The relationship between tendency to attend to detail, sensory sensitivity, and affective response to food cues – a registered report

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Abstract

Understanding the underlying drivers of food choice remains a challenge and has highlighted the need for measures that capture data over and above that offered by self-reporting tools. Consequently, a growing body of research has set out to interpret facial responses to food cues to offer a greater insight into the emotional responses that may drive food acceptance. However, interpreting facial responses is challenging, as there are numerous factors that may influence affective response to foods, including expectation, context, and individual differences.

Existing findings suggest there is a link between autistic traits and sensory sensitivities; research highlights further links between sensory sensitivities and eating behaviour, and autistic traits and eating behaviour, with a body of research focusing on the autistic trait attention to detail (ATD). As such, the current study aimed to examine rapid facial activity in response to foods cues while capturing these individual differences present in the general population.

This study found no evidence to suggest facial responses to food pictures were linked with attention to detail or hyper-sensitivity. The findings did support a general link between self-reported pleasantness ratings of viewed foods and activity of the facial muscles. Post-hoc analyses suggested scoring on the social skills sub-scale of the Autism Quotient (AQ) was associated with *levator* activity while viewing pictures low in pleasantness. This study offers a greater understanding of variations, at the individual level, which are associated with affective response to foods, and may help to inform the development of tools that set out to predict food acceptance.

Keywords

Food, facial electromyography, sensory sensitivity

1.Introduction

Understanding how people make their food choices is a pressing requirement as obesity, non-communicable diseases, and eating disorders remain prevalent and are, arguably, still poorly understood (Abarca-Gómez et al., 2017; Smink, van Hoeken, & Hoek, 2013; World Health Organization, 2017). Thus, understanding the mechanisms associated with sensory, cognitive, and emotional variations in response to foods could aid the development of suitable interventions (e.g., Roberts, Tchanturia, & Treasure, 2013).

Emotional processing can affect sensory perception, attention, and behaviour (Vuilleumier, 2005). In an effort to enhance knowledge of eating behaviour, emphasis has been placed on capturing emotion-related responses in food contexts, with evidence suggesting these data can enhance understanding of food choice better than hedonic measures alone (Desmet & Schifferstein, 2008; Gutjar et al., 2015; King & Meiselman, 2010). With this in mind, many researchers have turned to the examination of facial reactions to provide some insight into the emotions evoked by foods, with mixed levels of success (Danner, Sidorkina, Joechl, & Duerrschmid, 2014; de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014; Juodeikiene, Basinskiene, Vidmantiene, Klupsaite, & Bartkiene, 2014; Wendin, Allesen-Holm, & Bredie, 2011).

The idea that different emotions evoke specific distinct facial expressions is not new (Darwin, 1872.; Izard, 1994); however, this notion is not without controversy, with evidence suggesting variations in the display of emotions depend largely on context (Carrera-Levillain & Fernandez-Dols, 1994; Fernández-Dols & Ruiz-Belda, 1995; Ruiz-Belda, Fernández-Dols, Carrera, & Barchard, 2003; Siegel et al., 2018). In relation to affective responses during the viewing of food pictures, two recent studies have highlighted the influence of social context on facial displays (Nath, Cannon, & Philipp, 2019; Nath, Cannon, & Philipp, 2020). As such, using facial expression information alone to infer emotion may be fraught with assumptions and, thus, may be liable to error. Furthermore, when we relate basic emotion theories, in terms of facial expressions, to the context of food, then the complexity of interpretation increases as specific tastes such as bitterness evoke characteristic muscle activity (Cannon, Li, & Grigor, 2017; Wendin et al., 2011). This means measurement tools may capture both responses related to sensory perception and emotions elicited by foods (Garcia-Burgos & Zamora, 2013; Kaneko, Toet, Brouwer, Kallen, & Van Erp, 2018).

Evidence gained from studies using facial expression analysis suggests that individuals show limited expressions to palatable food-related stimuli (Danner et al., 2014; Le Goff & Delarue, 2017) making interpretation challenging. However, facial electromyography (EMG) can capture activity below the level of visual detection (Hess, Kappas, McHugo, Kleck, & Lanzetta, 1989) and evidence demonstrates the link between specific facial muscle activity and affective states. Therefore, this method can be used to offer an insight into one dimension of emotion - valence (Mauss & Robinson, 2009). For example, increased M.*zygomaticus* major (lifts corner of lips when smiling) contractions have been linked with positive affect and increased M.*corrugator* supercilii (knits brow when frowning) and M.*levator* labii contractions (involved in flaring the nostrils and raising the lip such as in a disgust expression) have been associated with negative affect (Cacioppo, Petty, Losch, & Kim, 1986; Hoefling et al., 2009; Larsen, Norris, & Cacioppo, 2003; Vrana, 1993). Moreover, studies investigating variations in affective response to foods have found some success with this method (Hoefling et al., 2009; Soussignan, Schaal, Rigaud, Royet, & Jiang, 2011). Furthermore, evidence gained during evaluations of food-related odours has demonstrated that facial activity can be indicative of sequential evaluations, with much of the processing related to valence and intensity taking place at early time points (<2000ms) (Delplanque et al., 2009; He, Boesveldt, de Graaf, & de Wijk, 2014). Recent research has also shown a link between facial activity and subjective liking of food pictures (Nath et al., 2019; Nath et al., 2020). As such, facial responses have the potential of offering insight into the dynamic nature of food evaluation and many studies have sought to investigate such displays, to gain a greater insight into food acceptance (de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012; Garcia-Burgos & Zamora, 2013; He, Boesveldt, de Graaf, & de Wijk, 2016; He, Boesveldt, Delplanque, de Graaf, & de Wijk, 2017).

Investigations into specific muscle associations and affective response have returned mixed findings depending on the question being addressed. For example, the *zygomaticus* and *corrugator* muscles have been targeted for distinguishing altered responses to palatable food pictures in individuals with disordered eating (Soussignan et al., 2011). However, in the wider literature (non-food related), there is evidence to suggest the *corrugator* has a stronger linear association with valence than that of the *zygomaticus* (Larsen et al., 2003). As would be expected, the nature of the food interaction is important, as evidence from a study adopting a tasting paradigm found the *levator* to be most insightful (over that of *corrugator* and *zygomaticus*) (Hu, Luo, & Hui, 2000). However, in such paradigms, there may be an increased desire to expel substances (for which this muscle would be required) (Hu et al., 2000) and, consistent with this finding, activity of the *levator* has been shown in paradigms evoking the disgust response (Hu et al., 1999; Vrana, 1993).

Interestingly, a link has been established between disgust and picky eating (Egolf, Siegrist, & Hartmann, 2018; Harris et al., 2019), which in turn has been shown to link with sensory sensitivity (Farrow & Coulthard, 2012; Nederkoorn, Jansen, & Havermans, 2015). As such, the proposed study will capture data from the *corrugator, levator,* and *zygomaticus* regions, to investigate associations between sensory sensitivity and tendency to attend to detail and affective response to foods.

1.1 Individual differences in sensory processing

Individual differences in sensory processing continues to be of great interest to the food industry. As a result, more knowledge is being gained on the influence genetic predisposition has on eating behaviour, including the examination of relationships between thermal tasters and 6-*n*-propylthiouracil (PROP) tasters and oral perception (Bajec & Pickering, 2008; Cruz & Green, 2000; Green & George, 2004; Tepper & Nurse, 1997). Such variations have been shown to influence acceptability of, and response to foods (Bajec & Pickering, 2008; Dinnella et al., 2018; Tepper & Nurse, 1997). These findings support the notion that individual differences influence subjective experience and subsequent behaviour towards food. Furthermore, there is growing amount of evidence to suggest that sensory sensitivity is related to eating behaviour (Farrow & Coulthard, 2012; Hebert, 2018; Johnson, Davies, Boles, Gavin, & Bellows, 2015; Naish & Harris, 2012). For instance, a recent study found that individuals with passive self-regulation strategies, as measured using the Adult/Adolescent Sensory Profile, reported higher emotional eating behaviours and response to external food cues (Hebert, 2018). The findings from another study have shown increased chocolate consumption during testing for a high sensory sensitivity group when compared against a low sensory sensitivity group (Naish & Harris, 2012). The first of these studies utilised self-reporting tools to establish the link, whereas the latter looked at behavioural measures. We expect the findings of the current study to be in line with the latter that is heightened sensory sensitivity would result in heightened behavioural response (increase in facial activity related to evaluation).

To establish tendency to attend to detail and sensory sensitivity, the current study utilised two questionnaires; the *attention to detail* (ATD) subscale of the Autism Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and the Glasgow Sensory Sensitivity questionnaire (GSQ) (Robertson & Simmons, 2013), as existing evidence supports the notion that variations in sensory sensitivity and perception ~~is~~ are often evident in individuals with Autism Spectrum Disorder (ASD), and variations have also been seen in the general population, based on autistic traits (Robertson & Simmons, 2013).

Such variations have been shown in the visual domain (Almeida, Dickinson, Maybery, Badcock, & Badcock, 2013; Grinter et al., 2009; e.g., Shah & Frith, 1993), with auditory (Aykan, Gürses, Tokgöz-Yılmaz, & Kalaycıoğlu, 2020), olfactory (e.g., Tonacci et al., 2019; Walker, Williams, & Moore, 2020), and gustatory stimuli (Clark, Hughes, Grube, & Stewart, 2013; Tavassoli & Baron-Cohen, 2012). Further investigations have highlighted links between tendency to attend to detail and eating disorders (in terms of self-reported scoring, task performance, or brain regions recruited during relevant tasks) (Fonville et al., 2013; Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014; Madsen, Bohon, & Feusner, 2013; Roberts, Barthel, Lopez, Tchanturia, & Treasure, 2011; Roberts et al., 2013).

Many of these studies have adopted an embedded figures test, which is a visual search task requiring a shape to be removed from a more complex surrounding, as a measure of attention to local detail (for example, the Embedded Figures Test Witkin, Oltman, Raskin, & Karp, 1971)). However, the link between the attention to detail subscale of the AQ and performance in visual search tasks requiring a focus on local detail has been mixed (Grinter, Van Beek, Maybery, & Badcock, 2009; Rusconi, McCrory, & Viding, 2012; Russell-Smith, Maybery, Bayliss, & Sng, 2012). As such, we have also included a visual disembedding task (Leuven Embedded Figures Test (L-EFT), (de-Wit, Huygelier, Van der Hallen, Chamberlain, & Wagemans, 2017)) to assess attention to detail in this study.

