the snack):
"I work for Kikkoman soy sauce company (in this project), do you know it? (...) It is really a nice company to work for. We recently made chips/popcorn (depending on the snack they just had) with soy sauce flavor, it tastes very good, we think it will be a success! (what do you think? ..) I think many people nowadays really start to appreciate Asian food. Before the lock down we had a sushi party with the people from TNO and we tasted all types of Japanese food, and compared different soy sauces, it was great. Kikkoman soy sauce was clearly judged the best. Now we will have a break for baselining. You will watch a movie of about 15 minutes on how Japanese Kikkoman soy sauce is made. We thought it is nice for you to watch a movie during the baselining break. I think it is quite interesting and fun to watch! It really rises your appetite for Asian food." After the movie:
"You really feel like Asian food now, don't you? It is really fascinating how soy sauce is made, I had a tour in the brewery in Sappemeer. We also got to taste many delicious snacks with

Kikkoman soy sauce, noodles with roasted chicken with lime and soy sauce, mmm. Soy sauce is actually an important ingredient of the majority of Asian dishes."

Control

Before the movie (right after the snack):
"Where do you come from? (..) I live in Delft/Amersfoort. It is a really nice city [i.e., also some social talk, neutral non/food related topic]. Now we will have a break for baselining. To make it less boring for you we show you a movie of about 15 minutes." After the movie: Basic social talk, not mentioning the content of the movie.

B.4. Attention questionnaire

1. Welke kleur waren de helmen van de fabrieksmedewerkers?

   A: Wit

   B: Geel

   C: Oranje

   D: Blauw

2. Wat is de naam van de porceleinen flessen die werden gebruikt voor de export van Kikkoman sojasaus in de jaren 70?

   A: Fles

   B: Container

   C: Kruik

   D: Amphora

3. In welk jaar begon Kikkoman met grootschalige marketing activiteiten in de Verenigde Staten?

   A: 1980

   B: 1957

   C: 1968

   D: 1950

4. Wat dronken de personen (aan het einde van de video) bij hun voedsel bereid met Kikkoman sojasaus?

   A: Water

   B: Bier

   C: Rode wijn

   D: Witte wijn

5. Wat zijn de basis stappen bij het bereiden van Kikkoman sojasaus voor het verhitten en vullen?

   A: Moromi maken -> Uitpersen -> Fermentatie

   B: Shoyu Koji maken -> Uitpersen -> Fermentatie

   C: Moromi maken -> Fermentatie -> Uitpersen

   D: Shoyu Koji maken -> Fermentatie -> Uitpersen

6. Naast sojabonen en zout, wat zijn de hoofdingredienten van Kikkoman sojasaus?

   A: Suiker, Water

   B: Suiker, Micro-organismen

   C: Tarwe, Water

   D: Gist, Water

7. Hoe dragen aminozuren en suikers (onderandere) bij aan Kikkoman sojasaus?

   A: Geeft het haar unieke smaak (umami), unieke kleur en verbeterd aroma

   B: Draagt bij aan alle vier de smaken van Kikkoman sojasaus en haar unieke kleur

   C: Suiker draagt bij aan de zoete smaak van sojasaus voor het bakken en als dip

   D: Enzymen breken de suiker af om bij te dragen aan de smaak van sojasaus en het aroma te verbeteren

8. Wat zijn de smaken van Kikkoman sojasaus?

   A: Zout, Bitter, Zuur, Hartig (umami)

   B: Zoet, Zout, Zuur, Bitter, Hartig (umami)

   C: Zoet, Zout, Zuur, Bitter, Pittig

   D: Zoet, Zout, Zuur, Bitter, Hartig (umami), Pittig

9. Welk effect van Kikkoman sojasaus is benoemd in de video?

   A: Virustatisch effect

   B: Zoet-zuur effect

   C: Contrast effect

   D: Pittig effect

10. Deze unieke Kikkoman sojasaus komt uit?

   A: Japan

   B: China

   C: Indonesië

   D: Thailand

11. Door een toename in vraag sojasaus in de Verenigde Staten bouwde Kikkoman haar eerste fabriek in het buitenland. In welke staat?

   A: Michigan

   B: Washington

   C: Minnesota

   D: Wisconsin

12. Welk voorbeeld van Kikkoman microorganismen was te zien in de video?

   A: Asparagus

   B: Aspergillus

   C: Esophagus

   D: Alagillus

B.5. Final questionnaire

- What do you think the goal of this experiment was? [free answer]
- If the experiment leader told you the enthusiastic story about Japanse food and Kikkoman just before the movie, answer this question. If not, you can ignore it and just press anywhere on the scale. The speech just before the movie was part of the experiment. Did you see through this? (Not at all - Certainly [VAS])
- How socially pressured did you feel to like Asian food? (Not at all - Very [VAS])

C

Stimulus Material

Food images were taken from the CROCUFID (Cross Cultural Food Images Database [45]). For this study two sets (subset A and B) consisting of 20 images each were selected for each category (Dutch, Japanese, palatable and unpalatable). The display order of the subsets were counterbalanced for the initial and post-social demand rating phases. We tried to equally distribute food types, e.g. sweets, in the two respective subsets. The number, description, normative valence and arousal ratings, as well as the corresponding subset of the image, are specified in Tables C.1, C.2, C.3 and C.4 for the Dutch, Japanese, palatable and unpalatable food image category respectively.

Table C.1: Dutch image stimuli from CROCUFID database [45], number, description, normative ratings of valence and arousal

Dutch	Number	Name	Valence		Arosual	
			Mean	SD	Mean	SD
Subset A	7	Liquorice	33.14	24.34	30.79	26.17
	21	Stroopwafels (syrup waffles)	59.19	22.71	49.85	25.44
	126	Fried cod bits with sauce	60.47	26.15	57.17	28.3
	140	Mixed cheese	63.23	23.35	58.95	26.51
	182	Sauerkraut with meatball, different angle	39.36	23.54	36.89	22.78
	248	Croquettes, random arrangement	42.47	24.64	36.48	24.88
	305	Gingerbread, cut	57.71	19.28	47.8	23.05
	322	Bami disk snack, cut	33.5	25.39	32.93	26.49
	327	Chocolate pieces	64.53	26.06	57.34	30.34
	335	sausage bread	55.34	24.85	51.1	25.88
	338	Fried fish + sauce	52.25	26.77	47.6	28.2
	344	Onion soup	30.23	23.93	23.53	21.85
	349	Mashed potatoes with vegetables	32.36	23.03	28.65	21.94
	684	Pumpernickel	-	-	-	-
	831	oliebollen (Dutch donuts) 5	-	-	-	-
	837	pepernoten (gingernuts) - large portion	-	-	-	-
	857	sandwich with chocolate flakes	-	-	-	-
	863	crispbake with anis seeds	-	-	-	-
	870	currant bun	-	-	-	-
	880	smoked sausage (cut)	-	-	-	-
Subset B	97	Fish haring and onions	26.47	20.97	25.97	21.58
	116	Viandel, overlay	35.63	24.18	30.11	22.48
	132	Wilhelmina peppermints	28.77	23.67	21.3	21.22
	177	Bread with sausage, overlay	54.61	27.72	49.5	29.96
	242	Carrero horizontal	32.76	22.69	33.14	24.37
	290	French fries + mayonaise	63.1	24.94	58.13	28.05
	296	Cajun corn cut	34.63	21.2	32.03	22.71
	306	Gingerbread with butter	47.26	24.3	43.61	23.26
	308	Cheese	61.76	24.08	54.28	26.18
	314	Mixed ice cream	69.21	23.23	61.6	23.98
	316	Hotdog with sauce	50.1	24.38	47.85	25.25
	328	Chocolate chip cookies	76.31	17.58	63.45	24.81
	334	Cheese souffle	41.33	20.51	35.11	21.25
	353	Mashed potatoes with carrot and meatball	35.74	21.89	34.4	25.09
	833	oliebollen (Dutch donuts) 3 with powder sugar	-	-	-	-
	859	prawn crackers	-	-	-	-
	866	apple turnover	-	-	-	-
	875	rye bread	-	-	-	-
	881	goat's feet cookie	-	-	-	-
	898	pea soup with smoked sausage	-	-	-	-

Table C.2: Japanese image stimuli from CROCUFID database [45], number, description, normative ratings of valence and arousal

Japanese	Number	Name	Valence		Arosual	
			Mean	SD	Mean	SD
Subset A	359	Roasted mochi pieces	50.85	29.25	42.73	27.8
	361	Candied sweet potato (spreaded)	38.02	27.34	34.76	26.49
	370	Kinpira burdock	41.69	22.94	35.85	23.48
	379	Octopus dumplings with Mayonnaise	49.29	25.62	44.28	26.48
	397	Steamed rice with wild vegetables (spreaded)	54.46	24.67	45.51	26.44
	398	Pickled eggplant (gathered)	37.05	25.13	32.33	23.82
	412	Sushi-2	58.42	31.66	53.03	32.33
	427	Rice ball, cut	56.62	28.41	48.34	29.23
	435	Pickled dish (seaweed, cucumber and octopus)	47.37	27.06	40.39	26.95
	437	Bibimbap bowl	53.95	27.18	52.27	26.86
	443	Skewered rice dumplings in a sweet soy glaze	46.37	30.21	42.82	29.1
	460	Steamed meat bun	55.62	26.01	48.47	24.03
	496	Bean-jam pancake	57.53	23.36	47.88	26.23
	503	Japanese wheat noodle (Udon)	48.32	27.32	38.85	26.76
	509	Capelin	38.26	29.59	32.9	28.01
	512	Simmered mackerel with miso, cut	36.38	28.11	32.22	26.12
	519	Pot stickers	61.24	26.03	54.59	25.85
	523	Ramen noodles in soy-sauce flavored soup	57.58	25.62	52.56	26.79
	524	Fried vegetables	55.13	22.66	47.7	23.52
	527	Curry and rice	59.77	26.7	53.7	27.83
Subset B	363	Sakura shrimp	27.62	22.82	23.85	20.84
	372	Simmered hijiki	35.75	26.65	30.04	24.66
	377	Octopus dumplings	37.72	26.92	38.07	25.91
	388	Grilled salmon	50.91	25.8	45.88	26.76
	393	Tempura Assorted	54.69	25.99	52.18	25.57
	405	summer roll (spring roll)	62.89	26.74	50.12	26.97
	411	Sushi-1	65.84	27.27	58.57	30.85
	414	Boiled wipe and Bamboo shoot (gathered)	33.03	23.47	27.06	21.44
	448	Japanese style skewered chicken (Assorted)	67.61	23.05	58.97	27.07
	451	Yellow pickled radish, gathered	51.73	25.05	39.86	24.15
	464	Rice cracker	45.04	22.97	36.51	23.32
	467	Boiled fish paste, cut	53	21.72	47.12	22.03
	476	Japanese hodgepodge (oden)	36.79	28.77	32.28	27.54
	487	stir-fried noodles	62.19	23.88	54.81	27.87
	517	Chilled tofu topped with dried bonito flakes	49.57	28.39	42.34	27.16
	531	Starchy sauce rice bowl	40.94	28.49	34.87	26.14
	533	Ramen noodles in pork broth	48.59	26.33	46.03	27.67
	551	Bean curd Szechwan style	44.8	27.74	41.65	28.69
	557	Grilled rice balls	48.8	22.1	44.24	24.67
	562	Rice dish cooked with chicken and burdock, spreaded	54.42	23.02	44.23	22.9

Table C.3: Palatable image stimuli from CROCUFID database [45], number, description, normative ratings of valence and arousal

Palatable	Number	Name	Valence		Arosual	
			Mean	SD	Mean	SD
Subset A	18	Onions	47.87	22.91	35.1	23.39
	23	Almonds	59.41	23.92	48.82	26.78
	31	Chips, Lays natural	61.44	22.23	59.06	24.64
	36	Cucumberhalf + parts	58.92	23.41	46.3	26.23
	43	Orange cut	73.56	19.39	61.85	25.51
	44	Pineapple slices	64.99	25.16	56.19	27.92
	65	Mushrooms + parts	46.95	24.64	37.82	23.9
	93	Eggs + peeled parts	51.75	26.98	43.15	27.92
	128	M&M's chocolate	67.2	24.64	59.73	27.74
	162	Mixed bellpepper parts	66.8	21.69	54.09	27.74
	187	Watermelon parts	72.18	23.92	60.59	26.96
	301	Croissants, random	71.1	20.8	62.06	24.03
	325	Chocolate bonbons	79.33	19.32	73.72	23.08
	351	Mixed fruit	74.18	20.47	62.6	26.8
	357	Pizza	75.8	17.23	69.41	21.44
	716	Pumpkin	-	-	-	-
	937	Cut Mango	-	-	-	-
	939	Sliced eggplant	-	-	-	-
	949	Yogurt	-	-	-	-
	953	sliced cabbage	-	-	-	-
Subset B	11	Kiwis + parts	66.37	22.21	55.47	25.74
	15	KitKat	69.25	23.23	61.46	26.9
	19	Onion + parts	47.53	23.6	35.02	25.08
	29	Cashew nuts	64.44	22.21	52.83	24.94
	42	Mixed nuts	59.44	26.23	53.87	27.75
	54	Tomatoes	67.35	21.4	56.88	26.14
	55	Tomatoes + cucumber parts	63.44	23.18	50.88	26.19
	58	White grapes	65.93	22.11	55.06	26.81
	77	Potatoes + boiled	58.94	22.5	45.19	25.89
	140	Mixed cheese	63.23	23.35	58.95	26.51
	144	Cherry sweet cakes	63.04	24.3	57.57	26.19
	145	Mixed sweets	77.94	18.09	68.25	25.23
	146	Strawberry	84.11	14.76	71.01	21.93
	292	Cheeseburger	52.13	24.74	47.99	27.65
	307	Green beans	52.46	24.71	37.45	23.46
	336	Popcorn	65.26	23.23	55.02	28.75
	631	Persimmon (Whole)	-	-	-	-
	935	Sliced brown breads	-	-	-	-
	942	Nectarine	-	-	-	-
	948	Cut Broccori	-	-	-	-

Table C.4: Unpalatable image stimuli from CROCUFID database [45], number, description, normative ratings of valence and arousal

Unpalatable	Number	Name	Valence		Arosual	
			Mean	SD	Mean	SD
Subset A	5	Grasshopper	17.05	21.04	24.89	27.16
	109	Greek salad	9.14	16.48	15.19	22.25
	111	Appleparts	13.84	19.69	20.28	26.35
	112	Banana + parts	35.03	29.83	29.34	27.58
	113	Omelet on bread	14.88	20.28	19.08	24.66
	154	Salmon salad	16.51	18.66	20.3	24.25
	184	Strawberries	4.17	10.32	20.49	33.15
	185	Mixed olives and feta	31.32	26.66	31.11	27.93
	189	Melon + parts	9.49	14.31	15.36	22.56
	191	Carpaccio	25.69	24.27	24.11	23.41
	711	Locust boiled down in soy	-	-	-	-
	957	Nectarine, molded	-	-	-	-
	963	Yogurt, molded	-	-	-	-
	965	Snails on broccori	-	-	-	-
	972	Avocado with mealworm (fake)	-	-	-	-
	978	Green beans, molded	-	-	-	-
	979	Sliced potatos, extremely molded	-	-	-	-
	982	Sliced carrots, extremely molded	-	-	-	-
	984	Sliced cabbages with cockroaches (fake)	-	-	-	-
	986	molded basil paste with mealworms (fake)	-	-	-	-
Subset B	114	Crostini	22	22.72	26	26.19
	152	Pear parts	7.85	14.2	15.37	23.99
	153	seaweed salad	20.4	21.92	22.37	25.22
	166	Appleparts	10.41	16.58	14.23	22.14
	167	Salad	5.8	10.97	17.17	28.85
	168	Omelet on bread	3.87	5.57	11.95	23.71
	169	Raw chicken	36.97	29.57	34.02	26.78
	190	Banana + parts	4.75	10.27	10.62	22.15
	340	Molded potatoes	12.95	17.36	20.97	28.25
	341	Mealworms, single portion	13.09	19.99	20.52	27.8
	661	Chicken feet	-	-	-	-
	954	Avocado, molded	-	-	-	-
	955	Potato, molded	-	-	-	-
	959	Mango, molded	-	-	-	-
	961	Eggplant, molded	-	-	-	-
	970	Mealworms (fake)	-	-	-	-
	974	Small spiders and cockroaches (fake)	-	-	-	-
	975	Mealworms with half cabbage (fake)	-	-	-	-
	976	Grapes with white mealworms (fake)	-	-	-	-
	977	Cut broccori, molded	-	-	-	-

D

Movie scene ratings

This section provides the initial movie scene ratings, based on which the approach, avoidance and neutral scenes for frontal alpha asymmetry computation were selected. Table D.1 shows the scene ratings of six colleagues, with start and end times, duration, event description and the type of the scene.

