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Associations between emotionality, sensory reactivity and food fussiness in young children

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Abstract

The present study investigated associations between children's sensory reactivity and food fussiness to determine whether these associations remained after controlling for child temperament. Data regarding children's sensory processing was obtained from 79 mother-child dyads via observation (children were presented with sensory stimuli) and maternal-report. Mothers also completed questionnaires measuring child temperament and food fussiness. Correlation analyses showed that high sensory reactivity in taste, olfactory and tactile sensory modalities were significantly positively associated with food fussiness. Hierarchical regression analyses revealed that taste, olfactory and tactile reactivity explained a significant proportion of variance in food fussiness over and above emotional temperament. There was no significant interaction between emotionality and sensory reactivity in predicting food fussiness across any measured sensory modalities.

Keywords: Food fussiness, emotionality, sensory reactivity, child, observation, maternal report

1 INTRODUCTION

Food fussiness, described as the consumption of an inadequate variety of foods through the rejection of both familiar and unfamiliar foods (Dovey, Staples, Gibson, & Halford, 2008) is frequently reported by parents as a challenge (Carruth, Ziegler, Gordon, & Barr, 2004; Mascola, Bryson & Agras, 2010). Food fussiness adversely influences dietary variety, quality and optimal nutritional intake (Carruth et al, 1998; Jacobi, Agras, Bryson & Hammer, 2003; Jacobi, Schmitz & Agras, 2008; Tharner et al. 2014; Volger et al. 2017). It is associated with functional constipation and low weight in early childhood (Tharner et al., 2015; Dubois, Farmer, Girard, and Peterson, 2007; Viljakainen, Figueiredo, Rounge, & Weiderpass, 2019), elevated levels of aggression, delinquency, anxiety and depression in early and mid-childhood (Jacobi et al., 2008; Zucker et al., 2015) and is a source of parental stress and family conflict (Goh & Jacob, 2012; Trofholz, Schulte & Berge 2017).

Research investigating the development of food fussiness has highlighted the role of a broad range of factors including experiential factors such as breastfeeding (Galloway, Lee & Birch, 2003; Shim, Kim, and Mathai, 2011) and weaning (Coulthard, Harris & Emmett, 2009; Northstone, Emmett, & Nethersole, 2001), parents' feeding practices (Webber, Hill, Cooke, Carnell & Wardle, 2010; Jansen et al., 2012) and maternal psychopathology (McDermott et al., 2010, De Barse et al., 2016). Child factors have also been implicated as risk factors for the development of food fussiness.

There is growing evidence to suggest that child temperament plays a role in the development of food fussiness. Temperament has been defined as "personal characteristics that are biologically based, are evident from birth onwards, are consistent across situations and have some degree of stability" (Schaffer, 2006, p. 70). Emotional temperament or emotionality in children which is the predisposition to get easily distressed and upset has consistently been demonstrated to be associated with food fussiness in cross sectional studies (Powell, Farrow & Meyer, 2011; Haycraft, Farrow, Meyer, Powell, & Blissett, 2011; Rendall, Dodd & Harvey, 2021). Greater emotionality has also been found to be a significant longitudinal predictor of food fussiness (Hafstad, Abebe, Torgersen, and von Soest, 2013). Explanations for the association between emotionality and food fussiness are still not clear. It has however been suggested that due to their persistent dissatisfaction in most situations, children who score high on emotionality may extend this discontentment to mealtimes, showing heightened emotional reactivity and may, as a result, be more difficult to feed and perceived as more fussy (Hafstad et al., 2013; Haycraft et al., 2011). This may result in difficult parent-child feeding interactions and parents use of controlling feeding practices such as pressure and restriction that have been found to intensify food fussiness (Birch & Fisher, 2000; Jansen et al. 2012). Recent research found positive feeding practices such as involving children in food choice and preparation to be associated with lower food fussiness, however this was moderated by emotional temperament; such that involvement was not associated with lower food fussiness in highly emotional children (Holley, Haycraft & Farrow, 2020).