As it stands, findings linking variation in sensory perception are difficult to interpret when found in ~~those~~ individuals with challenging eating behaviour; for example, it may be that such variations manifest as a result of the eating behaviour, or they may be risk factors. Consequently, there is a requirement for further investigations into associations between individual differences and food-related responses in the general population; this ~~can~~ may help to find potential drivers of variations in the processing of food cues, which may alter eating behaviour.

1.2 Study aims.

Based on the reviewed research, it can be suggested that there is a link between sensory sensitivities and food-related behaviours in clinical and non-clinical populations. The primary aim of this study is to examine hyper-sensitivity and tendency to attend to detail in relation to rapid facial activity evoked by pictures of foods varying in valence in a non-clinical population. We expect to find that as sensory sensitivity and ATD increase, so will the behavioural response (facial activity) to food pictures in line with the affective nature of the pictures being viewed. We also expect that facial activity of the target muscles will predict self-reported liking scores of food pictures. Our predictions are:

1) Attention to detail will predict change scores of the M.*corrugator supercilii* and M.*levator labii superioris alaeque nasi* during the viewing of food pictures rated low in valence (as attention to detail increases ~~as~~ so will the negative response)
2) Attention to detail will predict change scores of the M.*zygomaticus major*, during the viewing of food pictures rated high in valence (as attention to detail increases so ~~as~~ will the positive response)
3) GSQ hyper-sensitivity scores will predict change scores of the M.*corrugator supercilii* and M.*levator labii* during the viewing of food pictures rated low in valence (as hyper-sensitivity increases ~~as~~ so will the negative response)
4) GSQ hyper-sensitivity scores will predict change scores of the M. *zygomaticus major* during the viewing of food pictures rated high in valence (as hyper-sensitivity increases ~~as~~ so will the positive response)
5) Activity of the M. *zygomaticus major*, M.*corrugator supercilii* and *M.levator labii superioris* alaeque nasi (during the first 2 seconds of viewing) will predict self-reported ratings of food pictures

2. Power Analysis and planned statistical analysis.

It is our understanding that there are no previously published studies, which have looked at associations between facial muscle activity and sensory sensitivity and food domains. Thus, the Bayes Factors (BF) were referred to, to determine whether there was support in favour of the alternative or null hypotheses. Analyses was undertaken after the first 20 participants and when all available participants were tested (due to the understanding that changes may be made in terms of lab accessibility near the end of testing). Thus, we tested as many people as possible before further analyses were undertaken).

As this study is part of a PhD project, we took our limited resources into consideration and set the maximum participant number to 150. Stopping was based on the weight of evidence, with a Bayes Factor of >3 offering substantial evidence for the alternative hypothesis and <0.33 substantial evidence for the null hypothesis (Jeffrey et al. in Dienes, 2014).

We have also included a hypothesis related to a positive control in the experiment. This includes a block of pictures from the publicly available 72-image FACES database (Ebner, Riediger, & Lindenberger, 2010), which contains naturalistic facial expressions, where the expectation is for facial mimicry to occur during the viewing of facial expressions.

3. Materials and Methods

3.1 Participants

One hundred and four participants completed the full testing session. They were recruited from Abertay University via advertising on the university intranet and flyers posted across the campus inviting people to be involved in a food and sensory experiment. Participants were screened for exclusion criteria including any previous eating disorders, use of Botulinum toxin injections, use of medication affecting muscle movement, current adherence to a restricted diet, diagnosis of autism disorder, or any neurological condition. All had good or corrected to good eyesight. The study was approved by the ethics committee of the School of Applied Sciences, Abertay University. Participants were requested to refrain from eating for three hours prior to the study. Three participants scored greater or equal to 32 on the AQ and, due to a technical failure, scores on the L-EFT did not save for two participants. During the data acquisition stage, there were issues with recordings from at least one muscle of six participants. These participants were excluded from main analyses. 15% of 500ms data points were deemed outliers (food and face trials combined). Three participants had over 50% of 500ms datapoints termed outliers and they were removed from analyses. This resulted in 90 participants being included in full pre-registered analysis. The sample included in the analyses comprised of 51 females and 39 males. Participants had an average age of 26.7 (SD=9.2). For the mimicry stage of the experiment there were further exclusions for analyses relating to each muscle where values were not present for each time bin (86*n*). This was mainly due to talking or laughing during this stage of data acquisition. Participants were given a £5 voucher on completion of the study, which took approximately 50 minutes. All relevant data can be accessed at https://osf.io/9vkf5

3.2 Questionnaires

Participants were required to complete the basic demographic questionnaire capturing their age, sex, height (measured in lab), weight (measured in lab), when they last consumed food, and current hunger levels. Current hunger levels were rated on a scale of 1 (extremely full) to 10 (extremely hungry).

Participants also completed the 50-item AQ questionnaire (Baron-Cohen et al., 2001). The AQ is comprised of 5 sub-sets of questions, measuring *social skills, attention switching, attention to detail, communication, and imagination*. The test-retest reliability for the full questionnaire has been shown to be strong (*r*=.7) and the internal consistency has been shown to be moderate to strong on all sections of the questionnaire (.63 for ATD (Baron-Cohen et al., 2001)). Furthermore, Baron-Cohen and colleagues (2001) detail that 80% of those tested who were diagnosed with Asperger syndrome or High-Functioning Autism scored above the cut-off point (32), compared with 2% of controls, supporting the ability of the questionnaire to measure autistic traits. For the purposes of this study, it is the 10-item ATD subscale of the AQ questionnaire that directly relates to the main predictions, analyses of the full questionnaire were used to aid the interpretation of findings.

The Glasgow Sensory Questionnaire (GSQ) is comprised of 42 items (21 of which are related to hyper-sensitivity and 21 hypo-sensitivity) covering seven modalities; visual, auditory, gustatory, olfactory, tactile, vestibular, and proprioceptive. Likert-type answer options allow-scoring between 0-4 with a total maximum score of 168 (84 for hyper-sensitivity) (Robertson & Simmons, 2013). It is the hyper-sensitivity (Hyper) score that is of interest in this study. Robertson and Simmons (2013) have shown the questionnaire to have good levels of reliability (Cronbach's alpha *r*=.935), and content validity has been supported by the results aligning with sensory experience, as mentioned in a qualitative questionnaire (Robertson & Simmons, 2013). Paper-based versions of both these questionnaires were used and participants were given as much time as required to complete these.

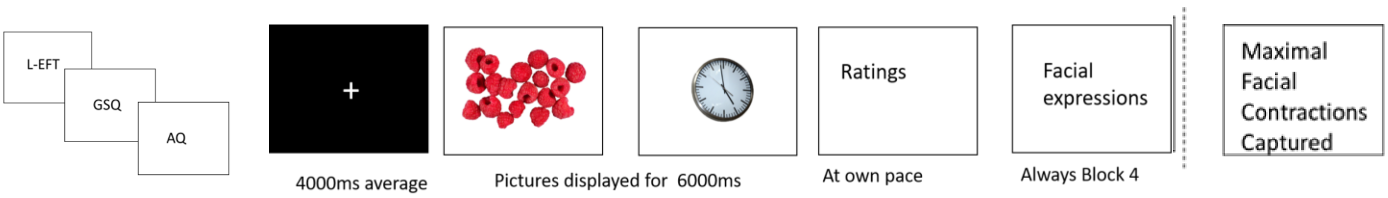

Figure 1: The order of the L-EFT, questionnaires, and picture viewing task were counterbalanced. The picture viewing task was comprised of a food, neutral, and a rating block (where the same food pictures from the food block were rated), as well as a block displaying facial expressions to test for spontaneous facial mimicry. Following the completion of all parts of the picture viewing task, participants were asked to mimic the researcher's facial expressions to allow for change scores to be calculated as a proportion of maximum voluntary contraction[1]*. Pictures are taken from the Food-*

[1] Please see *section* 10 for changes to protocol communicated to the editorial team after Stage 1 acceptance.

pics_Extended data base in line with the license agreement (Blechert, Lender, Polk, Busch, & Ohla, 2019).

3.3 L-EFT

The Leuven-EFT (L-EFT) is a visual search task that requires a shape to be removed from a more complex background and has been shown to have a comparable relationship with memory span and fluid intelligence as the EFT (Huygelier, Van der Hallen, Wagemans, de-Wit, & Chamberlain, 2018). Constructed to measure perceptual bias (Van der Hallen, Chamberlain, Huygelier, de-Wit, & Wagemans, 2015), we have chosen the L-EFT due to ~~the~~ its larger stimulus set than ~~that of~~ the EFT to prevent any ceiling effects. Consisting of 64 trials, the L-EFT uses 16 shapes and involves participants being presented with a target shape and 3 possible contexts (displayed below the target shape); one of the contexts contains the target object.

Participants were required to click a button corresponding to the correct context (1,2, or 3). This forced-choice task required participants to respond as quickly and as accurately as possible ~~within~~. Participants had a maximum viewing time of 3 seconds. 6 practice trials were shown to begin. Stimuli were presented as per a previous study (target and context shape 3cm², with context shapes being displayed 7cm below target shape) (Huygelier et al., 2018). Trials were randomized and a viewing distance of 45cm was set. The task was presented, and responses were captured with E-Prime 3.0 Professional, with a screen resolution of 1280 x1024 and a refresh rate of 60 Hz.

3.4 Picture viewing task

The picture viewing task was undertaken while facial electromyography (EMG)-was recorded. The viewing task comprised 4 blocks: foods (taken from the Food-pics_Extended database and detailed in Supplementary Materials) (Blechert et al., 2019), neutral non-food pictures, food rating block (food pictures shown again and participants asked to rate), and facial expressions (taken from the publicly available FACES database) (Ebner et al., 2010). All participants viewed the same pictures, but picture order within food, neutral, and rating blocks was randomised. Block order was counterbalanced. However, to prevent priming taking place, based on the facial expressions, faces were always presented last. Each block was made up of 18 pictures. The facial expression block included pictures of 6 different individuals expressing the emotions happiness, anger, and disgust. Pictures of each type of expression were shown together, but the order of expression was counterbalanced.