Table D.1: Movie scene ratings by six colleagues with start and end times, duration, event description and the type of the scene

Rater 1				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
01:49	02:00	00:11	Meat cooking	APP
06:28	06:37	00:09	Corn being heated and sizzling sound	APP
09:55	10:06	00:11	Display of Food with relaxing music - corn, salmon, etc.	APP
10:24	10:55	00:31	More display of food	APP
11:00	11:50	00:50	Heat effect 'appetite-stimulizing aroma', pastry, meat cooking	APP
13:52	14:07	00:15	Display of Food	APP
14:37	14:59	00:22	food scenes with music reaching climax	APP
Average:		**00:21**		
02:31	02:40	00:09	four ingredients	NEU
13:35	13:52	00:17	Locations of Kikkoman	NEU
05:37	05:48	00:11	Aminoacids	NEU
06:39	07:00	00:21	Addition of Air to Moromi	NEU
Average:		**00:14**		
02:44	02:57	00:13	Mold like looking sample taking	AVO
02:57	03:20	00:23	Reveal of Aspergillus	AVO
04:27	04:37	00:10	Time lapse of molding	AVO
05:05	05:15	00:10	Shoyu Koji (looking mud-like) transported into tanks	AVO
Average:		**00:14**		

Rater 2				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
00:19	00:35	00:16	Pouring soy sauce over different foods	APP
01:49	02:00	00:11	Grilling meat with soy sauce	APP
05:59	06:05	00:06	Soy Sauce Pooring	APP
06:20	06:37	00:17	Cooking of foods with sizzeling soy sauce	APP
08:23	08:41	00:18	Soy sauce dripping along the sheets	APP
09:20	09:30	00:10	Soy sauce dripping along the sheets	APP
10:27	10:37	00:10	Food being prepared	APP
11:00	11:07	00:07	Heating with aroma	APP
11:37	11:40	00:03	Sizzling meat	APP
Average:		**00:10**		
02:30	02:40	00:10	Four ingredients	NEU
04:42	04:50	00:08	Operators at computer	NEU
05:38	05:47	00:09	Protein + Starch	NEU
06:38	06:47	00:09	Operator on computer	NEU
08:12	08:22	00:10	Preparing for squeezing of soy sauce	NEU
09:30	09:45	00:15	Soy sauce in different languages	NEU
10:10	10:20	00:10	The four flavours of kikkoman	NEU
11:50	12:35	00:45	The export of kikkoman	NEU
13:35	13:52	00:17	Factories of kikkoman	NEU
Average:		**00:14**		
02:57	03:20	00:23	Kikkoman Aspergillus	AVO
04:27	04:37	00:10	Mold growing	AVO
04:50	05:05	00:15	Fermentation	AVO
06:47	07:01	00:14	Moromi	AVO
07:12	07:29	00:17	Moromi	AVO
Average:		**00:15**		

Rater 3				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
00:20	00:36	00:16	food	APP
01:49	02:28	00:39	food, wine	APP
06:29	06:30	00:01	mais	APP
09:58	10:07	00:09	food	APP
10:27	10:57	00:30	food	APP
11:27	11:47	00:20	icecream, cooked food	APP
13:54	14:08	00:14	food	APP
Average:		**00:18**		
			everything else is neutral	NEU
00:10	00:20	00:10	sparkles	AVO
01:41	01:42	00:01	fermentation bubbles	AVO
02:42	02:58	00:16	micro organiosms,	AVO
03:50	03:58	00:08	shoyu koji	AVO
04:29	04:36	00:07	kikkoman aspergillus	AVO
06:20	06:25	00:05	raw chicken	AVO
06:48	07:02	00:14	moromi	AVO
07:12	07:30	00:18	micro organisms	AVO
10:23	10:27	00:04	raw meat	AVO
10:59	11:26	00:27	raw food	AVO
11:48	11:50	00:02	raw chicken	AVO
Average:		**00:10**		

Rater 4				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
01:50	02:18	00:28	tasteful cooking	APP
05:48	05:53	00:05	tasteful food	APP
06:20	06:38	00:18	tasteful food cooking	APP
09:53	10:06	00:13	tasteful food	APP
10:23	11:51	01:28	tasteful food	APP
13:53	14:06	00:13	good food	APP
Average:		**00:27**		
00:00	00:46	00:46	intro to Japanese culture	NEU
00:56	01:50	00:54	intro to Kikkoman soy sause	NEU
02:22	02:48	00:26	ingredients of soy sause	NEU
02:58	04:28	01:30	abstract production process	NEU
04:38	05:48	01:10	abstract production process	NEU
05:53	06:20	00:27	abstract chemical process	NEU
06:38	09:30	02:52	chemical plant	NEU
09:30	09:53	00:23	intro movie	NEU
10:06	10:23	00:17	abstract animation	NEU
11:51	13:53	02:02	historical images	NEU
14:06	15:06	01:00	rather abstract summary	NEU
Average:		**01:04**		
02:48	02:58	00:10	fungi	AVO
04:28	04:38	00:10	grow of fungus	AVO
Average:		**00:10**		

Rater 5				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
01:49	02:00	00:11	Baking some meat with soy sauce	APP
02:09	02:16	00:07	Pan-fried vegetables with soy sauce	APP
06:23	06:37	00:14	Movie how soy sauce is used (e.g. chicken, meat, and corn)	APP
08:02	08:41	00:39	Movie showing "moromi" pressing	APP
10:21	10:55	00:34	Image how soy sauce is used	APP
11:37	11:40	00:03	Pouring soy sauce on heated meat	APP
12:37	12:57	00:20	Kikkoman commercial broadcasted in US	APP
Average:		**00:18**		
00:36	00:46	00:10	The title of the movie popped up	NEU
01:11	01:21	00:10	The historical soy sauce production image popped up	NEU
02:20	02:27	00:07	Schene of Western elderly couple eats meat with soy sauce	NEU
02:29	02:40	00:11	Image of ingredients of soy sauce	NEU
02:59	03:22	00:23	Visualized movie how Koji molds grow	NEU
07:13	07:29	00:16	Actual fermentation movie	NEU
10:09	10:21	00:12	Describing the taste and flavour of soy sauce	NEU
11:01	11:36	00:35	Description of function of soy sauce	NEU
11:52	12:00	00:08	Trading history showing ships with Dutch flags (mid 17th century)	NEU
12:25	12:36	00:11	Newly launched in US market (1957)	NEU
13:35	13:52	00:17	Soy sauce production overseas	NEU
14:59	15:04	00:05	Kikkoman log popped up	NEU
Average:		**00:14**		

Rater 6				
Time -Start	**Time - End**	**Duration**	**Event**	**Type**
00:20	00:35	00:15	different floating panels of nice food with soy sauce	APP
00:35	00:47	00:12	dramatic music	APP
01:50	02:00	00:10	brushing soy sauce on meat	APP!!
02:04	02:14	00:10	handling fish, wok	APP
02:20	02:27	00:07	couple dining with wine	APP
06:25	06:38	00:13	corn, nice food images	APP!!
09:32	09:52	00:20	dramatic music (world with names of soy sauces popping up)	APP
10:27	10:52	00:25	nice food (before and after it bit less nice food, raw meat)	APP!!
11:29	11:52	00:23	food varying in niceness	APP
12:39	12:50	00:11		APP!!
14:36	14:52	00:16	different floating panels of nice food with soy sauce	APP
Average:		**00:14**		
03:23	03:44	00:21	boring schematic	NEU
Average:		**00:21**		
00:55	00:59	00:04	mentioning of micro-organisms	AVO
01:38	01:42	00:04	bubbling stuff	AVO
02:50	02:57	00:07	green mould	AVO!!
02:57	03:23	00:26	growing nice looking micrsocopic mould	AVO
03:50	03:55	00:05	soyu koji that comes out of container	AVO
04:29	04:36	00:07	mould growing on beans	AVO!!
06:48	07:01	00:13	strirring the mixture, bubbles	AVO
07:13	07:30	00:17	popping bubbles	AVO
Average:		**00:10**		

E

Supplementary results

E.1. Temporal alpha asymmetry

It is expected that the frontal alpha asymmetry laterality coefficient would increase during approach scenes and decrease during avoidance scenes. For the neutral scene a rather constant trace would be anticipated. Figure E.1 visualizes frontal alpha asymmetry over the entire movie for all participants at electrodes F34 and F78 (top and bottom graph respectively). Preselected approach, avoidance and neutral scenes are indicated in light-green, light-red, and grey, respectively. Due to the long recording duration of 15 minutes, the frontal alpha asymmetry trace seemed very noisy, therefore data points are displayed in 5 second intervals.

It can be seen that the alpha asymmetry trace does not correspond as would be expected to all the scenes. Hence, pre-selected approach scenes as well as avoidance scenes were not strong in inducing their target emotion.

E.2. The effect of social pressure

E.2.1. Temporal alpha asymmetry

If social pressure would affect frontal alpha asymmetry, this measure would be increased (indicating approach motivation) for the social pressure compared to the control group, particularly during pre-selected approach and neutral scenes. In Figure E.2 the temporal frontal alpha asymmetry at F34 (top) and F78 (bottom) between individuals in the social pressure

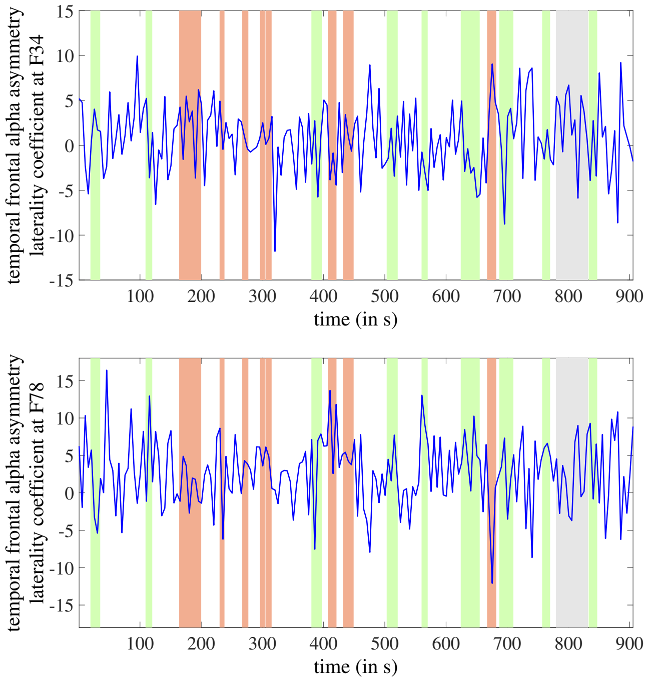

Figure E.1: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom), plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

and control group is shown. Statistical testing using independent-samples t test has shown no significant differences in the mean frontal alpha asymmetry laterality coefficient between groups (F34: $t(40) = -0.66$, $p = .513$ and F78: $t(40) = 0.77$, $p = .446$). This indicates that the social pressure intervention did not influence frontal alpha asymmetry during the movie.

A possible explanation for the lack of heightened frontal alpha asymmetry for the social pressure group compared to the control group could be higher variability between individuals. Hence temporal alpha asymmetry over the entire movie, including the standard deviation was plotted and is shown in Figure E.3. Statistical testing using independent-samples t test showed no significant differences between the standard deviations of the social pressure and control group (F34: $t(40) = 1.18$, $p = .244$, F78: $t(40) = 0.08$, $p = .935$). The individual variability within the two groups is not accountable for the ineffectively of the social pressure intervention.

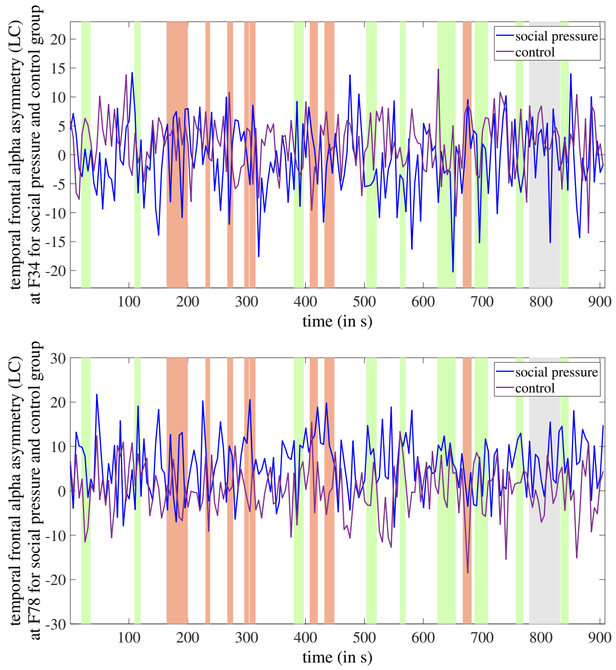

Figure E.2: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) between social pressure (blue) and control (purple) group, plotted at 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

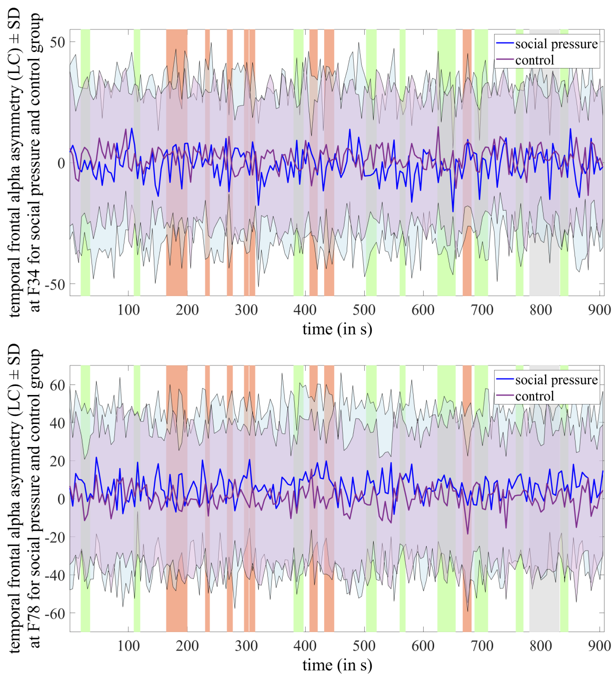

Figure E.3: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) including the standard deviation (shaded area) between social pressure (blue) and control (purple) group, plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

E.2.2. EmojiGrid ratings for palatable and unpalatable images

In Figure E.4 the mean EmojiGrid valence (left) and arousal (right) ratings for palatable and unpalatable pictures between the social pressure and control group is shown, before and after the application of social pressure. For valence there was no effect of groups ($F(1, 40) < 0.01$, $p = .969$), but an effect pre- and post the social pressure intervention ($F(1, 40) = 15.73$, $p < .001$), image types ($F(1, 40) = 555.25$, $p < .001$) and an interaction effect between the social pressure intervention and image types ($F(1, 40) = 4.16$, $p = .048$). There were no interaction effects between image types and groups ($F(1, 40) = 2.27$, $p = .140$) and between pre-post social pressure intervention and groups ($F(1, 40) = 0.22$, $p = .645$) and between image types, pre-post social pressure intervention and groups ($F(1, 40) = 1.13$, $p = .295$).

For arousal there was no effect of groups ($F(1, 40) = 1.79$, $p = .189$), but similarly an effect pre- and post the social pressure intervention ($F(1, 40) = 4.27$, $p = .045$), image types ($F(1, 40) = 5.84$, $p = .020$) and an interaction effect between the social pressure intervention and image types ($F(1, 40) = 9.59$, $p = .004$). There were no interaction effects between image types and groups ($F(1, 40) = 2.73$, $p = .106$) and between pre-post social pressure intervention and groups ($F(1, 40) = 2.83$, $p = .100$) and between image types, pre-post social pressure intervention and groups ($F(1, 40) = 0.17$, $p = .683$).

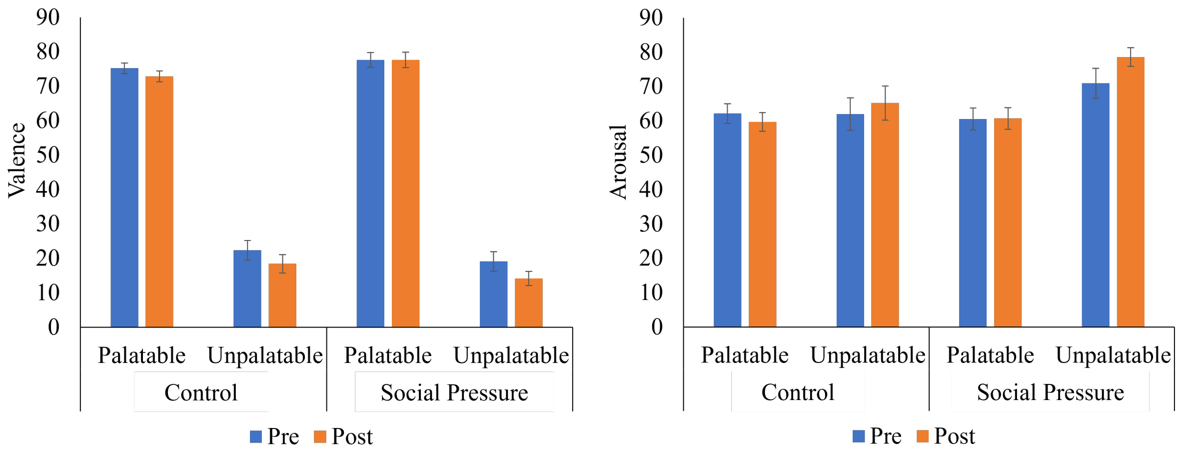

Figure E.4: EmojiGrid valence (left) and arousal (right) ratings of palatable and unpalatable images, pre- and post social pressure intervention; error bars indicate the standard error of the mean

E.3. The effect of food neophobia

E.3.1. Temporal alpha asymmetry

It is expected that individuals with higher food neophobia would show lower frontal alpha asymmetry (i.e., avoidance motivation) and vice versa. Figure E.5 shows the mean frontal alpha asymmetry over the entire movie between individuals with high and low food neophobia at electrode sites F34 (top) and F78 (bottom). Statistical testing using independent-samples t test found no significant group effects (F34: $t(40) = -0.87$, $p = .389$ and F78: $t(40) = 0.48$, $p = .636$).

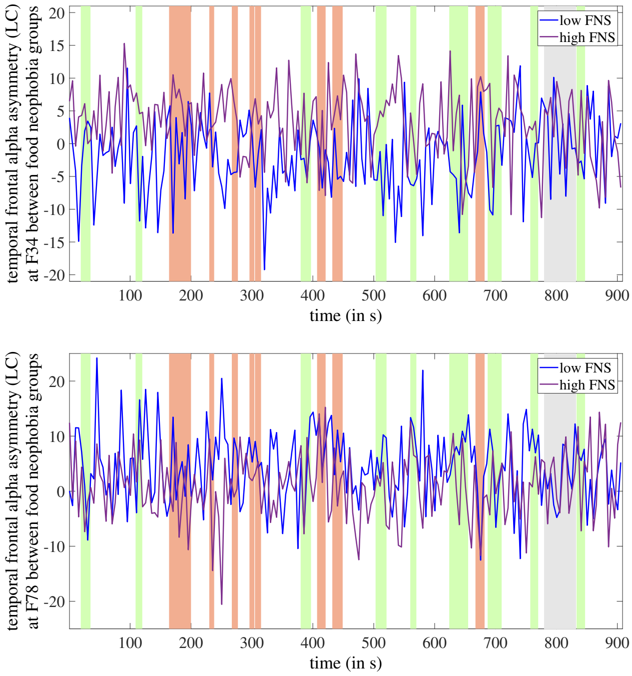

Figure E.5: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) between individuals with low (blue) and high food neophobia (purple), plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

To explore whether the lack of heightened frontal alpha asymmetry for the low relative to high food neophobia group is caused by higher variability between individuals, the temporal alpha asymmetry over the entire movie including the standard deviation was plotted and is shown in Figure E.6. Statistical testing using independent-samples t test showed no significant differences between the standard deviations of the low and high food neophobia group (F34: $t(40) = 0.17$, $p = .868$, F78: $t(40) = 0.58$, $p = .566$).

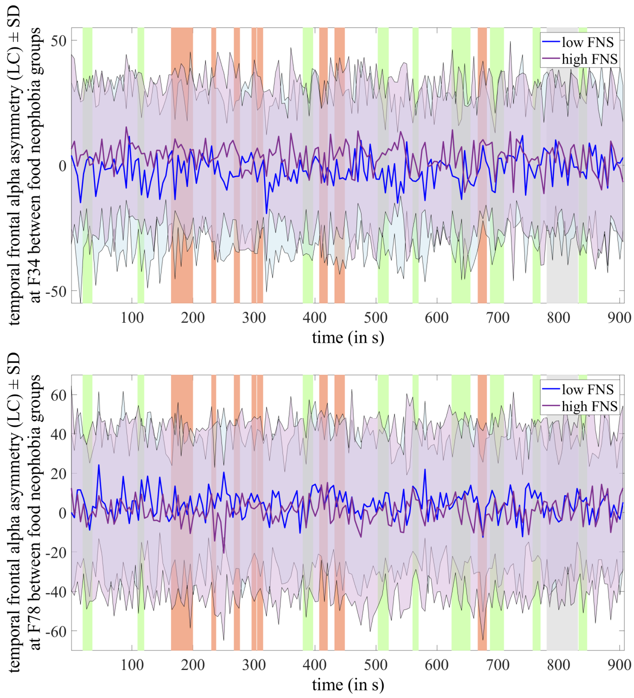

Figure E.6: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) including the standard deviation (shaded area) between individuals with low (blue) and high food neophobia (purple), plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

E.3.2. EmojiGrid ratings for palatable and unpalatable images

The EmojiGrid valence (left) and arousal (right) ratings of palatable and unpalatable pictures between individuals with high and low food neophobia is displayed in Figure E.7. As would be expected, there was a main effect of image type ($F(1, 40) = 526.29$, $p < .001$), where valence for palatable images was much higher than for unpalatable images. There was no effect of food neophobia groups ($F(1, 40) = 0.32$, $p = .576$) and no interaction between groups and image types ($F(1, 40) = 0.19$, $p = .666$).

For arousal there was a main effect of images ($F(1, 40) = 4.30$, $p = .045$), where unpalatable compared to palatable images were rated higher in arousal. There was no effect of food neophobia groups ($F(1, 40) = 0.47$, $p = .497$) and no interaction effect between images and groups ($F(1, 40) = 0.41$, $p = .528$).

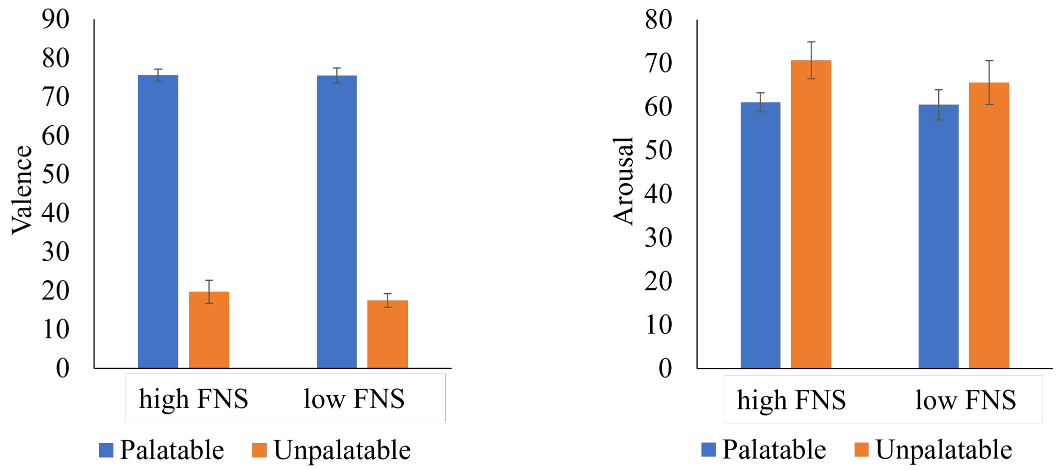

Figure E.7: EmojiGrid valence (left) and arousal (right) ratings of palatable and unpalatable images, between individuals with high and low food neophobia score; error bars indicate the standard error of the mean

E.4. The effect of BMI

E.4.1. Temporal alpha asymmetry

It is expected that individuals with higher BMI would show higher frontal alpha asymmetry as an indication of approach motivation. Figure E.8 shows the mean frontal alpha asymmetry over the entire movie between individuals with high and low BMI at electrode pairs F34 (top) and F78 (bottom). Statistical testing using independent-samples t test found no differences between BMI groups (F34: $t(37) = 0.98$, $p = .333$ and F78: $t(37) = 0.49$, $p = .624$).

Greater variability in the high BMI group could be an explanation why alpha asymmetry was not sensitive for BMI groups. Therefore, the mean temporal alpha asymmetry including the standard deviation between individuals with high and low BMI is shown in Figure E.9. Statistical testing using independent-samples t test revealed no significant differences between BMI groups (F34: $t(37) = -0.23$, $p = .814$, F78: $t(37) = -1.11$ $p = .275$). Thus individual variability does not explain the insensitivity of alpha asymmetry for BMI groups.

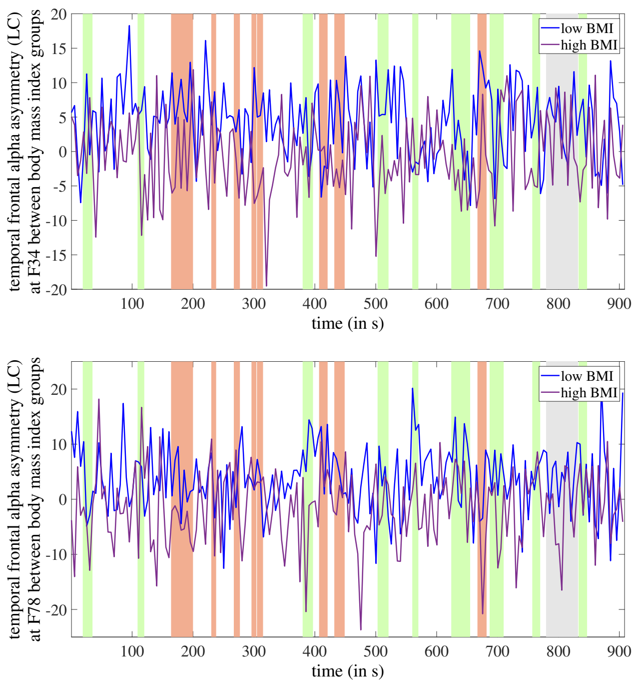

Figure E.8: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) between individuals with low (blue) and high BMI (purple), plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

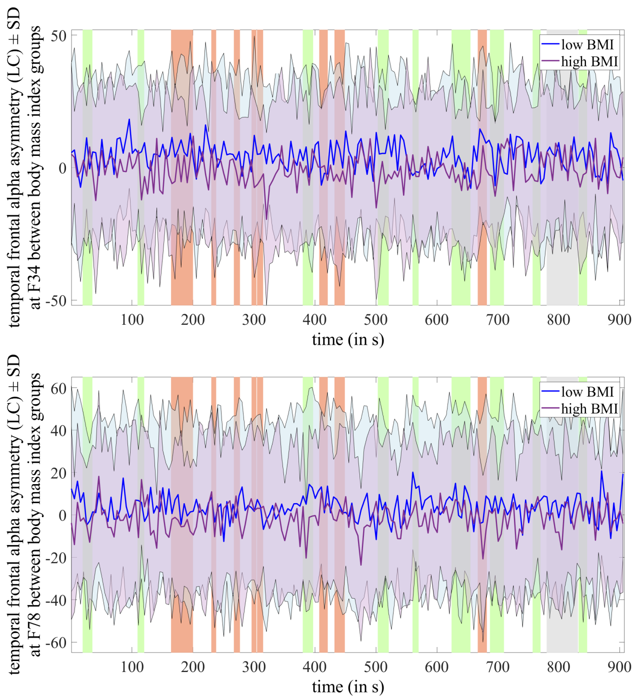

Figure E.9: Temporal frontal alpha asymmetry over entire movie at F34 (top) and F78 (bottom) including the standard deviation (shaded area) between individuals with low (blue) and high BMI (purple), plotted in 5 second intervals with approach, avoidance and neutral scenes highlighted in light-green, light-red and grey, respectively

F

Mobile approach avoidance task paper

As a part of the internship, data from a previous experiment on a mobile approach avoidance task to measure food liking was analysed. This was published ('Measuring Implicit Approach–Avoidance Tendencies towards Food Using a Mobile Phone outside the Lab', [60]) and can be found below.

foods

MDPI

Communication

Measuring Implicit Approach–Avoidance Tendencies towards Food Using a Mobile Phone outside the Lab

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Abstract: Implicit ('unconscious') approach–avoidance tendencies towards stimuli can be measured using the Approach Avoidance Task (AAT). We recently expanded a toolbox for analyzing the raw data of a novel, mobile version of the AAT (mAAT), that asks participants to move their phone towards their face (pull) or away (push) in response to images presented on the phone. We here tested the mAAT reaction time and the mAAT distance in a study with 71 Dutch participants that were recruited online and performed an experiment without coming to the laboratory. The participants used both the mAAT and (explicit) rating scales to respond to photographic images of food. As hypothesized, the rated wanting, rated valence and mAAT reaction time indicated a preference for palatable over unpalatable food, and for Dutch over Asian food. Additionally, as expected, arousal was rated higher for unpalatable than for palatable food, and higher for Dutch than for Asian food. The mAAT distance indicated that the unpalatable food images were moved across larger distances, regardless of the movement direction (pull or push), compared to the palatable food images; and the Dutch food images were moved across larger distances than the Asian food images. We conclude that the mAAT can be used to implicitly probe approach–avoidance motivation for complex images in the food domain. The new measure of mAAT distance may be used as an implicit measure of arousal. The ratings and the mAAT measures do not reflect the exact same information and may complement each other. Implicit measures, such as mAAT variables, are particularly valuable when response biases that can occur when using explicit ratings are expected.

Keywords: food images; consumer; approach–avoidance; Approach–Avoidance Task (AAT); valence; arousal; wanting; implicit measure; self-report; mobile phone

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1. Introduction

Emotional attitudes towards food are considered to be important in predicting consumer behavior [1–5]. It has been shown that, compared to verbal liking preferences, food-evoked emotions have more predictive value in foreseeing whether consumers will like a product or not [1]. Recent literature reviews on the use of implicit ('unconscious') and explicit (self-report) methods to measure food-evoked emotions show the dominance of explicit methods in the field [6,7]. Implicit and explicit measures of food-evoked emotions can convey similar information. For instance, for a range of physiological, behavioral and explicit measures, responses toward tasting a clearly unpalatable drink stand out with respect to responses toward regular drinks [8]. However, on closer examination, all of these measures do reflect different processes. For instance, skin conductance has consistently been found to be positively associated with arousal [9–12], and is influenced by factors unrelated to emotion, such as temperature, whereas explicit reports on arousal reflect 'arousal' as interpreted by the individual, to the extent that he or she is aware of this and chooses to share this information. A difference between explicit and implicit measures, and thus, the added value of implicit measures, is, e.g., expected in cases of social pressure for a certain explicit response, or when explicit responses are affected by cultural bias [13–15].

The tendency to energize behavior towards a positive stimulus or away from a negative stimulus [16] is one of several facets of emotional experience. In the case of food, this approach–avoidance tendency can be estimated by asking individuals their explicit response to whether they want the food. As an implicit measure, Electroencephalogram (EEG) alpha asymmetry has been used [17,18]. Another implicit method, that does not rely on brain signals, is the Approach–Avoidance Task (AAT), first developed by Solarz [19]. He asked participants to pull cards towards themselves, or push them away, and found that cards with positive words were pulled more quickly than cards with negative words, and that cards with negative words were pushed more quickly than cards with positive words. When the original AAT was redesigned to run on personal computers [20,21], this greatly increased the flexibility of the task and facilitated its application across many different research areas. In the redesigned AAT, participants are presented with images on a computer screen and push these 'away' to avoid stimuli or pull them 'near' to approach stimuli by moving a joystick in the direction away or towards themselves, respectively. However, a downside of this version compared to the original, is the ambiguity introduced by the joystick. If one pulls a joystick to oneself, it is ambiguous whether that motion reflects the self (i.e., 'moving myself away from the stimulus', indicating avoidance) or whether the motion reflects the stimulus (i.e., 'moving the stimulus to me', indicating approach). Thus, for a more natural experience, reminiscent of the original test, yet easy to run and quantify, Zech et al. [22] developed a mobile version of the AAT (mAAT), in which images are presented on a smartphone screen that participants have to push away or pull toward themselves. Indeed, it was found that participants were faster when they had to approach positive stimuli (happy faces) or avoid negative stimuli (angry faces), compared to when these instructions were reversed [22]. The mAAT seems a particularly suitable tool to measure approach–avoidance in the domain of food, given that food has a very natural, unambiguous relation to approach and avoidance (bringing food to the mouth, or pushing it away). The fact that the mAAT runs on a mobile phone enables the collection of data outside the lab, which is useful for testing in specific contexts of interest [22] or when coming to the laboratory is impossible or inconvenient for other reasons, such as the COVID-19 pandemic.

As noted by Zech et al. [22], reaction time (RT) may not be the only variable of interest that can be extracted from the mAAT. Participants may not only respond quicker when moving a stimulus in the direction that is congruent to their (approach or avoidance) motivation but may also move these stimuli over a larger distance. The potential advantage of distance over RT is that it may be less sensitive to factors that can affect RT besides approach–avoidance motivation. In cases where complex stimuli are used, such a factor may be the time it takes to recognize a stimulus. We recently improved the usability and analysis of the data generated by the mAAT [23], including calculating the new variable of mAAT distance.

In the food domain, the AAT has been used to investigate healthy eating [24], food craving [25–27] and eating disorders [28]. There are few studies investigating the implicit AAT approach–avoidance tendencies related to food experience. A notable exception is [29]. In this study, a computerized joystick AAT paradigm was used on appealing and disgusting food images, wherein, as expected, the participants exhibited an approach bias towards appealing food and an avoidance bias away from disgusting food.

In the current study, we benchmarked the mAAT and the updated toolbox on photographic images of food. We utilized standardized images [30] for which a very strong difference in approach or avoidance motivation is expected: regular, palatable food (congruent with pull, incongruent with push), and food that was unpalatable because of mold or because it was infested by insects, worms or snails (congruent with push, incongruent with pull). We also used images for which a subtle difference in approach or avoidance motivation is expected: food from the participant's own (in this case, Dutch) culture, and food from another culture (in this case, Asian). Previous studies consistently report that individuals overall prefer familiar food, or food from their own culture [13,15]. Both the mAAT RT and the mAAT distance were examined. The results were related to the explicit measures of approach–avoidance motivation (ratings of wanting) and emotion (valence and arousal) in response to the same set of images.

2. Materials and Methods

2.1. Participants

Participants were recruited through Prolific (www.prolific.co, Prolific, London, UK). In order to participate, participants had to have a Dutch nationality, fall within an age range of 18 to 65 years old and not follow any diet or suffer from any food allergy. See Supplementary File A for the recruitment text. A total of 120 individuals started the procedure. Complete datasets were obtained for 71 participants and were included in the analysis. Thirty of them were female, and their age ranged from 18 to 59, with a median of 30 years old. Their Body Mass Index ranged from 16.5 to 35.5, with a median of 24.5. Most of the participants reported eating Asian food weekly (n = 33), followed by monthly (n = 24). One participant reported eating Asian food every other day, and the remaining participants (n = 13) less than once a month. Participants who completed the experiment received a monetary reward of GBP 5.

2.2. Materials

2.2.1. Stimuli

Food images were taken from the CROCUFID (CROss CUltural Food Images Database; [30]) and represented the following four categories: Asian food, Dutch food, palatable food (i.e., universal food, such as fruits and vegetables) and unpalatable food (i.e., molded food, or food with snails or insects crawling on it). Each category was represented by 20 unique images. Figure 1 shows an example image from each category. The complete set of used images is in Supplementary B.

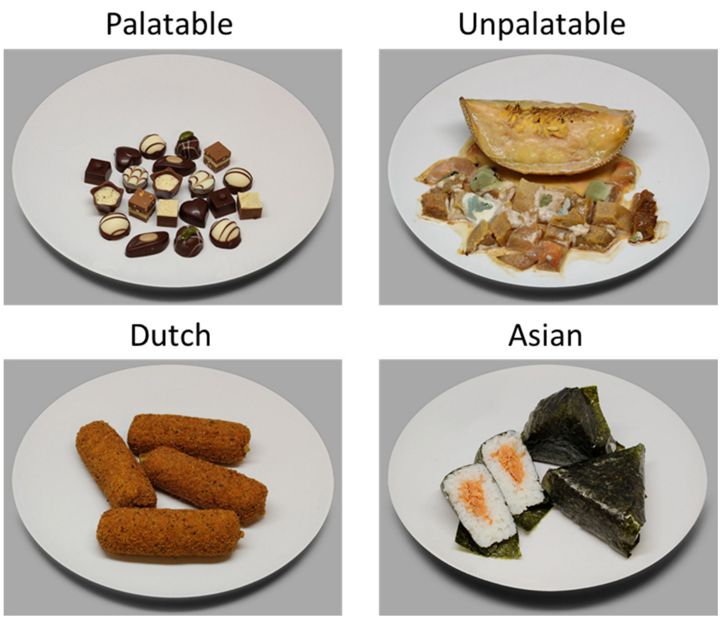

Figure 1. Example image from each of the four food image categories. Each category was represented by 20 unique images.

2.2.2. Questionnaires

Before the presentation of the food images, the participants filled out a questionnaire that was used to describe the participant sample and to enable the control of possibly relevant factors (such as current feelings of satiation and frequency of eating Asian food—see Supplementary File C). For the same reasons, they also filled out the Food Neophobia Scale [31], consisting of ten questions that the participant rated on a 7-point scale, ranging from 'strongly disagree' to 'strongly agree'. High scoring participants are considered food neophobic, meaning that they are unwilling to try new food, while low scoring participants are enthusiastic about trying new and different food. We used Gorilla (www.Gorilla.sc, Cauldron Science, Cambridge, UK, accessed on 1 June 2020) as the experimental platform to ask the questions and direct the participants through the experiment.

2.2.3. Stimulus Rating Scales

Each food image was rated using two rating scales. We used the EmojiGrid tool [32] to measure explicit food-related valence and arousal. The EmojiGrid is a 2D pictorial scale that separates the valence (x-axis) and arousal (y-axis) axes of emotion. To respond, participants click anywhere on the plane to express their food-related experience. For each trial, we recorded valence and arousal. Participants rated food wanting by using a slider on a VAS (Visual Analogue Scale) running from 'fully disagree' to 'fully agree' in response to the question 'I want this very much'.