The food block contained a mixture of 9 pictures rated highly palatable (with an average palatability rating of 75/100) and 9 less palatable food pictures (with an average palatability rating of 30/100) but did not contain any invariably disgusting pictures (e.g., no rotten or mouldy foods) (see Supplementary Materials Tables 1 and 2 for picture details). Normalised ratings are taken from research related to the construction of the picture database (Blechert et al., 2019). Each picture was presented for 6 seconds with a jittered inter-trial interval (average 4 seconds). During the food rating block the participant was shown the same food pictures again and asked, "*how pleasant do you find this image?", "how much would you like to eat this food",* and *"have you ever eaten this food?"*. Answers to the first two questions were entered on a visual analogue 100-point scale, anchored with "*extremely unpleasant*" and "*extremely pleasant*", and "*extremely dislike"* and "*extremely like",* respectively. For the third question participants had the option of clicking *Yes* or *No*. Participants were able to respond in their own time.

Following each block of pictures, participants were shown the instruction "*please click the mouse when you are ready to view the next block of pictures*". Participants were requested to use these times to make any large movements, such as adjusting their seating position. All pictures were presented using E-Prime 3.0 Professional on a screen with a resolution of 1280 x1024 and a refresh rate of 60 Hz. Participants sat approximately 80cm from the viewing screen.

Note: Tables detailing food pictures and normative ratings can be found in Supplementary Materials (Tables 1 & 2).

3.5 Facial EMG

Facial muscle activity was recorded with the ADInstruments PowerLab data acquisition system with Bioamp and LabChart software used to analyse data. Bipolar 4mm Ag-AgCl electrodes were used for capturing activity over the *zygomaticus*, *levator,* and *corrugator* areas, attached to the face using electrode collars. The grounding electrode was attached to the forehead. Electrodes were placed on targeted areas as per instructions given by Fridlund and Cacioppo (1986). Cleaning of the targeted areas was carried out using abrasive pads and alcohol wipes. Electrode gel was applied to the face and used to fill the electrodes.

3.6 Maximum Voluntary Contractions

To aid standardisation, the researcher entered the sensory booth, following completion of the picture viewing task, and asked the participant to mimic the facial expressions anger, happiness, and disgust. This was carried out for standardisation of muscle activation between participants and over different muscles within participants, controlling for the possibility that those with higher ATD or Hyper GSQ score simply move their faces more in general. Change scores were expressed as a proportion of the maximum contraction for the specific muscle and individual (Van Boxtel, 2010). This was always carried out last in the viewing task to prevent participants from being fully aware of the nature of the EMG element of the investigation.

3.7 Procedure

Following screening and informed consent, electrodes were attached. The demographic questionnaire was then completed. Prior to completing the viewing task, time was given to allow readings to stabilise and to allow participants to get used to the electrodes. Participants were then asked to complete-the L-EFT, AQ, the Glasgow Sensory Questionnaire, and the picture viewing task (see Figure 1). The tasks were presented in a counterbalanced order across participants using a Latin Square design. Prior to having electrodes removed participants were requested to mimic the researcher's facial expression (disgust, anger, and happiness) to capture maximum voluntary contractions (see section 3.6). Participants were debriefed after completion of all tasks. The tasks were completed in a sensory booth in Abertay University, with the researcher not in view (until MVC task) and giving instructions orally. Temperature was set at 21ºC with standard lighting used to allow for video capture.

3.8 Data Processing

The EMG raw data was sampled at a rate of 2000Hz with a 10Hz high pass and 500Hz low pass filter along with a 50Hz mains filter. The EMG recordings were automatically annotated with comments time-locked to EPrime stimuli presentation events. After recording, raw data was band-pass filtered (20 Hz - 500Hz) and rectified. To analyse the rapid responses to food stimuli, the facial activity following stimulus onset was broken down into 12 x 500ms bins. Baseline facial activity was identified as the mean muscle activity 500ms pre-stimulus onset. This was subtracted from the mean muscle activity during each key time bin to calculate change scores for each muscle. Change scores were expressed as a percentage of MVCs.

3.9 Artefact and outlier removal

Videos of all subjects were viewed following recording and trials were removed where movement unrelated to the task was evident (electrode wires hit, coughing, talking, non-task related, or excessive body/mouth movements). This was be done by use of the video recording module of the Labchart software and a webcam, which was set to automatically record participants' facial activity when the viewing task began and stop when testing ended. Throughout the recording, the facial electromyography data was notated with pre-set comments, synchronised with task events (such as stimuli onset etc.). Where an electrode fell off it was re-attached and the affected trials excluded from analyses.

We stated we would adopt the method used by van Peer and colleagues (van Peer, Coutinho, Grandjean, & Scherer, 2017) whereby outliers were defined as those exceeding 2 x the 75^{th} percentile value of ranges based on the targeted muscle (at baseline and following stimuli onset). It should be clarified we looked at the absolute value of datapoints and considered any that were 2 x the 75^{th} percentile (calculated across all datapoints, participants and trials for a specific muscle). Values of muscles were removed for the affected bin. It is understood that absolute values are not meaningful as baseline differences between participants may occur; however, any datapoint in which the mean absolute value exceeded 2 x the 75^{th} percentile was rejected to remove all datapoints containing original excess noise. This was done along with checking of participant recording.

We also excluded any trial where the change score (as a proportion of MVC) was extreme (+/- 8SD from the mean) as our pre-registration did not include further outlier removal. Thus, we aimed to remove only extreme outlier values from the dependent variable.

Where any participant had over 50% of 500ms datapoints of all trials termed outliers, the participant was removed from analysis. Those scoring 32 or above in the AQ were removed from analysis in line with our pre-registration (Baron-Cohen et al., 2001). There were no instances of missing data with the questionnaires.

Where a participant appeared disengaged and not paying attention to the picture viewing task, they were excluded. Participants who did not fully complete the session were also excluded from original analysis. As the L-EFT task is a forced-choice task, we stated that those scoring lower than chance (33.3%) would be removed from analyses. There were no instances of participants scoring below chance (33.3%) on the L-EFT. Only RTs of correct L-EFT trials were included in final RT analyses. Details of exclusions can be found in section 3.1.

3.10. Planned statistical analyses.

Statistical analysis was carried out using R with the package lme4 (Bates, Maechler, Bolker, & Walker, 2015) used for linear mixed models. JASP was also used to calculate Bayes Factors for all relevant correlations and repeated measures ANOVAs. Results from both frequentist (exact p values) and Bayes Factors are reported for all pre-registered analyses. To test linearity assumptions, bivariate scatterplots were referred to and plots of standardised residuals against predicted values were used to check for violations of homoscedasticity. Facial muscle activity change scores (as a percentage of MVC) were log-transformed to prevent skew (Beyts et al., 2017; Jäncke & Kaufmann, 1994).

Initial analysis was carried out to confirm there was a significant difference in valence ratings between the high and low palatable food pictures for each participant. As this was not the case, we identified the highest and lowest ranking pictures for each participant.

To determine whether variables of interest in each the first 4 hypotheses can explain variation in target muscle activity at each of the key timepoint (6x500ms), we initially intended to enter the predictor variable into a regression model. However, to reduce unexplained variance and deal with the clustered nature of the data analyses was carried out using linear mixed models. In these models the between-subjects continuous predictor variable (ATD, L-EFT RTs, or Hyper-sensitivity score) was entered into the model as a continuous predictor, and participant and picture as random factors (random intercepts). ATD was measured by both the score on the ATD sub-scale and L-EFT RTs. Where linear mixed models were run, support for hypotheses was demonstrated where the full linear mixed model, which includes the variable(s) of interest as a fixed effect (in this case, a continuous predictor) are compared with the null model (only random effects included) adopting the maximum likelihood approach. For hypothesis 5, where within-subjects continuous predictors were being investigated, the log-transformed change scores of the facial muscles were centred and standardised within-participant (Brauer & Curtin, 2018).

For the analysis related to the positive control, it was expected that facial mimicry would take place (Dimberg & Thunberg, 1998; Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002). Thus, inclusion of the task allowed us to determine whether the target muscle activity was being picked up as expected. Facial mimicry is demonstrated with angry expressions evoking higher *corrugator* change scores than happy expressions, and happy expressions evoking higher *zygomaticus* change scores than angry expressions. To determine whether the hypothesis related to facial mimicry is supported, two repeated measures ANOVAs were run on change scores (for each muscle) with the within-subject factors being time (3x500ms) and expression (happy, angry). We expected to find a significant main effect of expression and this was used to determine whether the hypothesis was supported. We stated that if only one of the ANOVAs, run on change score of target muscle, was found to have evidence for a main effect of expression, then the hypothesis would not be supported. Greenhouse-Geisser conservative ~~tests~~ corrections were applied, and generalised eta squared reported for all relevant repeated measures ANOVAs.

The pre-registered hypotheses are expressed as such:

Hypothesis 1: Mean change score of facial muscle during viewing of unpleasant pictures (corrugator/levator) during time ~~points~~ bins of interest~ ATD / L-EFT RTs+ (1|Participant) + (1|Food Picture)

Hypothesis 2: Mean change score of zygomaticus during viewing of pleasant pictures during time ~~points~~ bins of interest ~ ATD / L-EFT RTs+ (1|Participant) + (1|Food Picture)

Hypothesis 3: Mean change score of facial muscle during viewing of unpleasant pictures (corrugator/levator) during time ~~points~~ bins of interest ~ GSQ (hyper-sensitivity) + (1|Participant) + (1|Food Picture)

Hypothesis 4: Mean change score of zygomaticus during viewing of pictures of pleasant pictures during time ~~points~~ bins of interest ~ GSQ (hyper-sensitivity) + (1|Participant) + (1|Food Picture)

The following hypothesis is based on the first 2 seconds of viewing; thus, the model ~~will be~~ was run with data of facial activity captured during the first 4 x 500ms time bins.

Hypothesis 5: Pleasantness ratings of viewed foods ~ CS Levator + CSCorrugator + CSZygomaticus + (1|Participant) + (1|Food Picture).

3.11. Exploratory analyses

1. Initial descriptive analysis was carried out to detail the demographic composition of the sample, including information on gender, age, mean AQ, L-EFT and ATD, GSQ score, BMI, and hunger scores. A series of correlations were also carried out to identify whether any of the individual

differences under investigation were related (ATD, L-EFT RTs, Hyper, GSQ score, BMI, hunger) (detailed in Table 4). BMI and hunger scores were entered into a model to check for any relationships with facial muscle activity.