2.2.4. mAAT

The mAAT app developed by Zech et al. [22] was set up for our conditions and made available for download from the Google Play Store. Participants installed the app on their personal phone. The app presents images and records the accelerations and rotational rates (if gyroscopic sensors are present) of the phone.

2.3. Experimental Design

Participants performed the experiment in two halves, interleaved with a break during which they were asked to watch a 6-minute movie (One group of participants (n = 38) was asked to watch a movie about the making of Lego bricks; the other group (n = 33) was asked to watch a movie about the making of soy sauce. We suspected that Asian food might be liked better after watching the movie about soy sauce compared to the movie unrelated to food. Since no such effect was observed in any of the variables, in this study, we grouped the data for all analyses.) The experiment halves were identical except for the exact images used, where we divided each of the four sets of 20 images (palatable, unpalatable, Dutch, Asian) into two sets of 10. Which set was presented before the break, and which after the break, was counterbalanced across the participants. Each half consisted of (firstly) the rating task and (secondly) the mAAT.

In the rating task, participants rated the images, presented in random order, using firstly, the EmojiGrid and, secondly, the wanting VAS. The mAAT task consisted of the following two parts: first, the Dutch and Asian food images were presented and, second, the palatable and unpalatable. Before the start of each part, participants were instructed to pull the phone towards them upon presentation of one (randomly determined) type of stimulus (e.g., 'Dutch') and push the phone away upon presentation of the other stimulus type ('Asian'). When all of the images had been shown twice, the opposite instruction was given (i.e., in the example, to pull the phone when an 'Asian' food image was shown and push when 'Dutch' food was presented). Again, all of the images were shown twice. Thus, in the mAAT task, each of the images was presented four times; twice with the instruction to pull and twice with the instruction to push each image. Then, the part with the palatable and unpalatable food images was performed in the same way. After the break, the second half was performed.

2.4. Procedure

Figure 2 depicts the procedure of the complete experiment. Participants read about the experiment in Prolific and signed the informed consent by clicking a checkbox. They could not proceed before giving informed consent. They were then instructed to download the mAAT app from the Appstore on their phone and were redirected to Gorilla on their (desktop or laptop) computer. Participants completed the general questionnaire and Food Neophobia Scale. After that, instructions appeared regarding the rating scales, asking participants to indicate their first impression. Then, the first half of the experiment started. Participants started with rating the food images using the explicit tools. Each image was first presented alongside the EmojiGrid. After clicking the location on the grid that best represented their current emotion towards the presented stimulus using the computer mouse or touchpad, the image was presented again alongside the wanting VAS. After clicking the appropriate location, the next image and scale appeared until all 40 images were rated. Participants were then instructed on the mAAT, including a short movie of the desired type of movements. For each of the four combinations of food types (Asian/Dutch, palatable/unpalatable) and movement instruction (pull 'A'/push 'B' or pull 'B'/push 'A'), participants practiced 5 trials with a dedicated set of (CROCUFID) images from the relevant food categories that were distinct from those used in the experimental trials. Within each trial, participants first saw a fixation cross for 500 ms to guide the eyes to the center of the phone's display. After this, the current trial's image was shown until either the participant responded by moving the phone, or after 2 s had elapsed (this was considered as 'no reaction'). After pushing or pulling the phone, participants completed the response by immediately returning the phone to the initial position. Once the phone had come to rest, the next trial started. After finishing the mAAT, participants were directed to their computer to watch a movie as a break. Then, the second half of the experiment started, which was identical to the first, except for the exact images used. The whole procedure took about 1 h to complete.

2.5. Analysis

For each participant and each stimulus category (palatable, unpalatable, Dutch, Asian), an average score of EmojiGrid valence, EmojiGrid arousal and rated wanting was determined. Wilcoxon signed ranks tests were used to test for significant differences between the palatable and unpalatable, and between the Asian and Dutch food images.

Data from the mAAT app were processed using the expanded mAAT processing toolbox, as described in [23]. The toolbox is freely available for download at https://github.com/Jasper-van-beers/AAT (accessed on 30 November 2020). The mAAT RTs were defined as the time between stimulus onset and onset of the motion of the phone. Motion onset was defined as the moment that the acceleration is greater than the maximum (0.8, $(0.3 \cdot a_{max})$) ms^{-2}, with a_{max} denoting the maximum measured acceleration. Any RTs < 200 ms were discarded and any RTs > 2000 ms were considered to be 'no reactions'. Data from participants with less than 75% valid trials were considered to be incomplete datasets and were not included in the analyses. The innovative feature of mAAT distance was derived using the magnitude and the duration of the acceleration.

An average RT and an average distance were calculated for each participant, stimulus category and movement direction (pull or push). Repeated measure ANOVAs with stimulus category and movement direction were applied to the mAAT RT and the mAAT distance for the palatable and unpalatable food images, and for the Asian and Dutch food images.

To further explore how implicit mAAT responses relate to other measures that we expect to be associated with the approach and avoidance motivation, we computed an mAAT RT score by subtracting 'mAAT RT pull' from 'mAAT RT push' for each participant and each image category. A high mAAT score would correspond to approach motivation. It was expected to correlate positively with valence and wanting scores, and negatively with food neophobia for Asian food images. Pearson correlations were performed to test for these effects.

Repeated measure ANOVAs were performed using an SPSS 25 (IBM, Armonk, NY, USA). Wilcoxon signed ranks tests and Pearson correlations were performed using a MATLAB R2020a (The MathWorks Inc., Natick, MA, USA). For all statistical tests, we used an alpha level of 0.05.

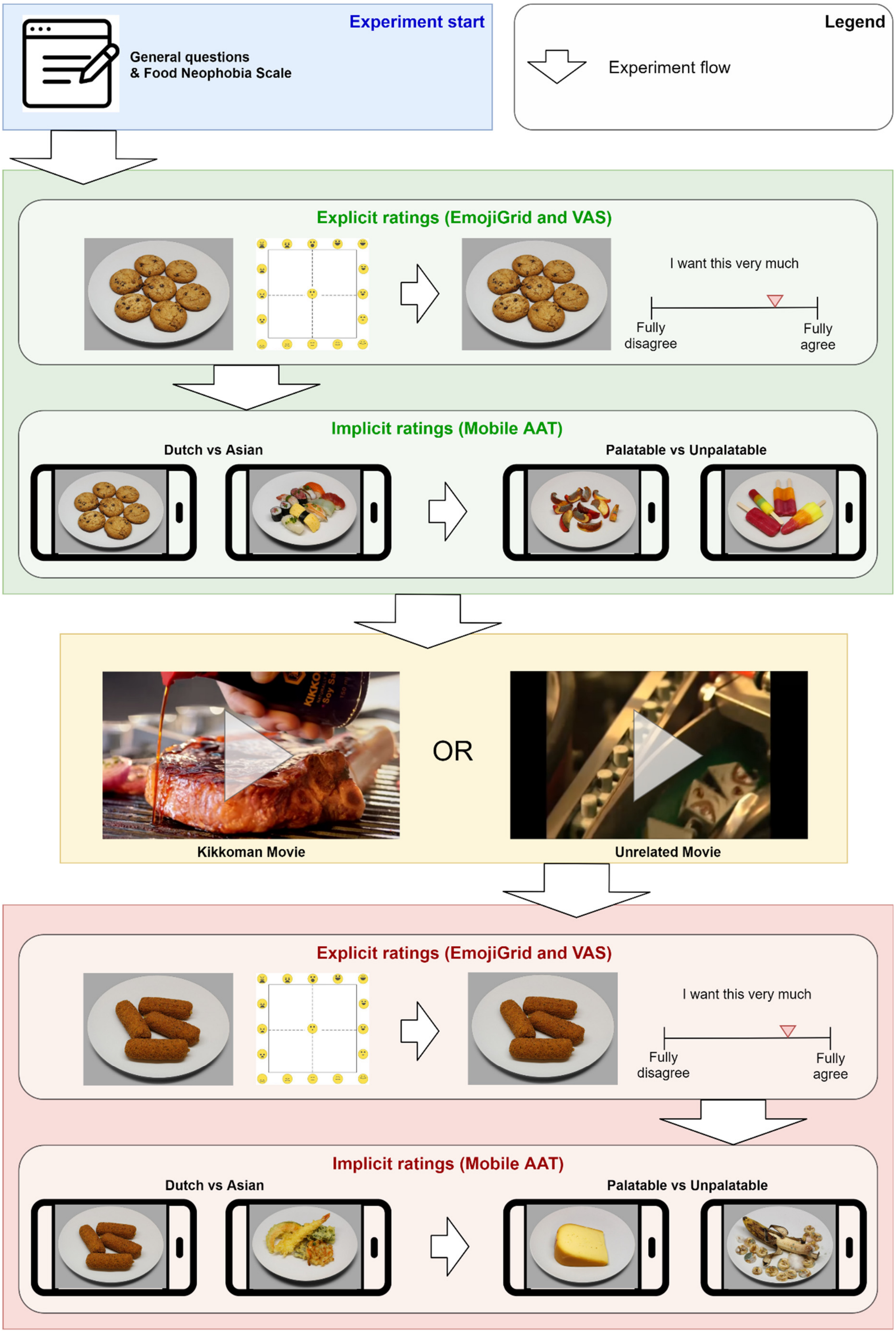

Figure 2. Schematic depiction of the experimental procedure.

3. Results

3.1. Explicit Ratings

Figure 3 shows the explicit ratings of valence (a), arousal (b) and wanting (c), averaged across the participants for each of the four stimulus categories. The Wilcoxon signed ranks tests indicated significant differences between the palatable and unpalatable food images, and between the Asian and Dutch food images, for all three explicit ratings (all p-values < 0.01). The valence and wanting indicated a preference for palatable over unpalatable, and a preference for Dutch over Asian food. The rated arousal was higher for unpalatable than for palatable food, and higher for Dutch than for Asian food.

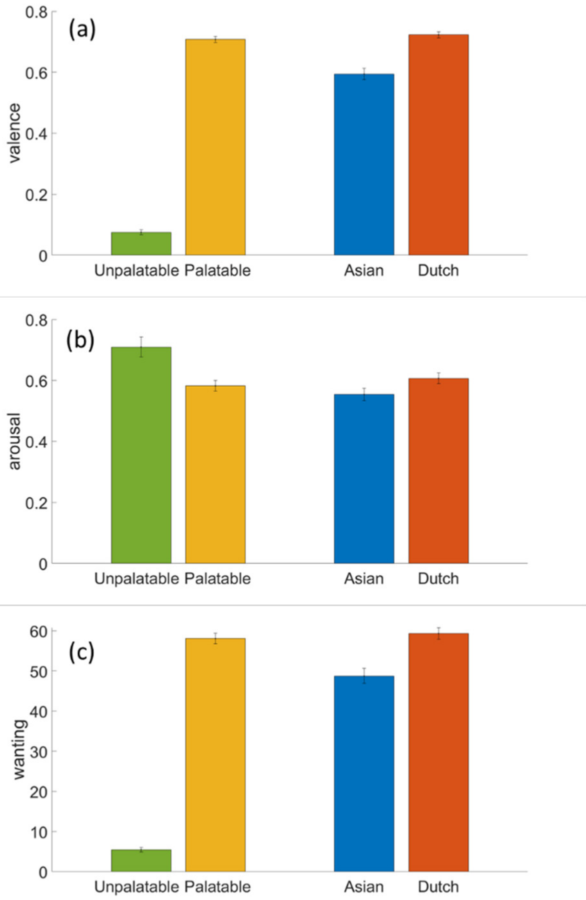

Figure 3. Explicit ratings valence (**a**), arousal (**b**) and wanting (**c**) for each of the four stimulus categories. Error bars indicate standard errors of the mean.

3.2. mAAT Measures

Figure 4 shows the mAAT RT (a) and the mAAT distance (b) averaged across the participants for each of the four stimulus categories and the push–pull direction.

For the mAAT RT, the ANOVA for palatable and unpalatable food showed that, in general, people responded quicker when making a pulling than a pushing movement (main effect of movement direction: $p < 0.001$) and that responses to unpalatable food were quicker (main effect of image type: $p < 0.001$). Importantly, a significant interaction effect between the movement direction and the image type ($p < 0.001$) showed that, as expected, the participants were quicker to push a stimulus congruent with avoidance motivation (i.e., unpalatable food) than a stimulus that was not, relative to pulling. The explicit ratings and the literature led to the expectation that familiar food (Dutch) and unfamiliar food (Asian) result in similar mAAT tendencies as palatable and unpalatable food, respectively. Indeed, the ANOVA for the Asian and Dutch food images showed similar results, with a main effect of the movement direction ($p < 0.001$) and of the image type ($p < 0.001$), as well as an interaction effect ($p = 0.007$), indicating quicker pulling responses than pushing, but especially for the Dutch food images.

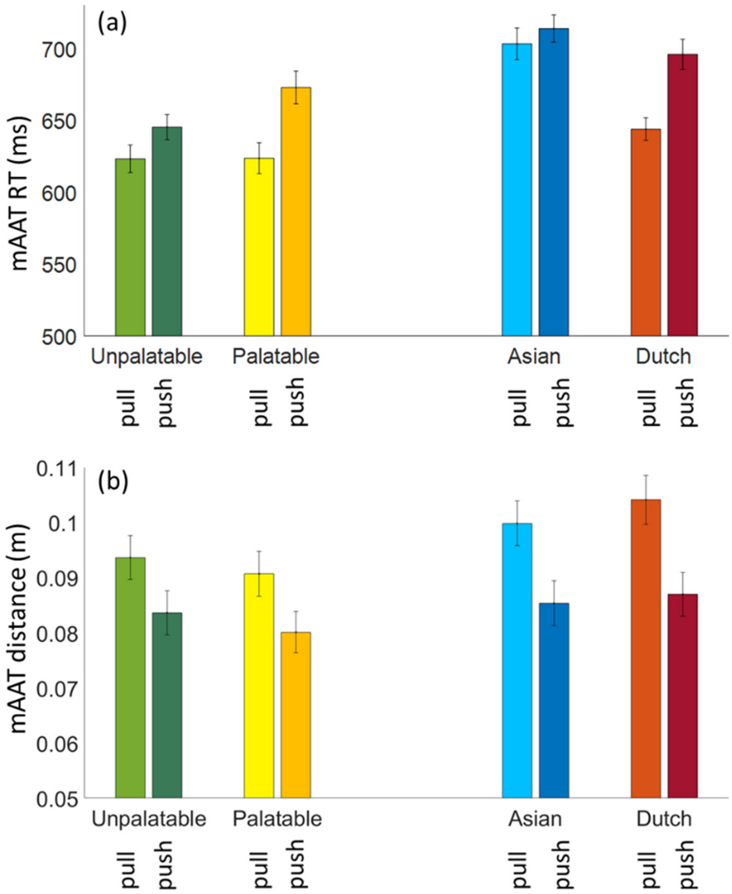

Figure 4. mAAT RT (**a**) and mAAT distance (**b**) for each of the four stimulus categories and each movement direction, pull and push.

For the mAAT distance, the ANOVA for palatable and unpalatable food showed a significant main effect of the movement direction ($p < 0.001$), with shorter distances for pushing than pulling, and a significant effect of the image type ($p < 0.001$), indicating that, overall, the unpalatable food images were moved across larger distances than the palatable images. There was no interaction ($p = 0.79$). The same pattern of results was found for Dutch and Asian food, with a main effect of the movement direction ($p < 0.001$), and a main effect of the image type ($p = 0.001$), where the Asian food images were moved across larger distances compared to the Dutch food images. No interaction effect was present ($p = 0.99$).

3.3. Correlations

The mAAT RT score did not significantly correlate with valence or wanting for any of the four food image categories. It also did not correlate with food neophobia for Asian food images. As a comparison, food neophobia did show a negative correlation with the EmojiGrid valence for Asian food images ($R^2 = 0.32$, $p < 0.001$; Figure 5a), and a similar negative correlation was found between food neophobia and wanting ($R^2 = 0.31$, $p < 0.001$; Figure 5b).

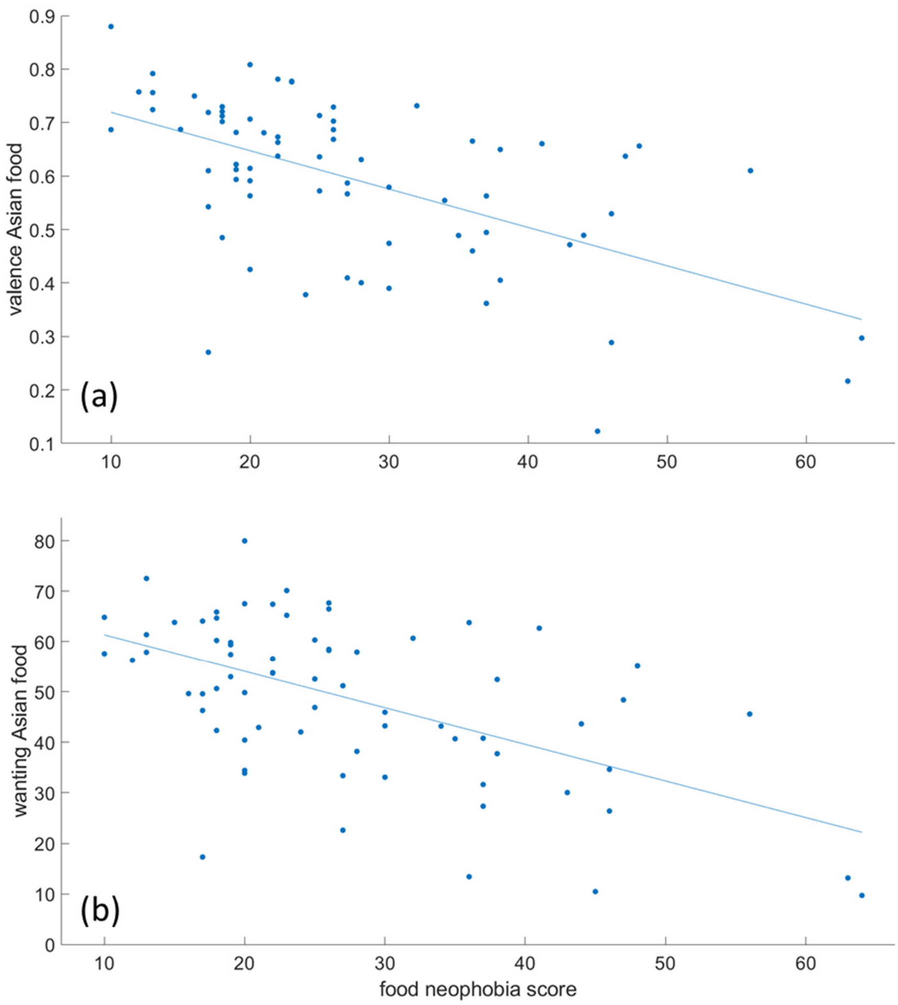

Figure 5. Correlation between food neophobia score and EmojiGrid valence (**a**) and wanting (**b**) for Asian food images. Each data point represents one participant.