2. As we expected to find a relationship with the ~~ATD~~ variables of interest and facial activity while viewing foods, and not while viewing facial expressions, we carried out further analyses to establish whether this is the case. We did this by carrying out a simple correlation between target muscle activity over the viewing period (focusing on *corrugator* for angry faces and *zygomaticus* for happy faces) and scores on ATD, Hyper, and L-EFT RTs.
3. Our research is very focused on individual differences, less so than group differences, with the aim of understanding whether knowledge of individuals can aid interpretation of facial activity in practice. Therefore, we made the decision to analyse the data captured on the traits of interest (ATD and GSQ hyper-sensitivity) as continuums, to preserve the individual variability in our sample (Iacobucci, Posavac, Kardes, Schneider, & Popovich, 2015). However, we have examined the difference of facial reactions to food pictures between participants scoring high and low on the traits of interest (ATD, Hyper, and social skills) based on a median split but found this offered no extra insights to the current analyses. We assessed scores on the AQ to determine whether the full score or scores on any of the other subscales show any association with facial activity during picture viewing and whether any of these results confound the interpretation of findings. We also checked for associations in scores between subscales.

   As we were also interested in investigating the time at which the activity of facial muscles most predicts hedonic liking, separate models were specified for the first 4x time bins (0-2000ms range). The first model included food picture and participant as random intercepts (picture was dropped as a random intercept where there was a convergence issue or an issue with singular fit). The second model included *corrugator*, *levator,* and *zygomaticus* change scores (as % of MVC) as continuous predictors.

   Initial investigations into the remaining AQ sub-scales were also carried out and social skills score was found to have an association with *levator* activity while viewing unpalatable pictures. As such, post-hoc analyses were carried out with social skills as a continuous predictor, with a model constructed for data from time bins 3 and 4. To further check whether key social skills score was associated with greater activity of the face in general, we investigated its correlation with maximum voluntary contractions. Post-hoc analyses used linear mixed modelling with a maximum likelihood approach to compare models. Bonferroni adjustments were carried out on all exploratory analyses where multiple comparisons were conducted.

4. Results

4.1 Preliminary Analysis

Regarding valence scores of food pictures, a paired t-test revealed participants scored the 9 pictures, categorised as unpleasant, lower (Mean= 40.88, SD=13.35) than the 9 categorised pictures as pleasant, for valence (Mean=77.5, SD=10.9, $t(89)=24.5$, $p<.001$), and for palatability (low palatability: Mean = 39.01, SD=14.37, high palatability: Mean=75.08, SD=13.36, $t(89)=20.3$, $p<.001$). However, one participant scored the unpleasant pictures only marginally lower for valence than the pleasant pictures (2.4 rating points lower). Thus, the highest and lowest ranking pictures were identified. This was done by categorising pictures with valence ratings lower than 50 as low in pleasantness and pictures with valence ratings higher than 50 as high in pleasantness for each participant (as 50 on the scale indicates neutrality). Valence rating scores were not correlated with any of the individual differences under investigation (ATD, Hyper or L-EFT RTs) (all *p*s >.066).

Correlation between MVCs and individual differences

Correlational analysis run on MVCs revealed a significant negative association between scoring on the ATD subscale of the AQ and MVC of the *levator* muscle, which remained significant even after a Bonferroni correction was applied (α=.017). There were no significant relationships between L-EFT-RTs or Hyper and MVCs of any of the muscles (Table 1). Descriptive statistics of the sample can be found in Table 2 and correlations between the individual differences under investigation and total scores for the AQ and the GSQ can be found in Table 3.

Table 1: Relationships between MVCs of each muscle and variables under investigation. MVC of the levator and ATD are shown to be significantly negatively correlated.

Muscle MVC	**ATD**	**L-EFT-RTs**	**Hyper**
Zygomaticus	ρ =.060	ρ =-.031	ρ =-.011
Levator	ρ =-.263*	ρ =.025	ρ =-.068
Corrugator	ρ =-.043	ρ =-.024	ρ =.160

*p<.05, **p<.01, **p<.001

Table 2: Descriptive statistics showing mean and SD of BMI, hunger, and main variables of interest.

	Mean	**SD**
BMI	26.1	6
Hunger	5.9	2.2
ATD	5.7	2.2
Hyper	26.5	10.2
L-EFT RTs	1775ms	189

Table 3: Relationships between individual differences of interest and full scales measuring autistic traits (AQ) and sensory sensitivity (GSQ)

	ATD	L-EFT_RTs	GSQ	BMI	Hunger	AQ
ATD		ρ =.042	ρ=.144	ρ= .070	ρ= -.056	ρ=.449***
L-EFT_RTs			*r*=.030	ρ=.019	ρ=.056	*r*=-.017
GSQ				ρ= -.089	ρ=.002	*r*=.289**
BMI					ρ=-.170	ρ=.076
Hunger						ρ=-.006

*p<.05, **p<.01, **p<.001

4.2 Pre-registered hypotheses

To maximise power, all available data from each 500ms time point were included. It was also of interest to find out how facial muscle activity changed over the 500ms time bins, therefore, we included subsequent models with time as a fixed factor (6 levels for hypotheses 1-4). The null models included participant and food picture as random intercepts. Interclass correlation *(*ICC) values for null models relating to hypotheses 1-4 are detailed in Table 4.

Table 4: ICC values in null models with Participant and Image as random intercept for models related to hypotheses 1-4

Muscle	ICC (Participant)	ICC (Picture)
Levator	0.15	0.007
Corrugator	0.18	0.03
Zygomaticus	0.18	0.004

Models of increasing complexity were constructed. For the first four hypotheses the first model included either ATD, Hyper scores, or L-EFT RTs as a continuous predictor. For hypothesis 5 change scores of all muscles were entered into the model predicting valence scores. Subsequent models also included time bin as a fixed factor. Results for the pre-registered predictor variables are reported here. Full LMM outputs, including those with time as a fixed effect, can be found in Supplementary Materials. Model comparisons were carried out using the likelihood-test ratio, and BIC values used to calculate a Bayes Factor. Bootstrapping was used to calculate 95% confidence intervals (2000 simulations).

4.2.1 Attention to detail

A preliminary investigation revealed there were no significant relationships between RTs on the L-EFT and scoring on the ATD sub-scale of the AQ, (ρ =.042, *p*=.697, BF10=0.148). To determine whether models predicting muscle activity were improved by adding different measures of tendency to attend to detail (self-report and visual task), both variables were included as continuous predictors. The LMM, with *levator* as dependent variable, did not reveal any significant associations with ATD (β = 0.08, *t* = 1.804, *p* =.071, 95 % CI [-0.09, 0.16]), or L-EFT RTs (β = 0.006, *t* = 0.128, *p* =.898, 95 % CI [-0.09, 0.09]). With *corrugator* as dependent variable ATD was also not found to be a significant predictor (β = 0.06, *t* = 1.22, *p* =.222, 95 % CI [-0.04, 0.151]) or L-EFT RTs (β = 0.07 *t* = 1.55, *p* =.121, 95 % CI [-0.018, 0.17]). This was also the same with *zygomaticus* as the dependent variable, ATD (β = -0.03, *t* = -0.542, *p* =.588 95 % CI [-0.12, 0.07]); L-EFT RTs (β = -0.03, *t* =-0.665, *p* =.506, 95 % CI [-0.12, 0.06]). On comparing the models with the pre-registered predictors (ATD or L-EFT RTs only as fixed factors) and null models the Bayes Factors offered evidence in favour of the null models (see Table 5 for results and full LMM outputs can be found in Supplementary Tables 3-5).

Table 5: Key likelihood test ratio outputs comparing the model including ATD, L-EFT RTs, or Hyper as a predictor for muscle change scores (as a % of MVC) with the random factor only model.

Muscle	**Predictor variable**	χ^2	***p***	**BF10 –** shows evidence in favour of null hypothesis
Zygomaticus	ATD	0.29	0.588	0.02
	L-EFT RTs	0.44	0.507	0.02
	Hyper	1.35	0.246	0.03
Levator	ATD	3.19	.074	0.10
	L-EFT RTs	0.016	.898	0.02
	Hyper	0.58	.445	0.03
Corrugator	ATD	.148	0.22	0.04
	L-EFT RTs	2.39	0.12	0.06
	Hyper	0.949	0.33	0.03

4.2.2. Sensory Sensitivity

Initial models included the participant as random intercept. Subsequent models included scoring on the Hyper sub-scale of the GSQ as a continuous predictor. Including Hyper score did not improve the models for any muscle (see Table 5). The LMMs with *levator* as dependent variable (β= 0.03, *t* = 0.77, *p* =.44, 95 % CI [-0.06, 0.09]), *corrugator* as dependent variable (β= 0.05, *t* = 0.98, *p* =.329, 95 % CI [-0.05, 0.15]), and *zygomaticus* as dependent variable, did not reveal any significant effects associations with of Hyper score (β= 0.05, *t* = 1.163, *p* =.245, 95 % CI [-0.04, 0.15]). There were also no significant interactions between Hyper score and time, for any muscle (full LMM outputs can be found in Supplementary Tables 3-5).

4.2.3. Muscle activity as a predictor of self-reported liking

A model investigating data from all time bins (1-4) was constructed with all 3 muscles as continuous predictors. Inclusion of these continuous predictors were was shown to improve model likelihood, $\chi^2(3)$ = 53.09, *p*<.001, (BF10=1.32^{12} 7.59e5). The LMM revealed significant effects of associations with *corrugator* (β =--0.04, *t* = -4.91 *p* <.001, 95 % CI [-0.06, -0.03]), *zygomaticus* (bβ =0.05, *t* = -5.29, *p* <.001, 95 % CI [0.03, 0.07]) but *levator* did not add to the model (β=-0.02, *t* =-1.65, *p* =.099 95 % CI [-0.03, 0.003]) (full LMM output can be found in Supplementary Materials (Table 6)).

4.2.4. Positive control

A repeated measures ANOVA with the within-subjects factors expression and time bin, and *corrugator* as dependent variable, revealed a significant main effect of expression (*F*(1,85)=7.748, *p*=.007, η^2_G =0.03, BF10=973) and a significant interaction between expression and time bin (*F*(1.79, 152)=4.995, *p*=.010, η^2_G =0.007). No main effect of time was found (*p*=.116). A repeated measures ANOVA with *zygomaticus* activity as dependent variable, and the within-subjects factors expression and time bin, revealed a significant main effect of expression (*F*(1,85)=6.05, *p*=.016, η^2_G =0.02, BF10=185.65), a main effect of time bin (*F*(1.5, 126)=13.13, *p*<.001, η^2_G =0.026), and a significant interaction between expression and time bin (*F*(1.71, 146)=11.27, *p*<.001, η^2_G 0.01). However, visual inspections suggested that the data did not clearly meet normality assumptions and to investigate the main effects further, a series of Wilcoxon-signed rank tests were run, these revealed there was a significant difference in *corrugator* activity at time bin 2 (*p*=.013) and time bin 3 (*p*=.019) during the viewing of happy and angry pictures. There was also a significant difference in *zygomaticus* activity at time bin 2 (*p*=.013) and time bin 3 (*p*=.002) during the viewing of happy and angry pictures. Results were in the expected direction.

Correlational analyses revealed no significant relationships between ATD, Hyper, L-EFT RTs, and facial activity of the zygomaticus or corrugator during the viewing of happy or angry facial expressions at any of these time bins (all *ps*>.063 *p*s>.015, α=.004).

4.3 Post-hoc Analyses

4.3.1. Relationship between pleasant ratings and facial activity ~~across~~ viewing period at each time bin.

There were no significant associations with ratings and facial muscle activity at time bin 1 (0-501ms) (all *p*s > .255). At time bin 2 the LMM revealed ratings had significant associations with *corrugator* (β = -0.04, *t* = -2.24, *p* =.025 95 % CI [-0.08, -0.005]) and *zygomaticus* (β = 0.04, *t* =2.04, *p* =.041 95 % CI [0, 0.08]), but not *levator* (*p*=.625) Inclusion of muscle change scores as fixed factors were shown to improve the model likelihood, $\chi^2(3)9.23$, *p*=.026. At time bin 3 ratings were shown to have significant associations with *corrugator* (β = -0.05, *t* = -2.75, *p*=.006, 95 % CI [-0.08, -0.01]), *zygomaticus* (β=0.06, *t* = 3.28, *p* = .001, 95 % CI [0.02, 0.10]) but not *levator* (*p* = .073) Model comparisons revealed inclusion of the muscle change scores improved model likelihood $\chi^2(3)$ 20.65, *p*<.001. At time bin 4 ratings were shown to have significant associations with *corrugator* (β= -0.07, *t* = -3.93, *p* <.001, 95 % CI [-0.10, -0.03), and *zygomaticus* (β=0.07, *t* = 4.00, *p* =<.001, 95 % CI [0.04, 0.106]), but not *levator* (*p*= .068). Model comparisons revealed inclusion of the muscle change scores improved the likelihood of the model, $\chi^2(3)$ 32.85, *p*<.001.

4.3.2. Social Skills

Social skills were shown to improve the model likelihood for *levator* activity when investigating responses to unpleasant pictures and including datapoints of all time bins $\chi^2(1)$ 5.49, *p*=.019. On further inspection, the association was apparent between 1001-2000ms of viewing (time bins 3 and 4). Thus, social skills score (as a continuous predictor) was investigated as a predictor for *levator* activity during viewing of less palatable food pictures at these times (one model for data from time bins 3 and 4). Social skills score was found to be a significant predictor of *levator* activity (β = 0.20, *t* = 3.38 *p*<.001, 95 % CI [0.08, 0.31]), and model comparisons revealed its inclusion improved model likelihood ($\chi^2(1) = 10.89$, *p*<.001) (BF10= 7.82).

To check whether this was driven by increased *levator* response in general when viewing food pictures (and not a response to the unpleasant pictures), we ran the analysis with the data from pleasant pictures (pictures rated >50 by each participant). The results revealed a similar trend, but the result was no longer significant, *p*=.195. Correlational analyses were run to check the relationship between social skills score and maximum voluntary contractions of the facial muscles. Social skills score was shown to have a negative trend with *levator* activity, but this was not significant (ρ=-0.220, *p*=.037 before Bonferroni corrections applied).

4.3.3. BMI and Hunger

BMI and Hunger did not have any significant correlations with any of the individual differences under investigation (all ρ*s*<.1 all *p*s>.35). BMI and Hunger were added separately to models predicting activity of each muscle during picture viewing. Neither were found to be significant predictors of facial activity (all *p*s>.044, α=.017).

5. Discussion

In this study, we set out to investigate whether ~~traits~~ individual differences related to sensory sensitivity and tendency to attend to detail, which have shown to be linked with eating and food-related behaviour (e.g., Christensen, Bentz, Clemmensen, Strandberg-Larsen, & Olsen, 2018; Coombs, Brosnan, Bryant-Waugh, & Skevington, 2011), would be associated with affective response when viewing food pictures. Specifically, we aimed to examine hyper-sensitivity and tendency to attend to detail in relation to rapid facial activity evoked by pictures of foods varying in valence. We expected to find that ~~such~~ food evoked facial activity would be associated with these traits and abilities. The secondary aim of the study was to investigate the association between facial muscle activity and self-reported pleasantness ratings of the food pictures.

The findings did not offer any evidence for a relationship between attention to detail or hyper sensory sensitivity and facial activity in response to food cues. The reasons for our interest in sensory sensitivity and tendency to attend to local detail come from evidence highlighting their link with eating behaviour in samples of the general population at different age points (e.g. Farrow & Coulthard, 2012; Zickgraf & Elkins, 2018; Zickgraf, Richard, Zucker, & Wallace, 2020), and in clinical cohorts (e.g. Cermak, Curtin, & Bandini, 2010; Chistol et al., 2018; Roberts et al., 2011). Furthermore, key researchers within the industry have highlighted the importance of considering individual differences in perception to better understand decision making regarding food (Jaeger et al., 2017).

To date, much of this work has focused on variations in taste. Thus, there appears a need to expand upon the traits investigated while considering the broad array of methods adopted to capture food-related response, including facial activity. However, with the protocol adopted, we found no clear evidence to suggest that variations in sensory sensitivity or attention to detail influenced this implicit measure of affect. It may be that our choice of food pictures did not offer enough variation as they did not include stimuli at the extreme negative end of the valence scale. For instance, as the traits under investigation have been shown in the literature to have associations with picky eating, it may be that any differences may only be present when viewing specific foods. Thus, future research may seek to address this by probing such associations using more extreme food pictures such as those included ~~used~~ in a recent study investigating facial activity in response to food pictures in varying social contexts (Nath et al., 2019; Nath et al., 2020).

A recent study found differences in facial activity in response to social reward (touch) based on autistic traits, with those with lower autistic traits eliciting greater *zygomaticus* activity (positive response) than those with high autistic traits (Haggarty, 2018). Furthermore, there is growing evidence supporting deficits in social reward processing related to autism. However, investigations into autistic traits or sensory sensitivity and brain activations elicited by foods (non-social reward) are limited, and, where they do exist, they often investigate scoring on a combination of all autistic traits. For instance, a study investigating brain activations brought about by food cues in children with autism, found enhanced responses in areas associated with interoceptive awareness and affect (Cascio et al., 2012). However, although autism has been found, in the wider literature, to have an association with altered primary responses, and we looked at traits associated with autism in this study, altered responses found in clinical samples may be driven by many non-related concomitant variations absent in non-clinical groups. When considering non-clinical groups, evidence has shown a variation in rapid brain activity associated with motivated attention towards social reward but not food reward, based on autistic traits (Cox et al., 2015).

We did, however, find some indication of a positive relationship between scoring on the ~~autistic trait~~ sub-scale social skills (as measured by the AQ) and negative affective response (*levator* activity) while viewing pictures rated lower in valence (occurring between 1001-2000ms). Further investigations showed that social skills score was not associated with more activity of the *levator* in general, with maximum voluntary contractions having a negative trend with this trait (but not significantly so following a Bonferroni correction). Although this was not one of our original predictions it is interesting, as previous research has found links between scoring on the social skills sub-scale and eating behaviour. For instance, higher levels of dieting have been found to be linked with social skills score (Coombs et al., 2011) and further research links scoring on the social skills sub-scale with the Eating Attitudes Test (bulimia scale) (Mansour et al., 2016). More generally, autistic traits have been linked with altered processing of social reward (e.g.,Vukusic, Ciorciari, & Crewther, 2017) and variations in facial responses to social stimuli - emotional faces (spontaneous mimicry) (Neufeld, Ioannou, Korb, Schilbach, & Chakrabarti, 2016); it may be that such variances also extend to primary reward (food) when considering the social skills sub-scale specifically.

We did not, however, capture any measures of disgust sensitivity. Thus, it may be that this is a confounding factor in this outcome. Otherwise, the trend may be some indication of altered affective responses to less palatable food pictures; there were no significant associations between valence scores of the pictures and any of the investigated traits. However, given that this is an exploratory finding, future work is required to establish whether these results can be replicated.

We also found patterns of facial activity in line with previous findings in other aspects of the study. For instance, the positive control used, which set out to test facial mimicry, supported previous findings of greater *corrugator* activity in response to angry pictures over happy pictures, and greater *zygomaticus* activity in response to happy pictures over angry pictures. These results strengthen the validity of the findings related to our pre-registered hypotheses.

Our results were also in line with the findings of recent studies in terms of the relationship between facial activity and food evaluation (e.g., Nath et al., 2019; Nath et al., 2020 found subjective liking of pictures could predict facial muscle activity during picture viewing); we found an association between facial muscle activity (*corrugator* and *zygomaticus*) and ratings of valence of the viewed foods when investigating data ~~across~~ for all time bins (500ms bins over first 2000ms). Furthermore, the nature of these associations was as expected (i.e., a negative association with *corrugator* and a positive association with *zygomaticus*), although the *levator* did not add to the models, the relationship was in the expected direction. Overall, our results do go some way towards supporting the use of measurements of facial activity to better understand food-related behaviour. However, the results also support the need for other tools to be used along with this method; ideally these would be used in conjunction with measurements from a variety of methods, capturing different dimensions of emotion-related response.