Given the effects of the food image categories on the mAAT distance and arousal, we computed an mAAT distance score by averaging the pull and push distance per image category and per participant. These values were correlated to rated arousal for each image category separately, but no significant relations were found.

4. Discussion

The current study showed that approach–avoidance tendencies for food can be reliably measured in participants in the field using a phone, without personal technical help or instructions.

The mAAT RT results showed the expected interaction between an image category and a movement direction, not only for the stimulus categories that were expected to differ strongly in approach–avoidance motivation (palatable and unpalatable food images), but also for more subtly differing food categories (images depicting food from the participant's own or another culture). The explicit ratings of valence, arousal and wanting showed the expected pattern of a strong preference for palatable over unpalatable food, and a preference for their own culture's (Dutch) food over another culture's (Asian) food. While our design did not allow for a direct statistical comparison, as one would expect, the size of the effect in the mAAT RT (i.e., the difference between pull and push), seems to be similar for the palatable and the Dutch food images, whereas the effect seems to be larger for the unpalatable than for the Asian food images. The overall shorter RTs to the palatable and the unpalatable food images compared to the Dutch and the Asian food images may be explained by the difference in the time it takes to identify and categorize the images. It may also be a time order (practice) effect—in each of the two experiment halves, participants responded to the Dutch and Asian food images before the palatable and unpalatable images.

The mAAT distance results showed a different pattern than the mAAT RT results. We had anticipated the mAAT distance to mirror the mAAT RT, i.e., the food images congruent with approach may be pulled both quicker and further towards oneself, and the images congruent with avoidance would be pushed both quicker and further away, where distance may have been relatively unaffected by aspects that are expected to affect RT, such as recognition of the stimulus. However, what we found were larger distances for the unpalatable and the Dutch food images, irrespective of the movement's direction. The unpalatable and the Dutch food images were also judged relatively high in arousal (as found before [15]). Given the specific food images used, depicting molded and infested food, high arousal for the unpalatable images does not come as a surprise. The finding that the Dutch food images were rated higher in arousal than the Asian ones can be understood by the fact that both types of images were generally rated as pleasant, in which case valence and arousal are commonly found to be positively related [33–35]. Since Dutch food is rated high in valence, the high arousal scores are not surprising. The finding that the mAAT distance may be associated with arousal is intriguing and important, since it has been argued that arousal is a crucial determinant in determining (sustained) the attractiveness of products [36,37], but is also hard to capture with explicit questionnaires [35,38]. It would also nicely complement the mAAT RT approach–avoidance motivation, that is more closely related to valence. Future studies need to replicate and further test the possible association between the mAAT distance and arousal.

Given the previous and current results, correlations between rated wanting and mAAT RT, as well as between rated arousal and mAAT distance, may have been expected. However, we did not find such correlations at the participant and stimulus category level. This suggests that these (explicit and implicit) measures reflect different processes. A discrepancy at the condition level may be observed if a discrepancy between the explicit and implicit measures is expected, such as may be the case when there is social pressure to shape explicit responses in a certain way.

A limitation of the study is the loss of participants and data. Twenty-four of the 120 participants that started the procedure quit after performing only a fraction of the experiment. Some of them may not have been able to generate proper mAAT movements. Another twelve participants did not reach the criterion of 75% valid mAAT trials. The number of valid mAAT trials may be increased in the future by setting more strict inclusion criteria for the phones that can be used (e.g., only those containing a linear accelerometer) and by giving participants more precise feedback about inappropriate movements (e.g., rotations rather than pulling and pushing) during the test. In our study, the data of another 13 participants were lost because they did not fill out the rating scales and questionnaires completely or filled out information incompatible with the inclusion criteria. Future online experiments can be made more robust against such omissions by preventing participants from proceeding whenever data is missing or incompatible.

5. Conclusions

In conclusion, the current study showed the sensitivity of the mAAT to measure an approach–avoidance motivation to complex food images, and with the new measure of mAAT distance, possibly arousal, therewith complementing the dominant use of explicit tools in research on food experience. The mAAT more closely maps onto approach–avoidance movement than joystick approaches do. Moreover, the mAAT is a promising tool for evaluating food experience, since it can be used to collect users' implicit tendencies remotely, which can be valuable both from a practical point of view and from a research perspective, when research questions are related to specific times and places that are not compatible with laboratory tests.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/foods10071440/s1, Supplementary A: Recruitment, Supplementary B: FoodImages, Supplementary C: Questionnaire.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Netherlands Organization for Applied Scientific Research (TNO) Institutional Review Board (protocol code 2020-091, 4 November 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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Literature review

Prior to this thesis a literature review on the role of stimuli in event-related frontal alpha asymmetry was conducted. From this it was concluded that video stimuli are potent in inducing an approach-avoidance effect. Based on that, frontal alpha asymmetry during the movie was analysed. The literature review is attached below.

A review on the role of stimuli in event-related frontal alpha asymmetry

Priya Sabu, Anne-Marie Brouwer, Dimitra Dodou, Daisuke Kaneko, Ivo V. Stuldreher

Frontal alpha asymmetry refers to the difference between the right and left alpha activity over the frontal brain region. Increased activity in the left hemisphere has been linked to approach behaviour and increased activity in the right hemisphere has been linked to avoidance or withdrawal. Research on alpha asymmetry is diverse and has shown mixed results, which may partly be explained by the emotional and motivational effect of the stimuli used. This review gives an overview of the types of stimuli utilized with the aim to identify which elicit a strong approach-avoidance effect. For this, the literature was systematically searched for studies exploring event-related frontal alpha asymmetry. The search resulted in 61 papers, which were categorized in seven stimulus categories that were expected to systematically differ in their potency to engage participants: tasks, social interaction, games, images, videos, real cues, sounds and music. Overall, task, game, video, sound and music stimuli were found to evoke significant approach-avoidance effects. Stimuli utilizing social interaction, images and real cues revealed mixed results. For experiments making use of images, studies that employed a more general participant sample (e.g., students) often failed to find an approach-avoidance effect, however those using a specific sample group (e.g., individuals with major depressive disorder) and presenting sample-relevant stimuli, reported the opposite. In sum, strongly engaging, salient and/or personally relevant stimuli are potent to induce an approach-avoidance effect as measured by frontal alpha asymmetry.

I. INTRODUCTION

Explicit measures, such as responses to questionnaires are often used in research to evaluate a person's attitude, beliefs, and personality characteristics. However, individuals may not always be willing or able to give an accurate description on their mental state. For instance, social desirability and self-presentational concerns often influence self-reported measures [1]. Dell et al. [2] found that respondents were about 2.5 times more likely to favour a technology believed to be developed by the interviewer than an exactly identical alternative.

Furthermore, questionnaires usually reflect summative emotions post-interaction [3]. Explicit measures are not well suited for continuous monitoring to understand how emotional experience changes during interaction with a stimulus. Continuous self-reporting is demanding and adds another task, and affects the emotional experience itself.

To overcome such limitations, researchers have been arguing for the use of implicit measures [1], such as those inferred from spontaneous behaviour or physiological signals. These allow for more objective measures that are not affected by response biases and continuous observation of the individual's affective state [4]. For instance, measures can be derived from electroencephalography (EEG), that reflects electrical activity on the scalp generated by the excitable neural tissue of the brain [5].

The circumplex model of affect [6], characterizes emotions by the valence and arousal dimension. Valence refers to pleasantness, i.e. the degree of positive or negative affect in response to a certain stimulus, whereas arousal describes the intensity of the affective response to a certain stimulus [6], [7].

Research has consistently linked skin conductance to physiological arousal [8], [9]. Whereas this measure aligns well with the arousal dimension of the circumplex model, valence has been found to be more difficult to assess using physiological measures.

In this regard, asymmetric frontal cortical activation is of particular interest for emotion processing [10]–[13]. Early research has reported high incidence of negative affect in individuals with unilateral left hemispheric brain damage [14], [15] characterized by increased negative responses, fear and pessimism about the future. Meanwhile patients with unilateral right hemisphere damage display euphoric reactions [16], such as inappropriate presentation of positive affect and laughing [17]. In the late 70s, patterns of emotion processing have been associated with differences in the EEG alpha band (8-12 Hz) between the left and right frontal cortex, and was termed frontal alpha asymmetry [18]–[20].

Initial research focused on an affective explanation of frontal alpha asymmetry responses to particular stimuli. Larger relative left hemispheric activation was argued to be associated with positively valenced stimuli and increased right hemispheric activation was found for negatively valenced stimuli [21]. Next to this valence model, the approach-withdrawal model has been explored, where activity in the right frontal cortex has been related to avoidance motivation, a tendency to withdraw from a certain stimulus, whereas activity in the left frontal cortex indicates approach motivation towards a certain stimulus [10]–[13], [22]–[25]. Since approach-related emotions are often associated with positive valence and avoidance-related emotions with negative valence, the expected cortical activity patterns of these two theories overlap to a substantial degree [4].

Studies that disentangled valence and approach-avoidance motivation were in line with the approach-avoidance model [26], [27]. The defining difference was found in the hemispheric activation pattern in response to anger [4]. Anger as a negatively valenced emotion was found to be lateralized in the left

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hemisphere just like happiness [28]. Further support for the approach-avoidance model was found in transcranial magnetic stimulation experiments [29].

Frontal alpha asymmetry as a diagnostic tool would be desirable in a variety of application fields, such as marketing, product design, human-computer interfaces, gaming and the diagnosis of affective disorders [21]. This is however limited, since frontal alpha asymmetry is not specific for motivational processes only, described as the reverse inference problem [30]. Studies found that frontal alpha asymmetry is moderated by unilateral hand contractions [13], seating position [31], and task difficulty [32], [33].

Such factors may underlie diverse results in recent literature, as well as different data recording (e.g., noise, number of participants, length), processing and analysis methods [34]. Additionally, researchers have used a wide variety of stimuli to induce frontal alpha asymmetry and found mixed results. This review focuses on the factor of stimuli potentially affecting the approach-avoidance effect as measured by alpha asymmetry.

Movement noise can cause large amounts of data loss in EEG studies, hence it is to be expected that stimuli employing movement will be less effective in producing an approach-avoidance effect. To avoid such artifacts, researchers should try to design the experiment in such a way that minimal movement is required. If it is desired to employ stimuli that involve motion, proper data pre-processing is essential. For a review on frontal alpha asymmetry recording, processing and analysing, see Smith et al. [34].

Also, there are some artifacts, such as muscle artifacts from eye blinks, that are inevitable. Thus, researchers often record electrooculography to subsequently remove ocular artifacts from EEG. However, the drawback of this is that recordings from two leads next to the eyes might contain some EEG signal [35] which is then removed as well. An alternative approach is to use blind source-separation techniques, such as independent component analysis (ICA) to isolate artifacts from EEG. It allows decomposition of independent components from EEG signals identified by statistical criteria.

Since frontal alpha asymmetry describes an approach-avoidance effect, stimuli that are strongly motivating in either of the directions are expected to produce clear results. Although it is extremely difficult to quantify this, i.e., set an independent, objective ground truth [36], strongly engaging stimuli are expected to produce more solid effects, where one would expect that games, tasks or movies are in general more engaging than static pictures. With regard to literal approach-avoidance, real cues (e.g., desired food) compared to representations of cues (e.g., an image or video of the desired food) are likely to be more engaging as well. Moreover, due to the high engagement aspect of social interactions and music, it is predicted that such stimuli would lead to a strong approach-avoidance effect.

Furthermore, clearer effects are predicted if interpersonal differences of the sample group are low and/or the stimuli are relevant for them. Hence studies should take such variabilities between people into account through pre-assessment, for instance by means of questionnaires.

To date there is no review focused on the stimuli that can evoke an approach-avoidance effect measured by frontal alpha asymmetry. Hence, as of yet it is unclear which types of stimuli elicit a strong approach or avoidance effect. Exploring this will help to understand better what is reflected by frontal alpha asymmetry, under which circumstances frontal alpha asymmetry can be expected to be an informative marker and what causes the diversity in literature in order to unify conflicting results.

II. Methods

Literature was searched on Scopus using the keywords *"alpha AND asymmetry" AND ("approach" OR "avoidance" OR "withdrawal") AND ("affect" OR "emotion")* and yielded 144 documents. Additionally, due to the research conducted by TNO in collaboration with Kikkoman and relevance for the upcoming thesis, a search on Scopus using the terms *("alpha" AND "asymmetry") AND "food"* was conducted as well, resulting in 28 more papers.

Out of these 172 documents, based on the abstract and title, only those that had measured frontal alpha asymmetry related to an event or a stimulus (i.e., not resting alpha asymmetry only) were included. Furthermore, studies using a machine learning approach without separately reporting on the exact alpha asymmetry results were excluded. This resulted in the inclusion of 61 papers for the present review, as visualized in Figure 1.

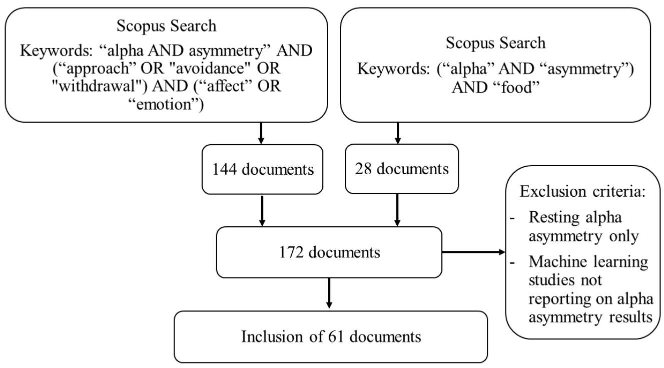

Fig. 1: Flow chart of inclusion process for the review

The 61 selected studies were divided into seven stimulus categories that were expected to systematically differ in their effectiveness to engage the subjects:

1. Tasks
   a) Imagery
   b) Modifying facial expression
   c) Speech, reading and writing
2. Social interaction
3. Games
4. Images
5. Videos
6. Real cues
7. Sounds and Music

Studies that could have fallen between multiple categories were ultimately categorized based on the study's context and the stimulus' pure affective content. Papers are summarized and evaluated per stimulus type. A summarized description of all 61 studies can be found in Table I of the Appendix. Studies were rated based on whether the stimulus' sole affective content was able to induce an approach-avoidance effect. This is indicated by "++" for a significant effect, "+" in case of a trend and "0" for no effect in the last column of Table I in the Appendix.

Furthermore, since research suggests that cortical hemispheric specialization of emotion may differ between left-and right-handed individuals [37], [38] handedness was included in this review, as far as it was reported. Most studies use right-handed participants and those that reported to have included left-handed persons stated that the results did not change by doing so. Handedness data can be viewed in the 'Participants' column of Table I in the Appendix.

III. Results

1. Tasks (n=11)

a) Imagery (n=4): Four studies used a variety of emotional imagery tasks, and all reported significant results. Menella et al. [39] measured EEG of a clinical sample of 23 dysphoric and 24 non-dysphoric individuals during pleasant, neutral and unpleasant narratives. They found reduced left relative to right activity at anterior sites irrespective of emotional condition in the dysphoric group compared to the control group. This indicates reduced approach motivation for individuals with dysphoria. Wacker et al. [40] found significant approach-avoidance effects using emotional imagery scripts of three approach-avoidance conflict scenarios and a sample of 93 men with either high or low behavioural inhibition system (BIS) sensitivity. Their results showed that only the group high in trait BIS sensitivity had a significant change toward right-sided activation for the imagery compared to the pre-stimulus phase. In addition, Wacker and colleagues [41] induced vivid imagery with relevant soccer scripts in a sample of 109 active, male soccer players. They found significant changes in the alpha band towards left frontal activation for the group with anger-inducing scripts and towards right frontal activation for the control and fear-withdrawal stimuli.

Papousek et al. [42] used a type of imagery task, where female university students (n=78) looked at anger-eliciting vignettes supplemented by matching photographs and were instructed to imagine the depicted situation happening to them. Subsequently, they wrote down possible ways to appraise the situation to diminish anger. Participants with greater capacity to generate reappraisal (measured by the number of non-identical ideas) showed greater left-sided activity in the pre-frontal cortex.

b) Modifying facial expression (n=2): Two studies aimed to induce different emotions with facial expression tasks. For both significant effects were found. In [43] students' (n=36) facial configurations of anger, disgust, fear, joy and sadness matched the expected frontal activation patterns, that is less left frontal activity in withdrawal states compared to approach and control states. In [44] the group with major depressive disorder showed relative less left frontal activity during approach and withdrawal conditions.

c) Speech, reading and writing (n=5): Studies that used giving a speech, reading and writing tasks reported promising outcomes. Pérez-Edgar et al. [45] presented face pairs depicting angry, happy and neutral expressions in a dot-probe paradigm, followed by speech preparation. Relative EEG asymmetry was calculated between the speech preparation and baseline. Individuals with increases in right frontal alpha activation were associated with avoidance of happy, and vigilance to angry faces in the dot-probe task.

Similarly, in [46] 92 students were first informed that they had to give a speech to elicit anxiety. Next they had to imagine the speech scenario or think of previous embarrassing experiences. This was followed by a possible writing task depending on the group (reappraisal writing, irrelevant writing and no writing) in the regulation period. Afterwards they were asked to re-imagine embarrassing speech scenarios. Results show that the reappraisal writing group had lower frontal alpha asymmetry scores during writing manipulation period and higher frontal alpha asymmetry scores reflecting approach following re-exposure to stress, compared to the irrelevant writing group. Li and colleagues [47] also used a writing task. Participants (n=29 students) were instructed to think of a situation when they were irritated by people with higher or lower social power. As expected, they found a significant association between high social power and increased left frontal alpha asymmetry compared to the low social power condition. In [48] six subjects performed a reading task, which was interrupted by internet advertisements. This caused changes in frontal alpha asymmetry though the direction of change differed between subjects. Similarly, in Brouwer et. al [49] 71 participants performed a reading task of a novel where emotional (generally negatively valenced events) and non-emotional sections were pre-defined. Contrary to their expectations, they found on average higher frontal alpha asymmetry indicating approach for high compared to low emotional sections.