5.1. Limitations

The current study may have benefitted from using a set of food pictures containing items that had a larger variation in terms of valence scores. Our decision was driven by a desire to investigate foods that are more likely to be encountered in daily situations. However, the experimental protocol may have been more likely to elicit variations if we had chosen more extreme food pictures. Furthermore, as the stimuli were restricted to pictures, it may be that there was limited reactivity to the food cues and the experiment may have been enhanced by including a tasting paradigm or by having participants view real foods.

Moreover, the fact that we adopted ~~the~~ a traditional lab-based study means caution should be applied when interpreting results to the wider context; findings may not extend to settings with greater ecological validity. With recent research highlighting the importance of social context on facial expressions when viewing food cues (Nath et al., 2019; Nath et al., 2020), future research may explore the relationship between individual differences in sensory sensitivity and autistic traits and the influence of social presence on affective response to foods. Additionally, the omission of measures of disgust sensitivity leaves a gap in the interpretation of the results; as such, we would include this in any future studies. Finally, the power of the study may have been enhanced by collecting data on key individual differences first and electing only those participants with high and low scores to take part in the facial EMG element of the study.

6. Conclusion

This study adds to a growing body of literature investigating facial electromyography as a method for capturing affective response related to food. Our results suggest there may be some utility in using measures of facial activity for understanding decisions regarding food. However, our results also stress the need for use of a range of methods when trying to capture such emotion-related responses, to ensure different dimensions of affect are being captured; facial electromyography, when used alone, is unlikely to give great insight into decision around food (when general foods are used and not those at extreme ends of valence scales), but it may be beneficial when used alongside other tools, and where the limitations of the method are considered during the interpretation of results. Furthermore, this study adds to the literature investigating individual differences in response to foods and highlights the increasing need to better understand variations in the general population that ~~can~~ may affect food-related behaviour; further research is currently being carried out in our lab to further understand any associations between social skills and food-related responses.

7. Timeline

The first participant was tested on 1/11/19 and the last on 3/3/20. The proposal was registered on the Open Science Framework on receipt of the in principle acceptance letter and prior to starting any data collection. This can be found at https://osf.io/9e8gr.

8. Competing Interests

No commercial or financial relationships exist that could be regarded as a conflict of interest.

9. Funding Acknowledgements

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10. Changes to Protocol

On 05/12/2019 we informed the editorial board of the following points:

> *1) Our initial report suggested we will have electrodes attached to subjects at all points during the experiment, although data would only be recorded and analysed from the picture viewing task. We have found that in doing this there is more likelihood of electrodes being moved during the testing session. This was not an issue in our pilot as there were fewer tasks, taking less time. To ensure we were getting the best EMG recordings we placed electrodes only during the picture viewing task (all included participants were treated in this manner).*
>
> *2) We initially suggested that the order of viewing blocks would be randomised; however, these were counterbalanced. The facial expression block remained as the final block as per our Stage 1 manuscript.*

References

Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., . . . Ezzati, M. (2017). *Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults* doi:https://doi.org/10.1016/S0140-6736(17)32129-3

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2013). Visual search targeting either local or global perceptual processes differs as a function of autistic-like traits in the typically developing population. *Journal of Autism and Developmental Disorders, 43*(6), 1272-1286. doi:10.1007/s10803-012-1669-7

Aykan, S., Gürses, E., Tokgöz-Yılmaz, S., & Kalaycıoğlu, C. (2020). Auditory processing differences correlate with autistic traits in males. *Frontiers in Human Neuroscience, 14*

Bajec, M. R., & Pickering, G. J. (2008). Thermal taste, PROP responsiveness, and perception of oral sensations. *Physiology & Behavior, 95*(4), 581-590. doi:10.1016/j.physbeh.2008.08.009

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5-17. doi:10.1023/A:1005653411471

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. journal of statistical software 67 (1): 1–48.

Beyts, C., Chaya, C., Dehrmann, F., James, S., Smart, K., & Hort, J. (2017). A comparison of self-reported emotional and implicit responses to aromas in beer. *Food Quality and Preference, 59*, 68-80.

Blechert, J., Lender, A., Polk, S., Busch, N. A., & Ohla, K. (2019). Food-pics_extended—an image database for experimental research on eating and appetite: Additional images, normative ratings and an updated review. *Frontiers in Psychology, 10* doi:10.3389/fpsyg.2019.00307

Brauer, M., & Curtin, J. J. (2018). Linear mixed-effects models and the analysis of nonindependent data: A unified framework to analyze categorical and continuous independent variables that vary within-subjects and/or within-items. *Psychological Methods, 23*(3), 389.

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology, 50*(2), 260.

Cannon, P. R., Li, B., & Grigor, J. M. (2017). Predicting subjective liking of bitter and sweet liquid solutions using facial electromyography during emptying, swirling, and while thinking about the taste.

Carrera-Levillain, P., & Fernandez-Dols, J. (1994). Neutral faces in context: Their emotional meaning and their function. *Journal of Nonverbal Behavior, 18*(4), 281-299. doi:10.1007/BF02172290

Cascio, C. J., Foss-Feig, J. H., Heacock, J. L., Newsom, C. R., Cowan, R. L., Benningfield, M. M., . . . Cao, A. (2012). Response of neural reward regions to food cues in autism spectrum disorders. *Journal of Neurodevelopmental Disorders, 4*(1), 9.

Cermak, S. A., Curtin, C., & Bandini, L. G. (2010). Food selectivity and sensory sensitivity in children with autism spectrum disorders. *Journal of the American Dietetic Association, 110*(2), 238-246.

Chistol, L. T., Bandini, L. G., Must, A., Phillips, S., Cermak, S. A., & Curtin, C. (2018). Sensory sensitivity and food selectivity in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 48*(2), 583-591.

Christensen, S. S., Bentz, M., Clemmensen, L., Strandberg-Larsen, K., & Olsen, E. M. (2018). Disordered eating behaviours and autistic traits—Are there any associations in nonclinical populations? A systematic review. *European Eating Disorders Review; Eur Eat Disord Rev, 27*(1), 8-23. doi:10.1002/erv.2627

Clark, A. I., Hughes, P. S., Grube, M., & Stewart, M. E. (2013). Autistic traits and sensitivity to interference with flavour identification. *Autism Research, 6*(5), 332-336. doi:10.1002/aur.1293

Coombs, E., Brosnan, M., Bryant-Waugh, R., & Skevington, S. M. (2011). An investigation into the relationship between eating disorder psychopathology and autistic symptomatology in a non-clinical sample. *British Journal of Clinical Psychology, 50*(3), 326-338.

Cox, A., Kohls, G., Naples, A. J., Mukerji, C. E., Coffman, M. C., Rutherford, H. J., . . . McPartland, J. C. (2015). Diminished social reward anticipation in the broad autism phenotype as revealed by event-related brain potentials. *Social Cognitive and Affective Neuroscience, 10*(10), 1357-1364.

Cruz, A., & Green, B. G. (2000). Thermal stimulation of taste. *Nature, 403*(6772), 889. doi:10.1038/35002581

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

Darwin, C. (1872.). *Expression of emotion in man and animal*. Oxford: Oxford University Press.

de Wijk, R. A., He, W., Mensink, M. G., Verhoeven, R. H., & de Graaf, C. (2014). ANS responses and facial expressions differentiate between the taste of commercial breakfast drinks. *PloS One, 9*(4), e93823. doi:10.1371/journal.pone.0093823 de Wijk, R. A., Kooijman, V., Verhoeven, R. H., Holthuysen, N. T., & de Graaf, C. (2012). Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods. *Food Quality and Preference, 26*(2), 196-203.

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

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

de-Wit, L., Huygelier, H., Van der Hallen, R., Chamberlain, R., & Wagemans, J. (2017). Developing the leuven embedded figures test (L-EFT): Testing the stimulus features that influence embedding. *PeerJ, 2017*(1) doi:10.7717/peerj.2862

Dienes, Z. (2014). Using bayes to get the most out of non-significant results. *Frontiers in Psychology, 5*, 781.

Dimberg, U., & Thunberg, M. (1998). Rapid facial reactions to emotional facial expressions. *Scandinavian Journal of Psychology, 39*(1), 39-45. doi:10.1111/1467-9450.00054

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11*(1), 86-89.

Dimberg, U., Thunberg, M., & Grunedal, S. (2002). Facial reactions to emotional stimuli: Automatically controlled emotional responses. *Cognition & Emotion, 16*(4), 449-471. doi:10.1080/02699930143000356

Dinnella, C., Monteleone, E., Piochi, M., Spinelli, S., Prescott, J., Pierguidi, L., . . . Predieri, S. (2018). Individual variation in PROP status, fungiform papillae density, and responsiveness to taste stimuli in a large population sample. *Chemical Senses, 43*(9), 697-710.

Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods, 42*(1), 351-362. doi:10.3758/BRM.42.1.351

Egolf, A., Siegrist, M., & Hartmann, C. (2018). *How people's food disgust sensitivity shapes their eating and food behaviour* doi:https://doi.org/10.1016/j.appet.2018.04.014

Farrow, C. V., & Coulthard, H. (2012). Relationships between sensory sensitivity, anxiety and selective eating in children. *Appetite, 58*(3), 842-846.

Fernández-Dols, J., & Ruiz-Belda, M. (1995). Are smiles a sign of happiness? gold medal winners at the olympic games. *Journal of Personality and Social Psychology, 69*(6), 1113.

Fonville, L., Lao-Kaim, N. P., Giampietro, V., Van den Eynde, F., Davies, H., Lounes, N., . . . Williams, S. C. (2013). Evaluation of enhanced attention to local detail in anorexia nervosa using the embedded figures test; an FMRI study. *PLoS One, 8*(5), e63964. doi:10.1371/journal.pone.0063964

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23*(5), 567-589.

Garcia-Burgos, D., & Zamora, M. (2013). Facial affective reactions to bitter-tasting foods and body mass index in adults. *Appetite, 71*, 178-186. doi:10.1016/j.appet.2013.08.013

Green, B. G., & George, P. (2004). 'Thermal taste'predicts higher responsiveness to chemical taste and flavor. *Chemical Senses, 29*(7), 617-628. doi:10.1093/chemse/bjh065

Grinter, E. J., Maybery, M. T., Van Beek, P. L., Pellicano, E., Badcock, J. C., & Badcock, D. R. (2009). Global visual processing and self-rated autistic-like traits. *Journal of Autism and Developmental Disorders, 39*(9), 1278-1290. doi:10.1007/s10803-009-0740-5

Grinter, E. J., Van Beek, P.,L., Maybery, M. T., & Badcock, D. R. (2009). *Brief report: Visuospatial analysis and self-rated autistic-like traits*. Norwell, MA : doi:10.1007/s10803-008-0658-3

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

Haggarty, C. J. (2018). *Individual Differences in Behavioural and Physiological Responses to Affective Touch,*

Harris, A. A., Romer, A. L., Hanna, E. K., Keeling, L. A., LaBar, K. S., Sinnott-Armstrong, W., . . . Zucker, N. L. (2019). The central role of disgust in disorders of food avoidance. *International Journal of Eating Disorders, 52*(5), 543-553.

He, W., Boesveldt, S., de Graaf, C., & de Wijk, R. A. (2014). Dynamics of autonomic nervous system responses and facial expressions to odors. *Frontiers in Psychology, 5*, 110.

He, W., Boesveldt, S., de Graaf, C., & de Wijk, R. A. (2016). The relation between continuous and discrete emotional responses to food odors with facial expressions and non-verbal reports. *Food Quality and Preference, 48*, 130-137. doi:10.1016/j.foodqual.2015.09.003

He, W., Boesveldt, S., Delplanque, S., de Graaf, C., & de Wijk, R. A. (2017). *Sensory-specific satiety: Added insights from autonomic nervous system responses and facial expressions* doi:https://doi.org/10.1016/j.physbeh.2016.12.012

Hebert, K. R. (2018). Sensory processing styles and eating behaviors in healthy adults. *British Journal of Occupational Therapy, 81*(3), 162-170. doi:10.1177/0308022617743708

Hermans, E. J., van Wingen, G., Bos, P. A., Putman, P., & van Honk, J. (2009). Reduced spontaneous facial mimicry in women with autistic traits. *Biological Psychology, 80*(3), 348-353.

Hess, U., Kappas, A., McHugo, G. J., Kleck, R. E., & Lanzetta, J. T. (1989). An analysis of the encoding and decoding of spontaneous and posed smiles: The use of facial electromyography. *Journal of Nonverbal Behavior, 13*(2), 121-137.

Hoefling, A., Likowski, K. U., Deutsch, R., Häfner, M., Seibt, B., Mühlberger, A., . . . Strack, F. (2009). When hunger finds no fault with moldy corn: Food deprivation reduces food-related disgust. *Emotion, 9*(1), 50.

Hu, S., Luo, Y., & Hui, L. (2000). Preliminary study of associations between objective parameters of facial electromyography and subjective estimates of taste palatability. *Perceptual and Motor Skills, 91*(3), 741-747.

Hu, S., Player, K. A., Mcchesney, K. A., Dalistan, M. D., Tyner, C. A., & Scozzafava, J. E. (1999). Facial EMG as an indicator of palatability in humans. *Physiology & Behavior, 68*(1), 31-35.

Huygelier, H., Van der Hallen, R., Wagemans, J., de-Wit, L., & Chamberlain, R. (2018). The leuven embedded figures test (L-EFT): Measuring perception, intelligence or executive function? *PeerJ, 6*, e4524.

Iacobucci, D., Posavac, S. S., Kardes, F. R., Schneider, M. J., & Popovich, D. L. (2015). Toward a more nuanced understanding of the statistical properties of a median split. *Journal of Consumer Psychology, 25*(4), 652-665.

Izard, C. E. (1994). Innate and universal facial expressions: Evidence from developmental and cross-cultural research. *Psychological Bulletin, 115*(2), 288-299. doi:10.1037/0033-2909.115.2.288

Jaeger, S., Hort, J., Porcherot, C., Ares, G., Pecore, S., & MacFie, H. (2017). Future directions in sensory and consumer science: Four perspectives and audience voting. *Food Quality and Preference, 56*, 301-309.

Jäncke, L., & Kaufmann, N. (1994). Facial EMG responses to odors in solitude and with an audience. *Chemical Senses, 19*(2), 99-111.

Johnson, S. L., Davies, P. L., Boles, R. E., Gavin, W. J., & Bellows, L. L. (2015). Young children's food neophobia characteristics and sensory behaviors are related to their food intake. *The Journal of Nutrition, 145*(11), 2610-2616.

Juodeikiene, G., Basinskiene, L., Vidmantiene, D., Klupsaite, D., & Bartkiene, E. (2014). The use of face reading technology to predict consumer acceptance of confectionery products. Paper presented at the *9th Baltic Conference on Food Science and Technology "Food for Consumer Well-being",* 276.

Kaneko, D., Toet, A., Brouwer, A., Kallen, V., & Van Erp, J. B. (2018). Methods for evaluating emotions evoked by food experiences: A literature review. *Frontiers in Psychology, 9*, 911. doi:10.3389/fpsyg.2018.00911

King, S. C., & Meiselman, H. L. (2010). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference, 21*(2), 168-177.

Lang, K., Lopez, C., Stahl, D., Tchanturia, K., & Treasure, J. (2014). Central coherence in eating disorders: An updated systematic review and meta-analysis. *The World Journal of Biological Psychiatry, 15*(8), 586-598.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology, 40*(5), 776-785. doi:10.1111/1469-8986.00078

Le Goff, G., & Delarue, J. (2017). Non-verbal evaluation of acceptance of insect-based products using a simple and holistic analysis of facial expressions. *Food Quality and Preference, 56*, 285-293. doi:10.1016/j.foodqual.2016.01.008

Madsen, S. K., Bohon, C., & Feusner, J. D. (2013). Visual processing in anorexia nervosa and body dysmorphic disorder: Similarities, differences, and future research directions. *Journal of Psychiatric Research, 47*(10), 1483-1491. doi:10.1016/j.jpsychires.2013.06.003

Mansour, S., Rozenblat, V., Fuller-Tyszkiewicz, M., Paganini, C., Treasure, J., & Krug, I. (2016). Emotions mediate the relationship between autistic traits and disordered eating: A new autistic-emotional model for eating pathology. *Psychiatry Research, 245*, 119-126.

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. *Cognition and Emotion, 23*(2), 209-237.

Naish, K. R., & Harris, G. (2012). Food intake is influenced by sensory sensitivity. *PloS One, 7*(8), e43622. doi:10.1371/journal.pone.0043622

Nath, E. C., Cannon, P. R., & Philipp, M. C. (2019). *An unfamiliar social presence reduces facial disgust responses to food stimuli* doi:https://doi.org/10.1016/j.foodres.2019.108662

Nath, E. C., Cannon, P. R., & Philipp, M. C. (2020). *Co-acting strangers but not friends influence subjective liking and facial affective responses to food stimuli* doi:https://doi.org/10.1016/j.foodqual.2019.103865

Nederkoorn, C., Jansen, A., & Havermans, R. C. (2015). Feel your food. the influence of tactile sensitivity on picky eating in children. *Appetite, 84*, 7-10.

Neufeld, J., Ioannou, C., Korb, S., Schilbach, L., & Chakrabarti, B. (2016). Spontaneous facial mimicry is modulated by joint attention and autistic traits. *Autism Research, 9*(7), 781-789.

Roberts, M. E., Barthel, F. M., Lopez, C., Tchanturia, K., & Treasure, J. L. (2011). Development and validation of the detail and flexibility questionnaire (DFlex) in eating disorders. *Eating Behaviors, 12*(3), 168-174.

Roberts, M. E., Tchanturia, K., & Treasure, J. L. (2013). Is attention to detail a similarly strong candidate endophenotype for anorexia nervosa and bulimia nervosa? *The World Journal of Biological Psychiatry, 14*(6), 452-463. doi:10.3109/15622975.2011.639804

Robertson, A. E., & Simmons, D. R. (2013). The relationship between sensory sensitivity and autistic traits in the general population. *Journal of Autism and Developmental Disorders, 43*(4), 775-784. doi:10.1007/s10803-012-1608-7

Ruiz-Belda, M., Fernández-Dols, J., Carrera, P., & Barchard, K. (2003). *Spontaneous facial expressions of happy bowlers and soccer fans*. Hove, East Sussex : doi:10.1080/02699930302288

Rusconi, E., McCrory, E., & Viding, E. (2012). Self-rated attention to detail predicts threat detection performance in security X-ray images. *Security Journal, 25*(4), 356-371. doi:10.1057/sj.2011.27

Russell-Smith, S. N., Maybery, M. T., Bayliss, D. M., & Sng, A. A. (2012). Support for a link between the local processing bias and social deficits in autism: An investigation of embedded figures test performance in non-clinical individuals. *Journal of Autism and Developmental Disorders, 42*(11), 2420-2430.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry, 34*(8), 1351-1364. doi:10.1111/j.1469-7610.1993.tb02095.x

Siegel, E. H., Sands, M. K., Van den Noortgate, W., Condon, P., Chang, Y., Dy, J., . . . Barrett, L. F. (2018). Emotion fingerprints or emotion populations? A meta-analytic investigation of autonomic features of emotion categories. *Psychological Bulletin, 144*(4), 343. doi:10.1037/bul0000128

Smink, F. R., van Hoeken, D., & Hoek, H. W. (2013). Epidemiology, course, and outcome of eating disorders. *Current Opinion in Psychiatry, 26*(6), 543-548. doi:10.1097/YCO.0b013e328365a24f

Soussignan, R., Schaal, B., Rigaud, D., Royet, J., & Jiang, T. (2011). Hedonic reactivity to visual and olfactory cues: Rapid facial electromyographic reactions are altered in anorexia nervosa. *Biological Psychology, 86*(3), 265-272. doi:10.1016/j.biopsycho.2010.12.007

Tavassoli, T., & Baron-Cohen, S. (2012). Taste identification in adults with autism spectrum conditions. *Journal of Autism and Developmental Disorders, 42*(7), 1419-1424. doi:10.1007/s10803-011-1377-8

Tepper, B. J., & Nurse, R. J. (1997). Fat perception is related to PROP taster status. *Physiology & Behavior, 61*(6), 949-954. doi:10.1016/S0031-9384(96)00608-7

Tonacci, A., Calderoni, S., Billeci, L., Maestro, S., Fantozzi, P., Ciuccoli, F., . . . Muratori, F. (2019). *Autistic traits impact on olfactory processing in adolescent girls with anorexia nervosa restricting type* doi:https://doi.org/10.1016/j.psychres.2019.02.026

Van Boxtel, A. (2010). Facial EMG as a tool for inferring affective states. Paper presented at the *Proceedings of Measuring Behavior,* 104-108.