2. Social interaction (n=5)

Brooker et al. [50] conducted a longitudinal twin study (n=89) with three emotion eliciting episodes: conversation with the experimenter, with a stranger and listening to a stranger reading a script. They found that children showed increased asymmetry scores during conversing with a stranger and experimenter compared to the stranger script episodes. Significant sex differences were also observed.

Two infant studies also reported significant results. Bolinger and colleagues [51] used positive (e.g., parent played peek-a-boo with the infant) and negative prompts (e.g., parent pretended that the infant has rash on his/her face) and found significantly increased right-sided frontal alpha asymmetry (reflecting avoidance or withdrawal) for the negative prompts. No effects were observed for positive and neutral stimuli.

Missana et Grossmann [52] studied a sample of 20 four-month-old and 20 eight-month-old infants, of which the latter showed increased left-sided frontal alpha asymmetry in response to point-lighted display of happy body expressions and higher right-sided activation in response to fearful body expressions. Uusberg et al. [53] and Pönkänen et al. [54] explored how eye-contact is related to frontal alpha asymmetry. In [53] the degree of social contact was varied by gaze direction and neuroticism was predicted to be related to avoidance (higher right-sided activation) of direct gaze. A significant relationship between neuroticism and frontal alpha asymmetry in the indirect gaze condition was found. In [54] the expected left-sided asymmetry in response to a direct gaze was not observed. However, they found a trend for the correlation between the overall frontal alpha asymmetry score (averaged across all conditions) and the gaze direction index (difference in asymmetry scores for direct and averted gaze).

3. Games (n=5)

Significant results were found in studies using different game stimuli for non-clinical samples [55]–[57]. Rodrigues et al. [55] asked 30 participants to move freely via a joystick in a virtual T-maze with monster (negative) and sheep (positive) trials. The results aligned with the approach-withdrawal model with more left frontal alpha activation during positive event condition and increased right frontal alpha activation in the negative event condition. In [56] 60 participants underwent a delayed reaction time task with manipulations of the incentive, expectancy, and response. They found that variations in monetary incentives led to the expected changes in alpha asymmetry, being more relative left frontal activation during reward and shifts to right frontal activation during punishment conditions.

Similarly, Sobotka et al. [57] manipulated reward and punishment in a sample of 15 students. They used imperative stimuli of approach (finger press) or withdrawal response (finger lift). Reward trials were associated with higher activation in the left frontal hemisphere and during punishment trials higher right-sided activation was found.

In clinical samples results were mixed. Shankman and colleagues [58] used a slot machine game with reward and no incentive outcomes. Participants included 70 individuals with major depression and 37 controls. No differences in hemispheric asymmetry for the two outcome conditions were observed, and no overall difference between the depressed and non-depressed group. However, they found a trend between age of depression onset and hypothesized approach during reward trials. It appeared that subjects with early onset-depression exhibited less left frontal activity during reward conditions compared to participants with late-onset depression and the control group.

Lastly, Harmon-Jones et al. [37] explored frontal cortical responses of 41 individuals with bipolar disorders and 53 controls. For this they used anagrams of different difficulty levels (easy, medium and hard) and valence (win money or avoid losing money). They found that as expected, individuals with bipolar disorder showed greater left frontal activation in preparation for the hard-win task compared to controls. Furthermore, while non-bipolar subjects showed a decrease in left frontal activation from medium to hard win trials, those on the bipolar disorder spectrum did not.

4. Images (n=16)

Studies utilizing images appeared to show a significant effect only when the stimulus was particularly relevant for the participant group. This pattern can be seen in [59], where drug abstainers' (n=40) responses to drug-related images were compared to positive, negative, and neutral pictures in the context of evaluating the effect of a working memory training on emotion regulation. Improved alpha asymmetry scores for negative and drug-related pictures were found for the training group pre-and post-training.

Similarly, Gayathiri and colleagues [60] reported elevated right hemispheric activity, indicating avoidance, when individuals with major depressive disorder (n=15) viewed images of high valence and arousal relative to neutral ones.

Furthermore, Rabe and others [61] described that patients with posttraumatic stress disorder from motor vehicle accidents had increased right-sided activation during exposure to trauma-related pictures compared to neutral pictures. Cognitive behavioural therapy led to a significant reduction of right anterior activation for the group receiving therapy (n=17) compared to wait-list controls (n=18) in response to the trauma stimulus.

Likewise, Wiedemann et al. [62] conducted a study where patients with panic disorder and without depression (n=23) compared to healthy controls (n=25) were confronted with neutral (mushroom), panic-relevant (emergency situation), anxiety-relevant but panic-irrelevant (spider), or anxiety-irrelevant but emotionally relevant pictures (erotic image). They found significant decreases of right compared to left frontal alpha power, in response to the emergency picture category for the group with panic disorder but not for the healthy control group.

Additionally, Cartocci et al. (2018) [63] found higher frontal alpha asymmetry for heavy smokers compared to light smokers and non-smokers when viewing effective public service announcement (PSA) pictures. In their earlier study [64] frontal alpha asymmetry for different PSA images did not differ, which might be attributed to several differences between the studies, such as a lower number of participants in the earlier study (n=22 versus n=39).

In a study by Ischebeck and colleagues [65] twenty patients with obsessive compulsive disorder were compared to the same number of matched controls during viewing neutral, aversive and OCD-related images. No significant group differences were found.

The previously described pattern of relevant group selection is probably also relevant for non-clinical samples. Schöne et al. [66] asked seventeen male participants to view erotic pictures of high salience as well as depictions of dressed attractive women and found significant results of picture category.

Comparably, Winter et al. [67] used food images to assess the effect of hedonic hunger and restrained eating on frontal alpha asymmetry with 58 female participants. They found that higher Restraint Scores were associated with increased right frontal asymmetry and higher hedonic hunger measured by the Power of Food Scale was associated with increased left frontal asymmetry. Additionally, they found that overweight compared to normal weight individuals displayed greater left asymmetry. However, for the condition of fasted and fed state no differences emerged.

Gable et Harmon-Jones [68] found that for 26 female students dessert picture stimuli alone did not evoke significant asymmetric activation in the frontal cortex, but more time since eaten and dessert liking related to increased left frontal asymmetry for dessert pictures.

Experiments with an image viewing task and a regular participant group mostly fail to show significant alpha asymmetry based on the picture's affective content alone [63], [64], [68]–[74]. An exception is Huster et al. [75] who presented 36 photographs from the International Affective Picture System (IAPS; [76]) in a restricted randomized order to a sample of 28 students. They reported lower alpha asymmetry values for frontal, parietal and temporal electrodes, indicating withdrawal in response to negative compared to positive affective pictures.

5. Videos (n=13)

In most studies using video stimuli, a strong approach-avoidance effect was found [38], [63], [64], [77]–[82]. Unlike the anti-smoking image stimuli used, as described above in [64], anti-smoking video announcements classified as "awarded" induced an increased approach-avoidance effect compared to the "ineffective" and "effective" ones.

Zhao et al. [82] presented three film clips to 37 students to elicit three target emotions, being tenderness, anger and neutrality (duration of 99, 73 and 65 seconds, respectively). They found greater left frontal activation during the tender film clip. The anger eliciting film clip (dealing with the Nanjing massacre) led to expected greater right frontal activation since participants had no opportunity to retaliate or act on their anger. Similarly, in [78] they showed four video clips (duration of 3 minutes each) from cinema and documentary repertoires to induce relaxation, happiness, anxiety and sadness. Their sample consisted of 40 female students divided into four groups (n=10, each): extroverted, introverted, neurotic and emotionally stable. They found that right frontal asymmetry is associated with negative affect for the introvert and emotionally stable groups.

Aftanas and colleagues [77] showed 10 emotional film clips (neutral, relaxation, joy, anger, sexual arousal, disgust, fear, sadness, stress stimulation) each of 1.5 to 4.5 minutes duration to individuals with alexithymia (n = 17), a personality trait characterized by difficulties in emotional self-regulation, and non-alexithymic (n = 27) participants. In all cases subjects with alexithymia showed greater reactivity of the right hemisphere, suggestive of increased avoidance motivation.

Papousek et al. [79] displayed a film with a duration of approximately 10 minutes consisting of scenes of severely injured, mourning and dying people, to 148 female students, where EEG was recorded during the last five minutes of the film. The expected effect of a right-sided shift of dorsolateral prefrontal asymmetry became apparent.

In [80] 65 students viewed a neutral film (10 minutes duration) followed by a sexual film (3 minutes duration). Increased alpha power was found in the left hemisphere (i.e., approach) during sexual compared to neutral films. Furthermore, self-reported mental sexual arousal and alpha asymmetry were positively correlated.

In a study by Hajal et al. [81] 26 mothers of 5- to 8-month-olds watched a 15-minute video made of 10 second clips of their own infants expressing distress. They found an association between greater right frontal asymmetry shift (from baseline to infant distress video) and higher self-reported sadness.

Olszewska-Guizzo et al. [83] found no significant effect for frontal alpha asymmetry for video type (nature exposure and busy public spaces, repeated three times for 20 seconds), but a significant decrease of frontal alpha asymmetry as recorded following a national lockdown with a Stay-at-Home order compared to before the pandemic.

Neuromarketing studies using advertising videos have shown mixed results. Joaquim and colleagues [84] have reported a close to significant trend in correlation between the asymmetry index for low alpha frequency band and negative emotions elicited by commercials viewed by 25 subjects. In a study by Hakim et al. [85] 33 subjects watched skits from a comedy series followed by commercials of food products and later completed a binary choice task consisting of six products altogether. Results show that frontal alpha asymmetry as recorded during commercial viewing did not significantly differ for neither closely (rank 3 and 4) nor distantly ranked products. Vecchiato and colleagues [86] showed a 30-minute documentary with three advertising breaks, in which a total of six TV commercials (duration around 30 seconds) were displayed to 15 healthy volunteers. Participants were divided into "LIKE" and "DISLIKE" group according to their pleasantness response and the "LIKE" group displayed increased left hemisphere activity compared to the "DISLIKE" group.

Walsh et al. [38] recruited 40 students and showed them breakfast meal videos of 40 seconds in duration. The clips contained emotion-eliciting events with hygiene, safety, and spoilage concerns and almost identical controls without such concerns. For the spoilage videos they found greater right hemisphere activation indicating avoidance response when compared to its matched control. For the hygiene and safety videos they did not find significant differences.

McGeown et Davis [87] recorded the brain activity of 93 female students while watching a confederate consuming potato chips, followed by conducting a visual-probe task with non-food and food items of high craving ratings. Overweight participants (based on BMI) compared to leaner counterparts showed increased left frontal alpha asymmetry during the confederate video and greater attentional bias towards food pictures.

6. Real cues (n=8)

One would expect that in general, real cues should produce strong approach-avoidance effects. However, mixed results have been observed for this stimulus category.

Kaneko et al. [88] and Lagast et al. [89], who explored the effect of different types of drinks on frontal alpha asymmetry, observed no significant effects. However, odors as researched by Kline and colleagues [90] recording EEG in 58 women have led to increased relative left frontal activation for the pleasant stimulus (vanilla) when compared to unpleasant (valerian) and neutral (water).

Two neuromarketing studies were found reporting significant results for frontal alpha asymmetry. Modica and others [91] compared different categories of food items: daily and comfort food, major and private brands, and foreign and local products. They found increased tendency for approaching comfort compared to daily food and foreign compared to local products during visual exploration and visual and tactile exploration phases. In addition, the private label compared to major brand also showed higher approach in the visual and tactile exploration phases. Similarly, Sargent et al. [92] compared two machines to prepare hot beverages, one from a market leader and the other from a follower machine in an office setting. It was shown that the market leader machine's user interface was preferred, indicated by self-reports and supported by significant valence measured by frontal alpha asymmetry and arousal extracted from electrodermal activity measures.

Another study which used a real food-related stimulus, was conducted by Brouwer et al. [93], where participants were instructed to cook and taste two stir fry dishes. For one the main ingredient was chicken (hypothesized to induce approach) and for the other mealworms (hypothesized to evoke avoidance effect). The expected effect of food condition was found in frontal alpha asymmetry throughout the entire cooking and tasting session, significantly during the frying interval.

Olszewska-Guizzo et al. [94] passively exposed 22 adults to pre-selected real landscape scenes, consisting of six landscape scenes within two green spaces and three busy urban spaces. They found a non-significant trend in the expected direction with higher approach motivation for park compared to urban spaces. After adjusting for external conditions however, alpha asymmetry was significantly different between the residential green site and the busy downtown control site.

Last, but not least Knott and colleagues [95], exposed 11 regular and 11 light smokers to a neutral and a cigarette-cue (holding a pen and holding a lighted cigarette above an ashtray respectively), while EEG was recorded. Results show that regular female smokers only exhibited withdrawal-related negative affect to holding the cigarette compared to holding the pen.

7. Sounds & Music (n=3)

Research on alpha asymmetry using sound and music stimuli established mainly positive results. Papousek et al. [96] (n=62 university students) explored inter-individual differences in frontal alpha asymmetry to other people's affect using sound recordings of three categories: anger (shouting), sadness (crying) and neutral (trivial everyday sounds) as a reference condition. Results show that individuals with higher compared to lower level of antagonism (assessed by a Personality Inventory) had less relative right frontal activation (approach) in response to the anger stimulus, whereas subjects with higher levels of detachment displayed greater relative right hemisphere activation (withdrawal) to the crying stimulus.

Similarly, in [97] a sample of 18 university students listened to scary and soothing sounds. Subjects who showed a greater withdrawal response to scary sounds displayed a decreased pleasant state, and participants with higher approach motivation showed an increased pleasant state. For the soothing stimulus no such effects were found.

Lee et al. [98] investigated cross-modal perception using visual music and synthetic stimuli. They found that during the first 10 seconds of the visual music stimulus, frontal alpha asymmetry correlated with the valence ratings.

IV. Discussion

The aim of this review was to investigate what types of stimuli are effective in inducing an approach-avoidance response in frontal alpha asymmetry.

The effectiveness of certain types of stimuli is caused by an interplay of different factors. One such factor is motivational engagement, possibly explaining the effectiveness of games, tasks, videos, sounds and music.

Studies utilizing videos and images have led to different results. Video stimuli have mostly shown significant frontal alpha asymmetry results. Consistent with these findings, Huster et al. [75] argue that videos relatively to pictures might be more effective in inducing emotional responses. However the disadvantage of film clips is that it is unclear when exactly these responses occur.

The findings of this review revealed that picture presentation induced approach-avoidance effects only if the images were emotionally relevant for the sample group, for instance anxiety-relevant pictures shown to patients with panic disorder [62]. This indicates that in a more general sample group affective images alone might be insufficient to create motivational intensity and/or that interpersonal differences potentiate frontal alpha asymmetry [48], [68], [71], [99]. For this reason, researchers sometimes report significant correlations between frontal alpha asymmetry and differences in emotive tendencies (e.g., dessert liking) or personality traits (for examples see [40], [53], [67], [68]).

Next to relevance for the sample group Schöne et al. [66] have shown that salience of pictures can lead to significant results, even in a brief (three seconds) picture presentation task. They argue that pictures that are the actual desired object themselves, e.g., erotic pictures, *can* create a strong approach motivation in contrast to to pictures that are a depiction of something that is desirable, such as food.

Another way to improve motivational engagement for pictures, as Gayathiri et al. [60] and Huster et al. [75] have shown, is by using a non-randomised presentation paradigm. In [75] successively displaying three pictures of the same affective category has successfully increased subjects' emotional reactivity. However, more research using a restricted randomised picture presentation order is needed to validate if the image presentation paradigm is the genuine origin of significance in results. Additionally, by showing pictures of the same category successively allows for computation of frontal alpha asymmetry over a longer time period increasing robustness of the measure. Therefore, another factor is the total recording length that usually increases the reliability of the EEG measure [75]. Next to the likely increased potency of videos to engage observers, this could also be the reason why video stimuli generally work better than pictorial stimuli.

One would also generally expect real cues to be effective as they are not just a depiction of something creating a tendency to approach or avoid, but can be the genuine objects to approach or avoid. Indeed, experiments using food, odours and cigarettes found significant effects for frontal alpha asymmetry. However, those employing landscapes and tasting of drinks have reported otherwise. In these studies, noise caused by movement could have led to data loss. In [94] participants went from one scene to the other, leading to long time intervals between recordings and hence noisy comparisons between conditions. Furthermore, in [88] participants took sips from cups themselves, which led to noise through movement. On the other hand, Lagast et al. [100] minimized such movements by using plastic tubes but were still not able to find a significant approach-avoidance effect. It is also possible that these stimuli might have not been salient enough to create an approach-avoidance effect for everyone.

Next to the stimuli used, also data recording, processing, and analysis lead to different results (for an extensive review, see Smith et al. [34]). A few essential points of consideration are the EEG recording length [101], selection of the electrode reference [102]–[104] and the reliability of the EEG measurement [105]–[107].

This brings us to the limitations of this literature review. One is that experiments are very diverse and thus difficult to compare. Especially the number of participants and required trials, as well as the way of recording (e.g., reliability of electrodes used), analysis (e.g., choice of electrode references) and processing (e.g., methods for artifact removal) are not standardized and can lead to big differences. Including this would have gone beyond the scope of this review and hence is only shortly discussed.

Secondly, even though keywords were clear, it was noted that not all relevant papers were captured. However, we believe that the inclusion of 61 papers is a sound number.

Thirdly, one might have noticed that the stimulus categories into which the documents have been divided are not exactly exclusive and sometimes overlapping, e.g., the cooking and tasting experiment by Brouwer et al. [93] could be arguably belonging to tasks rather than real cues. In such cases, the stimulus' pure affective content led to the final categorisation decision.

Furthermore, most of the papers reviewed, in fact about 77%, have reported significance or trends in evoking approach-avoidance responses. Papers that reported null findings possibly did not include the same keywords as used for this search. Another possibility is that such findings were withheld from publishment in the first place, commonly known as publication bias.

For a large part the highly competitive environment for promotion and funding is what drives researchers to positive publication bias, aware that they are more favoured for publication by editors, reviewing by peers, and citing. Adding to that, editors are similarly incited due to the competition for citation index and financial survival of journals [108].

However, not publishing could lead to another research group investigating the same line of thought, leading to null findings again, ultimately wasting resources and steering against the collaborative nature of science. Furthermore, negative outcomes are valuable for science since they force critical reflection, validation of current thinking and direct new approaches [109]. Therefore, researchers should be more encouraged and journals more open to publish manuscripts reporting negative results.

Publication bias has detrimental consequences, it leads to distortion of literature and damages the integrity of knowledge [108]. Therefore, the results and conclusions drawn from this review might be biased, since the literature reviewed might be inclined towards positive results.

To sum up, the stimuli categorization based on the engagement potency has demonstrated to be fundamentally relevant, since general patterns in effectiveness were detected. It was found that tasks, games, videos and sounds and music were generally found to induce a significant approach-avoidance effect. Social interaction, picture and real cue stimuli revealed mixed results.

Despite of the afore-mentioned limitations, the exploration of frontal alpha asymmetry as an indicator of approach-avoidance can be helpful in marketing, human-computer interfaces and the diagnosis of affective disorders. It provides a more objective measure of mental state monitoring than traditional methods that are influenced by social factors. However, this review has shown that strongly engaging, salient and/or personally relevant stimuli are significant for inducing an approach-avoidance effect.

Although research on alpha asymmetry is still in its infancy, it continues to grow, due to its great number of application possibilities, as was demonstrated by the diversity of the studies. To conclude, the present review shows that the selection of stimuli for a large part accounts for the diversity in alpha asymmetry research, especially since data recording and processing methods are becoming increasingly better.

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Appendix

TABLE I: Overview of literature references (Ref.) divided into stimulus types with approach-avoidance effect (Eff.) indicated by ++ (significant), + (trend) and 0 (none) and participant's handedness data by R (right), L (left) or NA (not available)

Ref.	Stimuli	Context	Participants	Results	Eff.
Tasks (n=11): Modifying facial expression (n=2), Imagery (n=4), Speech, reading and writing (n=5)					
[39]	imagery task including pleasant, neutral, and unpleasant narratives	investigating influence of dysphoria on posterior alpha asymmetry sites during emotional task	dysphoric (n=23) and non-dysphoric (n=24) individuals R	group with dysphoria showed reduced left cortical activity at anterior sites irrespective of emotional condition, at posterior sites they showed reduced right parietal activity during unpleasant imagery compared to non-dysphoric individuals	++

[40]	emotional imagery scripts of three scenarios of approach-avoidance conflict (approach a fear-provoking object/ situation to get to a desired goal)	compare widely adopted model with alternative relating left anterior region to behavioural activation independent of direction of behaviour (approach or withdrawal) and right anterior region to goal conflict-induced behavioural inhibition	93 young men either high or low in trait behavioural inhibition system sensitivity R	high BIS sensitivity group had a significant change toward right-sided activation from pre-stimulus to imagery phase, results in favor of behavioural activation and inhibition model	++
[41]	emotional imagery	disentangle influences of emotion and motivational direction (MOT) on frontal alpha asymmetry	109 active, male soccer players R	irrespective of MOT, anger compared to fear led to larger changes toward relative left frontal activation (LFA); higher negative valence ratings were associated with greater changes toward LFA in withdrawal but with larger changes toward relative right frontal activation in approach	++
[42]	Reappraisal Inventiveness Test with anger-eliciting vignettes	correlation of frontal EEG alpha asymmetry with capacity for cognitive reappraisal in terms of the participants' inventiveness in generating alternative appraisals of anger-evoking events	78 female university students of different faculties R	individuals with higher capacity for generating cognitive reappraisals showed increased left-lateralized activity in lateral prefrontal cortex - effect observed separate from activation during novel idea generation without emotional component	++
[44]	facial emotion task - make approach (angry and happy) and withdrawal (afraid and sad) facial expressions	testing whether brain activity during emotional challenge will be a more powerful indicator of predispositions toward psychopathology than activity observed at rest	individuals with (MDD+, n=143) and without (MDD-, n=163) lifetime major depressive disorder (MDD) R	MDD+ group displayed relatively less left frontal activity than lifetime MDD- group during approach condition as well as withdrawal condition; current-source-density transformed asymmetry indicative of lifetime MDD status under resting and task-elicited conditions	++
[43]	producing facial configurations denoting anger, disgust, fear, joy, and sadness	emotion eliciting potential of voluntary facial movement and approach-withdrawal model are investigated	36 students (10 male) R	facial poses of emotions in the withdrawal condition compared to approach and control conditions led to relatively less left frontal activation; approach condition less supportive of approach-withdrawal model	++
[45]	dot-probe paradigm with face pairs depicting angry, happy, and neutral emotional expressions and stressful speech condition	frontal EEG asymmetry patterns at rest and under social threat among young adults	45 students (23 male) R/L	increased right frontal alpha asymmetry difference (from baseline to stressful speech condition) associated with attentional bias to angry faces and avoidance of happy faces	++

[46]	give public speech	explore neural electrical changes correlated with expressive writing in a reappraisal approach	92 university students, divided into three groups: reappraisal writing, irrelevant writing, non-writing R	during writing manipulation reappraisal group showed lower frontal alpha asymmetry scores but following re-exposure to stress they showed higher frontal alpha asymmetry scores than irrelevant writing group; frontal alpha asymmetry of non-writing group did not change significantly across different stages	++
[47]	writing task describing an anger-eliciting event, where participants were irritated by people with higher or lower social power	explore neural mechanism behind power and its influence on expression tendency	29 students (13 male) R	high social power was associated with increased anger expression tendency and greater left frontal activation compared to low social power	++
[48]	internet advertisements during a text-reading task	effect of the interruption on a web user is analysed directly by studying brain activity	6 subjects (5 male) R	advertisement presentation induces changes in the frontal/ pre-frontal asymmetry index, direction of change differed among the subjects	+
[49]	reading a novel with emotional and non-emotional sections	examine physiological signals during the reading of a novel or other long text	71 participants (35 female) NA	on average greater frontal alpha asymmetry for high than low emotional sections at F7/F8	++
			Social interaction (n=5)		
[50]	three emotion-eliciting episodes (conversation with experimenter, with stranger, stranger reading a script)	test degree to which early maternal negativity affects physiological systems associated with coping response	89 longitudinal twin sample (around 54% male) R	children showed greater left frontal alpha asymmetry during conversation episodes relative to stranger script episode, significant sex differences	++
[51]	positive prompts: express love, play peek-a-boo and sing; negative prompts: pretend infant has a rash and crawled to an electrical outlet	characterize basic neurophysiological features behind affective function at developmental age, where emotional expression emerges	25 infant (-parent dyads), 12 females NA	negative prompts induce strong right hemispheric increase in the prominence of the resonant frequency ($\sim$5–6 Hz) in the infant frontal EEG; asymmetry scores during the other states (positive and neutral) did not statistically differ from zero	++
[52]	dynamic happy and fearful body expressions presented as point-lighted two second clips	perception of emotional body expressions evokes brain responses linked to motivational processes in infants	20 four-month-old (10 female) and 20 eight-month-old (10 female) infants NA	emotional expressions presented in upright orientation led to significant differences in frontal asymmetry responses for 8-month-olds only (not 4-month-olds): greater lateralization to left hemisphere (approach) in response to happy expression, and greater lateralization to the right hemisphere (withdrawal) in response to fearful expressions	++

[53]	degrees of social contact was varied by different gaze directions of a ”live” model	anterior functional brain asymmetry has been linked to individual differences in affect and motivation, exploring its relation with the Five Factor Model personality traits	40 students (13 male) R/L	negative relation of neuroticism to anterior EEG asymmetry scores in response to direct gaze, indicating that greater levels of neuroticism were associated with relative right-sided functional brain asymmetry (avoidance)	++
[54]	for the participants unknown faces of two young females, neutral and smiling with a direct and an averted gaze, presented ”live” through a liquid crystal shutter	modulation of autonomic arousal and frontal EEG alpha-band asymmetry by facial expression (neutral vs. social smile) and direct vs. an averted gaze	22 right-handed female undergraduates R	gaze direction and facial expression did not affect frontal EEG asymmetry, for gaze direction marginally significant correlation between asymmetry index and gaze direction index	0
Games (n=5)					
[55]	move around freely in a virtual T maze via joystick, with monster trial (negative event) and the sheep trial (positive event)	Investigation of theories: • motivational model • bilateral frontal activation part of behavioral activation system if actual behavior is shown • linked model of reinforcement sensitivity • here: relative left frontal activation shows revised behavioral activation system and behavior and relative right frontal brain activation indicates revised behavioral inhibition system, representing experience of conflict	30 participants (12 male) R	virtual reality task: increased relative left frontal brain activation during approach behavior and greater relative right brain activation for withdrawal behavior of any kind; increased bilateral frontal activation when participants were engaged in behavior relative to doing nothing; frontal asymmetry represents behavioral approach or avoidance motivation, bilateral frontal activation representative for behavior, observable behavior determined by frontal asymmetry and relevant traits	++
[58]	bogus computerized slot machine paradigm with three reels of numbers and fruit and two different payoff situations: reward (R) and no incentive (NI)	depression characterized with reduced reward-seeking behaviour (approach motivation) hence reduced left frontal activity, two neural systems of motivation and emotion hypothesized to be responsible for individual differences in emotional reactivity or affective styles	70 individuals with current MDD (about 29% male) 37 control participants (about 34 % male) R	no condition-dependent difference in hemispheric asymmetry among depressed compared to control; during the approach task control participants and individuals with late-onset depression showed increase in left frontal activity but individuals with early-onset depression did not	0

[37]	cues indicating that an easy, medium, or hard anagram (scrambled word) would be presented and whether they would receive money or avoid losing money for the correct solution	dysregulation theory of bipolar disorder: individuals with bipolar disorder would display greater relative left frontal activity in response to goal striving, especially positive challenges	individuals with bipolar spectrum diagnosis (n=41, 61% female) and individuals with no major affective psychopathology (n=53, 49% female) R	individuals with bipolar disorder compared to non-bipolar individuals showed higher relative left frontal activation in preparation for the hard/win trials, non-bipolar individuals showed a decrease in left frontal cortical activation from medium to hard win trials, when bipolar individuals did not; also bipolar individuals' self-reported activation was related to more left frontal activation for the hard/win trials	++
[56]	delayed reaction time task including manipulations of incentive, expectancy, and response	clarify psychological functions associated with frontal brain asymmetry	60 students (30 male) R	variations in monetary incentives led to changes in frontal alpha asymmetry, higher relative left alpha suppression during reward compared to punishment conditions; manipulations of expectancies related to mid-frontal EEG changes, which were different for men and women	++
[57]	imperative stimuli using either an approach response (finger press) or a withdrawal response (finger lift)	effect of manipulations of reward and punishment contingencies on brain's electrical activity	15 students (7 male) R	reward trials associated with less alpha power in left frontal regions compared to punishment trials, which were associated with less alpha power in the right frontal regions	++
Images (n=16)					
[59]	viewing pictures (including neutral, positive, negative and drug-related contents) before and after the training	effect of working memory training (WMT) on emotion regulation in drug abstainers	40 male drug abstainers: training group (n=20) with running memory task and control group (n=20) without training task R	training group adopted more spontaneous emotion regulation strategies and improved asymmetry scores when viewing negative and drug-related pictures compared to pretest, suggesting right- to left-brain asymmetry conversion, WMT enhances emotion regulation of drug abstainers	++
[73]	images depicting snakes, spiders, butterflies, and birds	investigating whether asymmetrical frontal activity is modulated by evolutionarily threatening stimuli	34 students (28 female) R	late frontal positive potential (f-LPP) asymmetry, but not alpha asymmetry was modulated by stimulus category, especially threatening stimuli led to large f-LPPs over right-frontal hemisphere; no effect in frontal alpha asymmetry for images	0
[60]	neutral and high valence and arousal (HVHA) pictures from the International Affective Picture System (IAPS)	major depressive disorder: analyse brain activity during emotional processing in depressed individuals	15 adults suffering from major depressive disorder (7 male) NA	higher relative right frontal activity (withdrawal) for viewing HVHA and neutral pictures compared to resting periods	++

[74]	passively viewing negative, neutral, and positive emotional pictures	investigate the association of frontal asymmetry with attentional and emotional responses to approach- and avoidance-related emotional stimuli	43 students (28 female) R	FAA for picture viewing was not different for picture type; greater right frontal activation was associated with increased N1 amplitudes and more negative subjective assessment of all stimuli	++
[66]	erotic pictures (high salience to evoke approach motivation), pictures of dressed attractive women and control pictures (extreme sport and daily activities)	explore whether alpha asymmetry can be elicited by brief affective–motivational stimuli, as typically used in event-related designs	17 male students NA	relative alpha reduction on left hemisphere for erotic pictures and significant asymmetry for daily activity pictures	++
[72]	anger pictures and neutral pictures	explore influence of traits related to behavioral approach or avoidance on responses to anger-eliciting stimuli using multiple measures: event-related potentials, electroencephalographic (EEG) alpha asymmetry and self-report	32 introductory psychology students (15 female) R	no significant effect of picture type for alpha asymmetry; behavioural approach system scale predicted greater left-frontal asymmetry to anger pictures; larger LPPs related to larger left-frontal EEG asymmetry for anger pictures	0
[71]	affective pictures ranging from very pleasant to unpleasant	testing explanation that alpha asymmetry fails to emerge (especially for affective pictures) due to insufficient motivational intensity, and/ or overshadowing inter-individual differences within responses to emotional pictures	70 students (28 male)	stimuli did not induce expected asymmetry effects, even though systematic stimulus-dependent individual differences arose in self-reports and LPP amplitudes, asymmetry variability was dominated by stimulus-independent inter-individual differences	0
[65]	neutral, aversive, and OCD-related pictures	exploring whether alpha asymmetry linked to approach/avoidance indexes a risk for anxiety disorders and depression	20 patients (9 male) with obsessive-compulsive disorder (OCD) and 20 matched healthy controls (8 male) R	compared to the control group, OCD patients showed altered asymmetry, with frontal alpha power in the 8-10 Hz band being more dominant in the left hemisphere across all conditions, no significant differences in frontal alpha asymmetry during rest, negative, neutral, OCD-related pictures	0
[70]	approach-positive, approach-negative, and withdrawal-negative pictures from the internet and IAPS	illuminate whether frontal asymmetry is related to motivation or affective valence by examining frontal-lateralized late positive potentials (f-LPPs) and frontal cortical alpha power activation	Forty-eight students (36 female) R	approach-negative and withdrawal-negative pictures in comparison to neutral pictures did not evoke differences in frontal alpha asymmetry; f-LPP results support relation between asymmetric hemisphere activation and motivational direction rather than affective valence	0

[75]	36 photographs from the IAPS in restricted randomized order - three pictures of the same affective category presented successively	investigate on minimum number of stimuli required for psychometrically stable outcomes	28 students (13 female) R	significant effects of affective picture category: negative affective stimuli relative to positive led to lower alpha power density, which was more pronounced in the right hemisphere	++
[61]	presentation of four pictures (from IAPS) for one minute each of category neutral, positive, negative, and trauma-related	explore changes in neural processing through cognitive behavioral therapy (CBT) in patients with posttraumatic stress disorder (PTSD) following severe motor vehicle accidents	participants with PTSD/ subsyndromal PTSD receiving CBT (n = 17, 15 females) before and after a CBT program, wait-list controls (n = 18, 10 females) investigated before and after three months R	pre-treatment assessment: increased right-sided activation during exposure to trauma-related picture (compared to neutral picture) observed in both CBT and wait-list subjects, post-treatment: greater reduction of right frontal activation in CBT group relative to wait-list controls; in both groups PTSD symptom reduction was significantly correlated with a decrease in right frontal activation in response to the trauma stimulus	++
[62]	confrontation with neutral, panic-relevant, anxiety-relevant but panic-irrelevant, or anxiety-irrelevant but emotionally relevant pictures, and performance of a motor task	expectation of greater right than left frontal hemisphere activation for patients with panic disorder, since they are characterized by negative emotions and avoidance-withdrawal behavior	patients with panic disorder without a diagnosis of depression (n=23, 3 male) and healthy control participants (n=25, 6 male) R	right compared to the left frontal alpha power was significantly decreased during resting phases and when confronted with anxiety-relevant stimuli in patients with panic disorder, comparable frontal asymmetry for patient and controls during neutral picture viewing or performing a motor task	++
[68]	pictures of dessert or neutral pictures of objects	investigating the role of individual differences in emotive tendencies for positive stimuli and relation to regional brain activation	26 female students R	picture stimuli alone did not evoke asymmetrical frontal cortical activity, regression analysis showed more time since eaten (/dessert liking) was significantly correlated to higher relative left frontal activation for dessert pictures; for neutral pictures this was not the case	0
[67]	food images	investigate restrained eating and hedonic hunger in relation to frontal asymmetry	58 female participants paid two visits: once fed once fasted R	no significant difference by hunger state in frontal asymmetry score, higher Power of Food scores were associated with increased left frontal asymmetry; higher Restraint Scores were associated with increased right frontal asymmetry, main effect for overweight individuals showing increased left asymmetry compared to normal weight	++

[69]	unpleasant, neutral and pleasant pictures, selected from IAPS before after rest/ exercise condition	effect of 30 min of cycling exercise compared to 30 min of rest on emotional responses to pictures	34 volunteers (13 female) from university and surrounding (young, fit and active) R	exercise did not alter frontal alpha asymmetry responses during picture viewing	0
[63]	six neutral images from IAPS, followed by ten ineffective, effective, and awarded anti-smoking Public Service Announcements (PSAs)	investigating the response to differently effective anti-smoking PSAs in the young population (higher risk of developing tobacco addiction)	39 volunteers: 3 HS (heavy smokers), 11 LS (light smokers), 15 NS (non-smokers) NA	main effect of smoking habit: non-smokers expressed lower frontal alpha asymmetry compared to HS and LS, effective PSAs led to increase in frontal alpha asymmetry for HS group compared to LS and NS, regression analysis for effective PSAs revealed a correlation between the number of cigarettes regularly smoked and relative frontal alpha asymmetry	++
			Videos (n=13)		
[83]	nine fixed-frame videos, filmed before the pandemic: busy downtown and residential green	investigating longitudinal changes in frontal alpha asymmetry due to COVID-19 pandemic and exploring the role of nature exposure on mental health and well-being	25 healthy adult Singaporeans (14 female) R	significantly higher frontal alpha asymmetry before pandemic compared to lockdown, landscape (video type) had no significant effect on frontal alpha asymmetry; decrease in frontal alpha asymmetry	0
[84]	emotion-eliciting commercials, two times respectively: neutral, tenderness, amusement, sadness, disgust, anger and fear	deeper understanding of human emotional states, exploration of deep learning techniques to analyse physiological data using a raw two-channel pre-frontal EEG and photoplethysmography	25 male and female subjects NA	trend in correlation between frontal asymmetry index (low alpha frequency band) and negative emotions evoked by commercials	+
[82]	three film excerpts (standard emotional film database) to evoke three emotions: tenderness, anger, and neutrality	explore valence and motivational direction model of frontal alpha asymmetry	37 students (17 males) R	higher left frontal activation during tender film, hence tenderness (positive emotion) related to approach motivation; increased right frontal activation during anger-eliciting video, suggesting anger (negative emotion) associated with withdrawal motivation	++
[64]	spots and images of awarded, effective and ineffective antismoking public service announcements (PSAs)	study responses to selected PSAs using EEG and autonomic signals	22 young healthy subjects (7 non-smokers, 9 light-smokers 6 heavy-smokers) NA	increased approach withdrawal (AW) index for "awarded" video spot compared to "ineffective" one; AW index between the three image campaigns was not statistically different	++