Van der Hallen, R., Chamberlain, R., Huygelier, H., de-Wit, L., & Wagemans, J. (2015). The leuven embedded figures test (L-EFT): Re-embedding the EFT into vision sciences. Paper presented at the *Annual Meeting of the Vision Science Society (VSS), Date: 2015/05/15-2015/05/20, Location: St. Pete Beach, Florida, USA,*

van Peer, M., Coutinho, E., Grandjean, D., & Scherer, K. R. (2017). *Emotion-antecedent appraisal checks: EEG and EMG datasets for novelty and pleasantness PloS one. zenodo. http://Doi.org/10.5281/zenodo.197404*. Unpublished manuscript. Retrieved 16/04, Retrieved from Zenodo. http://doi.org/10.5281/zenodo.197404

Vrana, S. R. (1993). The psychophysiology of disgust: Differentiating negative emotional contexts with facial EMG. *Psychophysiology, 30*(3), 279-286.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585-594. doi:10.1016/j.tics.2005.10.011

Vukusic, S., Ciorciari, J., & Crewther, D. P. (2017). Electrophysiological correlates of subliminal perception of facial expressions in individuals with autistic traits: A backward masking study. *Frontiers in Human Neuroscience, 11*, 256.

Walker, S. C., Williams, K., & Moore, D. J. (2020). Superior identification of component odors in a mixture is linked to autistic traits in children and adults. *Chemical Senses, 45*(5), 391-399.

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

Witkin, H., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). A manual for the embedded figure test.

World Health Organization. (2017). Noncommunicable diseases: Progress monitor 2017.

Zickgraf, H. F., & Elkins, A. (2018). Sensory sensitivity mediates the relationship between anxiety and picky eating in children/adolescents ages 8–17, and in college undergraduates: A replication and age-upward extension. *Appetite, 128*, 333-339.

Zickgraf, H. F., Richard, E., Zucker, N. L., & Wallace, G. L. (2020). Rigidity and sensory sensitivity: Independent contributions to selective eating in children, adolescents, and young adults. *Journal of Clinical Child & Adolescent Psychology,* , 1-13.

Supplementary Material

Table 1: Chosen images in each of the picture blocks (reference numbers/file name taken from respective database). All images are publicly available and can be accessed from the original source in accordance with the relevant licensing agreement.

Pictures– high palatability/valence taken from food-pic extended (Blechert et al., 2019)	**Pictures – low palatability/valence taken from food-pic extended (Blechert et al., 2019)**	**Facial Expressions – taken from publicly available FACES database (Ebner et al., 2010)**
317 -potato wedges	497 – meat pie	004
715 -panini	147- marshmallow	066
234 -strawberries	336 – liquorice wheels	079
115 - sundae	191- grilled sausage	079
685 -pizza	502 – mixed veg	079
690 -pasta with tomato sauce	512 – crispbread	116
662 -chocolates	322 – knuckle of pork	140
823 -slices of cheese	190 – meatballs	168
727 -cake with berries and cream	538 – liver sausage	

Table 2: List of all selected pictures with image characteristic and normative ratings taken from Blechert et al. (2019). Note that the rating scale for palatability, which was defined as how delicious the participant found the food in the image (regardless of whether they wanted) and ranged from 0 (not at all) to 100 (extremely)

Parameter	**High palatability/valence foods (mean)**	**Low palatability/valence foods (mean)**
Contrast (SD)	63	49
Intensity	105	116
Complexity	0.37	0.30
Spatial frequencies	15.6	16.1
Palatability	75/100	30/100
Valence	67/100	34/100
Kcal total (k/cal)	341	411

Table 3: LMM outputs for all pre-registered continuous predictors and time as a fixed effect, with levator as dependent variable

	Dependent variable:							
	zLevator Change Score (log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
zHyper		0.034				0.020		
zATD			0.078*				-0.008	
zLEFTRTs				0.006	0.005			0.045
Timebin2					0.104*	0.103*	0.102*	0.104*
Timebin3					0.244***	0.242***	0.241***	0.236***
Timebin4					0.224***	0.222***	0.222***	0.220***
Timebin5					0.291***	0.291***	0.289***	0.288***
Timebin6					0.273***	0.272***	0.270***	0.268***
zHyper:Timebin2						0.016		
zHyper:Timebin3						0.050		
zHyper:Timebin4						0.033		
zHyper:Timebin5						-0.009		
zHyper:Timebin6						0.00003		
zATD:Timebin2							0.056	
zATD:Timebin3							0.153***	
zATD:Timebin4							0.132**	
zATD:Timebin5							0.098*	
zATD:Timebin6							0.084	
zLEFTRT:Timebin2								0.006
zLEFTRT:Timebin3								-0.096
zLEFTRT:Timebin4								-0.046
zLEFTRT:Timebin5								-0.042
zLEFTRT:Timebin6								-0.066
Constant	0.007	0.007	0.007	0.007	-0.180***	-0.179***	-0.177***	-0.176***
Observations	2,674	2,674	2,674	2,674	2,674	2,674	2,674	2,674
Log Likelihood	-3,529.181	-3,528.890	-3,527.584	-3,529.173	-3,509.920	-3,508.918	-3,503.927	-3,507.812
Akaike Inf. Crit.	7,066.363	7,067.780	7,065.169	7,068.347	7,039.840	7,047.836	7,037.855	7,045.623
Bayesian Inf. Crit.	7,089.928	7,097.236	7,094.626	7,097.803	7,098.754	7,136.206	7,126.225	7,133.993
Note:								*p<0.1; **p<0.05; ***p<0.01

Table 4: LMM outputs for all pre-registered continuous predictors and time as a fixed effect, with corrugator as dependent variable

	Dependent variable:							
	zCorrugator Change Score (log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
zHyper		0.048				0.018		
zATD			0.059				0.025	
zLEFTRT				0.075				0.035
Timebin2					0.073	0.071	0.072	0.077
Timebin3					0.118**	0.115**	0.117**	0.124**
Timebin4					0.132**	0.130**	0.131**	0.135**
Timebin5					0.042	0.040	0.041	0.045
Timebin6					0.051	0.049	0.050	0.054
zHyper:Timebin2						0.039		
zHyper:Timebin3						0.048		
zHyper:Timebin4						0.035		
zHyper:Timebin5						0.019		
zHyper:Timebin6						0.041		
zATD:Timebin2							0.051	
zATD:Timebin3							0.024	
zATD:Timebin4							0.039	
zATD:Timebin5							0.045	
zATD:Timebin6							0.048	
zLEFTRT:Timebin2								0.049
zLEFTRT:Timebin3								0.079
zLEFTRT:Timebin4								0.039
zLEFTRT:Timebin5								0.037
zLEFTRT:Timebin6								0.037
Constant	0.136**	0.135**	0.135**	0.139**	0.068	0.069	0.068	0.067
Observations	2,674	2,674	2,674	2,674	2,674	2,674	2,674	2,674
Log Likelihood	-3,577.295	-3,576.820	-3,576.553	-3,576.100	-3,573.816	-3,572.920	-3,572.531	-3,571.748
Akaike Inf. Crit.	7,162.589	7,163.640	7,163.106	7,162.200	7,165.633	7,175.840	7,175.061	7,173.496
Bayesian Inf. Crit.	7,186.155	7,193.097	7,192.563	7,191.656	7,218.655	7,264.210	7,263.431	7,261.866
Note:								*p<0.1; **p<0.05; ***p<0.01

Table 5: LMM outputs: all pre-registered continuous predictors and time as a fixed effect, with zygomaticus as dependent variable

	Dependent variable:							
	zZygomaticus Change Score (log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
zHyper		0.054				0.050		
zATD			-0.025				0.021	
zLEFTRT				-0.031				-0.018
Timebin2					0.104**	0.104**	0.103**	0.104**
Timebin3					0.236***	0.237***	0.235***	0.237***
Timebin4					0.304***	0.305***	0.303***	0.304***
Timebin5					0.289***	0.289***	0.287***	0.289***
Timebin6					0.306***	0.305***	0.305***	0.306***
zHyper:Timebin2						-0.010		
zHyper:Timebin3						0.036		
zHyper:Timebin4						0.027		
zHyper:Timebin5						0.003		
zHyper:Timebin6						-0.033		
zATD:Timebin2							-0.038	
zATD:Timebin3							-0.059	
zATD:Timebin4							-0.055	
zATD:Timebin5							-0.068*	
zATD:Timebin6							-0.058	
zLEFTRT:Timebin2								0.031
zLEFTRT:Timebin3								-0.018
zLEFTRT:Timebin4								-0.036
zLEFTRT:Timebin5								-0.050
zLEFTRT:Timebin6								-0.007
Constant	0.079	0.079	0.079	0.079	-0.127**	-0.127**	-0.126**	-0.127**
Observations	5,447	5,447	5,447	5,447	5,447	5,447	5,447	5,447
Log Likelihood	-7,266.899	-7,266.227	-7,266.753	-7,266.679	-7,221.114	-7,218.666	-7,219.157	-7,218.513
Akaike Inf. Crit.	14,541.80	14,542.45	14,543.50	14,543.36	14,460.23	14,467.33	14,468.31	14,467.02
Bayesian Inf. Crit.	14,568.21	14,575.47	14,576.52	14,576.37	14,519.65	14,566.37	14,567.36	14,566.07
Note:								*p<0.1; **p<0.05; ***p<0.01

Table 6: LMM outputs: Change score of muscles (within-person centred) as continuous predictors and time as a fixed effect, with valence ratings as dependent variable

	Dependent variable:			
	zPleasantrating			
	(1)	(2)	(3)	(4)
zCorrugatorCS		-0.045***	-0.046***	-0.045***
zZygomCS			0.047***	0.051***
zLevatorCS				-0.016*
Constant	-0.010	-0.010	-0.008	-0.008
Observations	5,827	5,827	5,827	5,827
Log Likelihood	-5,961.269	-5,948.712	-5,936.083	-5,934.723
Akaike Inf. Crit.	11,930.540	11,907.420	11,884.170	11,883.450
Bayesian Inf. Crit.	11,957.220	11,940.780	11,924.190	11,930.140
Note:	*p<0.1; **p<0.05; ***p<0.01			