[79]	film comprising scenes of real injury and death	exploring relevance of individual differences in EEG alpha in response to emotional events	148 female university students R	while watching the film the magnitude of EEG alpha asymmetry response correlated with transient heart rate in response to sudden horrifying events happening to people (withdrawal/avoidance motivation and increased attention), viewing video showing disaster led to shift of dorsolateral prefrontal asymmetry to the right side	++
[80]	neutral and a sexually motivating film	extended approach (/avoidance) motivation-model in response to pleasant, high-arousal, approach motivation, sexual stimuli, which may play an important role to reward system function	65 participants (22 females) R	decreased asymmetry score during sexual film compared to neutral film; positive relationship between self-reported sexual arousal and alpha asymmetry, EEG alpha power coherence was stronger in women	++
[86]	TV commercials	relate brain activity and autonomic parameters to estimate emotional valence, arousal and approach-withdrawal (AW) behavior in marketing contexts	experiment 1: 15 healthy volunteers (7 female); experiment 2: 24 subjects (12 female); whole sample divided into like and dislike groups, based on rated pleasantness score on the clips NA	experiment 1: no alpha asymmetry assessed; experiment 2: temporal variations in frontal alpha asymmetry show differences between young and old viewers, AW-index displayed two segments were significantly different between like and dislike group	++
[78]	movie clips from cinema and documentary repertoires to induce relaxation, happiness, anxiety and sadness	explore patterns of aymmetries in reaction to affective film stimuli for different personality groups (extroverts, introverts, neurotics and emotionally stables)	40 female students R	patterns of activation were different between personality groups, partly consistent with approach-withdrawal model, right frontal asymmetry for introverts and emotionally stables in anxiety state	++
[77]	emotional film clips (neutral, relaxation, joy, anger, sexual arousal, disgust, fear, sadness, stress stimulation)	examine the effect of alexithymia on regional brain activity during emotion-inducing videos	non-alexithymic (n = 27, 7 male) and alexithymic (n = 17, 14 male) participants R	alexithymics showed overall enhanced right hemispheric activity in response to positive and negative films, indicating avoidance motivation	++
[85]	video commercials of six food products (3 x 6 commercials = 18 views)	marketing research: improve choice prediction using EEG and machine learning, instead of self-reports alone	33 (13 male) subjects, aged 19-41 NA	no significant difference for watching product commercials of distant rankings nor close mid-ranged rankings in alpha asymmetry	0
[38]	videos of food concerns (safety, hygiene and spoilage) and matched control (no food concern)	improve understanding of consumers' emotional response to food using implicit physiological tools next to traditional sensory techniques	40 students (31 female) R	significant difference between spoilage videos, with greater activation of the right hemisphere (withdrawal), no differences for hygiene and safety concern videos	++

[81]	videos of own infants expressing distress	look at association between mothers' neural activity (frontal alpha asymmetry) and emotions (facial expressions) and their appraisal processes (parenting efficacy)	26 mothers of 5- to 8-month-olds R	infant distress videos have led to increased right hemispheric activity, associated with longer sad and tense face expressions in mothers of average or lower parenting efficacy	++
[87]	chips to eat and video of confederate eating (EEG recording), visual-probe task: 20 food (highest ratings on food cravings) and non-food items	explore whether frontal alpha asymmetry moderates attentional bias (AB) to food and body mass index (BMI)	93 female students R	significant association of higher AB towards food pictures and larger BMI for participants with left frontal alpha asymmetry, overweight individuals compared to others showed increased left frontal alpha asymmetry when watching the video, and greater AB towards food pictures	++
			Real cues (n=8)		
[90]	pleasant (vanilla), unpleasant (valerian), and neutral (water) odors	explore changes in frontal alpha asymmetry in response to odors	58 women, aged between 58 and 70 NA	vanilla compared to valerian and water induced relative left frontal activation, frontal alpha asymmetry was not different for valerian compared to water	++
[88]	drink samples: apple juice, orange juice, yogurt drink, milk, buttermilk, rooibos tea, black tea, cola, diluted vinegar	compare performance of explicit ratings, (neuro)physiological and behavioural measure in distinguishing drinks inducing different emotional experience	70 healthy participants (19 men) NA	valence and arousal ratings for vinegar solution were lowest and highest of all drinks hence suitable as ground truth, frontal alpha asymmetry: no significant difference hence not sensitive enough to distinguish between drinks	0
[100]	universally accepted (sucrose) and non-accepted (caffeine) solution, a personally selected accepted and non-accepted drink, and plain water	exploring consumers' experience during drink-tasting by means of arousal (heart rate, electrodermal responses) and approach/withdrawal motivation (frontal alpha asymmetry)	32 participants NA	no significant difference when tasting different drinks was observed for frontal alpha asymmetry	0
[92]	two machines to prepare hot beverage	explore body (electrodermal activity, EDA) and brain activity (EEG) correlates during hot beverage preparation, and consumption in a real office environment	26 participants (14 females) R	market leader's user interface had higher self-reported product preference supported by significant differences in arousal (EDA) and valence (EEG) during coffee production and drinking	++
[93]	cooking and tasting two stir-fry dishes (chicken and mealworms)	explore implicit food preferences and choices using neurophysiological measures	41 participants (19 female) NA	frontal alpha asymmetry results show constant effect of 'approach' for chicken and 'avoidance' for mealworms present throughout entire cooking and tasting session, in frying interval this effect was significant	++

[94]	six landscape scenes within two urban green spaces (park and neighborhood green space) and three scenes of a busy urban downtown (control)	explore association between urban green space exposure and mental health	22 adults (13 female) R	trend: increased frontal alpha asymmetry in park compared to control site, indicating more positive mood, trend for interaction between site and scene suggestive of individual site variability	+
[95]	induction neutral (holding a pen) or depressive (cigarette-cue exposure: holding lighted cigarette over an ashtray without bringing to mouth) mood	explore neural basis of evoked cigarette craving and variations due to induced depressed mood, gender differences and smoker type	11 (5 male) regular and 11 (6 male) light smokers NA	cigarette-cue exposure led to reduced left frontal alpha asymmetry (withdrawal), increased cravings and negative affect, especially in female and regular smokers	++
[91]	experiment 1: 15s visual and visio-tactile exploration (VE and VTE) of two daily food (major and private label) and two comfort food items (foreign and local product); experiment 2: 15s tactile exploration (TE), VE and VTE of four different comfort and daily foods, two local and foreign products (major or private brand)	investigate cross-sensory (sight and touch) evoked EEG and the autonomic reactions over different products	experiment 1: n=19; experiment 2: n=13 (5 males) NA	higher approach for comfort compared to daily food in VE and VTE, increased approach withdrawal (AW) index for foreign relative to local products during VE and VTE, but not in TE, higher AW for private relative to major label during VTE (experiment 2), greater AW and emotional index (EI) for foreign relative to local products during VTE, phases not significantly different	++
Sounds and Music (n=3)					
[96]	three sound recordings (90s each): anger/ aggression, sadness/ desperation, neutral (reference)	explore inter-personal differences in motivational responses to sound recordings of individual's desperation and aggression and its relationship with DSM-5 personality traits	62 university students (30 male) R	anger: higher antagonism levels displayed approach motivation (less relative right hemisphere activation), desperate crying: higher detachment levels showed withdrawal activation (greater relative right hemisphere activation)	++
[98]	experiment 1: visual music as an emotional stimulus experiment 2: synthetic stimuli	explore emotional meanings of visual music and its underlying affective audio-visual integration mechanisms between different modalities	experiment 1: 16 people, experiment 2 with students divided into groups: audio-only (n=33), visual-only (n=27), original (n=42) and altered (n=53) visual music NA	EEG measured for experiment 1 only, where for visual music stimulus early phase (first 10s) frontal alpha asymmetry correlated significantly with perceived valence evaluation	++

[97]	sound stimuli (scary and soothing)	investigating responses to scary and soothing sound stimuli assessed by frontal alpha asymmetry and the emotion (AAE) and Comfort Vector (CV) models	18 healthy students (16 male) divided into three groups based on their baseline frontal asymmetry NA	scary sound stimulus: groups 1 and 3 displayed a decrease in frontal asymmetry (AAE) and in pleasantness (CV model); correlation between AAE and CV models for scary stimulus, but not for soothing stimulus	++

H

Measuring Behavior 2022 conference paper

As an output of this internship, a conference paper ('An Attempt to Assess the Effects of Social Demand using Explicit and Implicit Measures of Food Experience') was submitted to the online conference Measuring Behavior 2022, which is attached below.

An Attempt to Assess the Effects of Social Demand using Explicit and Implicit Measures of Food Experience

Abstract

Explicit (questionnaire) and implicit (EEG and behavioral) measures were used to assess the impact of social demand on appreciation of Japanese and Dutch food. Applied social pressure was too weak to increase liking of Japanese food – however, the different measures were sensitive to other variables of interest such as food neophobia.

Introduction

Food experience is generally measured using explicit, verbal measures such as responses to questionnaires [1]. However, implicit measures based on signals generated outside of conscious awareness, such as physiological responses or facial expression, may add valuable information. For instance, it was previously found that when testing responses to images and drinks in both Thai and Dutch participants, explicit measures showed a known cultural response bias (Western participants using a larger range of the response scale than Asian participants), while heart rate responses did not show this bias and were in line with hypothesized liking of the food from the own culture [2]. Implicit measures may thus help to compare food experience across cultures, avoiding response bias. Another case where response bias in explicit measures of food experience may be expected, and implicit measures may aid assessment of food experience, is when social demand plays a role. An example of the effect of social demand on an explicit measure is a study by Dell and colleagues [3]. They showed that respondents were about 2.5 times more likely to favor a technology believed to be developed by the interviewer compared to an exactly identical alternative which was not developed by the interviewer. In the current study, we investigate whether social pressure towards favoring Asian food differentially affects explicit and implicit measures of food experience. We hypothesize that it affects explicit measures (in this case, reported valence (pleasantness) and arousal). Depending on whether social demand genuinely affects the experience, or only the conscious report, we expect to see a concurrent change in implicit measures as recorded using a behavioural measure (amount consumed) as well as Electroencephalograpic (EEG) brain measures: event related potentials, alpha asymmetry [4,5] and intersubject correlation [6,7]. Another research question concerned the relation between food neophobia (unwillingness to try novel foods [8]) and implicitly and explicitly recorded responses towards the different types of food stimuli (further elaborated upon in anonymous et al., in preparation).

Methods

We recorded from 19 female and 23 male Dutch participants, with ages ranging from 19 to 64 years (M= 46.6, SD= 15.3), who were free of any food allergy and not following any type of diet.

Participants were fitted with a 32-electrode EEG cap and randomly assigned to the social demand or control group. The experiment consisted of three phases: 1. pre-social demand, 2. movie, and 3. post-social demand (see Figure 1). In phase 1 and 3, participants were presented with pictures of food from the CROCUFID (Cross Cultural Food Images Database [10]) on a computer screen in a randomized order. The images were of four different categories: Japanese food, Dutch food, palatable food (universal food, such as fruits) and unpalatable food (molded food and food beleaguered by insects or snails). In both phase 1 and phase 3, 80 unique images (20 from each category) were presented for two seconds, preceded by a fixation cross displayed for 0.5 seconds. Immediately after viewing each image, participants were prompted to rate their emotion using the EmojiGrid, which is a graphical and language-independent self-reporting tool to measure the emotional dimensions of valence (x-axis) and arousal (y-axis) [11]. After viewing and rating the images, a Dutch (Vegetable or Tomato) and a Japanese (Miso or Sumashi) soup were presented to the participants in a randomized order to taste and rate using the EmojiGrid. The amount of soup consumed (sip size), was recorded.

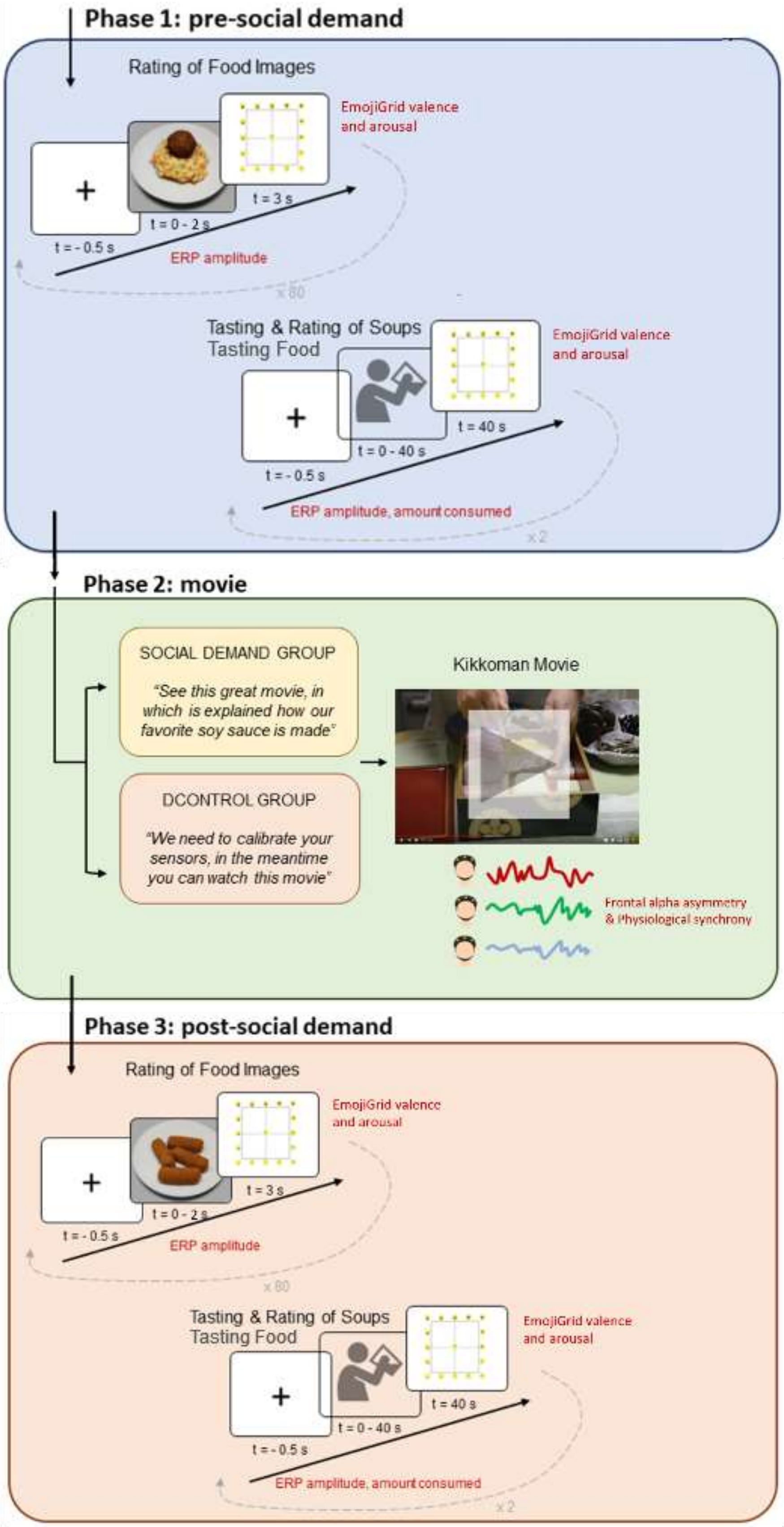

Figure 1. Overview of the experimental design

After phase 1 (pre-social demand), the movie phase started. In this phase, participants watched a 15-minute movie on the origin, production and use of Japanese Kikkoman soy sauce. Just prior to the movie, we attempted to exert social pressure on participants to increase liking for Japanese food. For this, one of the experiment leaders, who is visibly from Japanese origin, told the participants anecdotes and his favorable opinion of Japanese food. The control group was told neutral anecdotes by a different (non-Japanese) experiment leader. After watching the movie, the experiment leader again intended to apply social pressure to the social demand group by referring to the movie. With the control group, the other experiment leader conducted basic small talk without mentioning anything about the movie's content. The conversation around the attempt to induce social pressure, and the control in the other group, followed a predetermined protocol.

Results and Discussion

We had expected that after applying social pressure, participants would score Japanese food more favorably with respect to Dutch food as compared to how they scored them before the social pressure, and compared to the control group. After establishing this, evaluating the implicit responses would have indicated whether social pressure only caused the participants to adjust their scores, or whether the social pressure affected food experience more profoundly. However, there was no effect of social pressure on explicit measures in the first place. It also did not affect any of the other variables. We did find hypothesized effects of other factors on our dependent variables. We found effects of food image category (Japanese, Dutch, palatable, unpalatable) on explicit scores and ERPs, and we found effects of drink category (Japanese, Dutch) on both explicit scores and sip size. In addition, food neophobia affected, or tended to affect, all of these variables. Food neophobia also strongly affected EEG inter-subject correlation (reflecting attentional engagement during watching the movie) though not alpha asymmetry (reflecting approach-avoidance motivation during watching the movie). The effects of food category and food neophobia indicate that the lack of effect of social pressure was not caused by a complete lack of sensitivity of the variables. The method we used of applying social pressure appeared to not have been strong enough. We speculate that the major aspect that could be improved in future experiments is to ask participants for explicit reports in a way that it is clear that the person inducing social pressure perceives their response. Repeating a study similar to the current one but with a more potent way to induce social demand would still be of strong interest in order to increase our understanding of the pervasiveness of social demand on food experience. Especially when implicit and explicit measures diverge, this would speak to expanding the usual measuring toolbox from explicit measures only to including implicit ones.

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