The act of eating involves processing sensory information across several sensory modalities such as taste, smell, vision and touch (Rolls, Rowe, & Rolls, 1982). The sensory properties of food have been found to be a major determinant of food preferences in children as the taste, texture and visual properties of food have been observed to influence liking (Baxter, Jack, & Schroder, 1998; Blossfeld, Collins, Kiely, & Delahunty, 2007; Russell & Worsley, 2013). Sensory aspects of food are also often cited as an underlying factor in the rejection of food (Martins & Pliner, 2005). It is well established that there are differences in the ways individuals perceive and respond to sensory information (Dunn, 1997). Sensory reactivity also known as sensory over-reactivity has been defined as a stronger and heightened response to sensory stimuli including information from touch, auditory, vision, olfactory and taste senses (APA, 2013; Dunn, 1997). In the context of food, it has been suggested that highly sensory hyperreactive individuals may have a lower threshold for detecting sensory information, meaning that they are more likely to notice subtle aspects of the sensory properties of food, and as a result, may be more likely to reject foods (Farrow & Coulthard, 2012). In addition to reactivity to specific tastes, tactile reactivity; individual differences in tactile perception and aversive responses to tactile stimulation (Cascio et al., 2008; Shula, Haim, Avraham, & Marsha, 2008) may also influence food preferences. Children who have greater tactile reactivity show aversion to the feel of sand and grass and appear to be more sensitive to oral touch and to the textures of food (Dunn, 1997). It is possible that heightened reactivity to tactile stimuli may cause some children to discriminate between foods based on their textures. This is supported by findings of an association between tactile reactivity and food fussiness in both children and adults (Smith, Roux, Naidoo & Venter, 2005; Farrow & Coulthard, 2012; Coulthard & Blissett, 2009; Kauer, Pelchat, Rozin & Zickgraf, 2015; Nederkoorn, Jansen & Havermans, 2015; Werthmann et al., 2015). A few studies also provide evidence of an association between food fussiness and sensory reactivity in taste as well as olfactory domains (Farrow & Coulthard, 2012; Zucker et al. 2015). Further, parents who described their children as fussy eaters reported extreme reactivity to texture and smell (Boquin, Moskowitz, Donovan, & Lee, 2014). Sensory reactivity has also been found to be a longitudinal predictor of food fussiness (Steinsbekk, Bonneville-Roussy, Fildes, Llewellyn, & Wichstrøm, 2017).

While sensory reactivity and food fussiness have been investigated in the context of child anxiety as a risk factor for fussiness in children and adolescents (e.g., Farrow & Coulthard, 2012; Zickgraf & Elkins, 2018), to date, there is no published research investigating sensory reactivity and food fussiness, in the context of child temperament. This is an important next step in light of the consistent associations found between emotionality and food fussiness (e.g., Jacobi et al., 2003; Haycraft et al, 2011; Haftstad et al, 2013). Emotionality differs from anxiety; emotionality is a dimension of temperament and therefore represents normal variation between individuals while anxiety is an emotion linked to psychopathology. A key difference between emotionality and anxiety is that emotionality, as a temperament style is relatively stable over time, whereas anxiety can be a transient emotion. Although emotionality and anxiety are separate constructs, they are associated, with emotionality placing a child at risk for developing anxiety disorders and influencing severity of anxiety difficulties once they have emerged (Perez-Edgar & Fox, 2005).

The aims of the present study were to further investigate associations between sensory reactivity in taste, olfactory and tactile sensory domains with food fussiness, and to evaluate whether these associations remain after controlling for the effects of emotionality. The study also aims to explore whether emotionality moderates the association between sensory reactivity and food fussiness, that is whether sensory reactivity is associated with food fussiness only in children who are also high on emotionality. A moderation pathway was proposed because children high in emotionality exhibit strong emotional reactions and it seems likely that the combination of high sensory reactivity with high emotionality would lead to strong emotional reactions to the sensory aspects of food and, in turn, greater perceived fussiness. This contrasts with children who might be high in emotionality but with low sensory reactivity, or children high in sensory reactivity but low in emotionality, for whom mealtimes may be less challenging and, in turn, they may be perceived as less fussy relative to those who are high in both. A clear limitation of the majority of research investigating associations between food fussiness and sensory reactivity is the reliance on parental report, which is subject to bias. To address this limitation, data were obtained via both parent report and observation of sensory processing.

It was hypothesized that high sensory reactivity in taste, olfactory and tactile sensory domains would be positively associated with food fussiness. Given the lack of previous research examining sensory reactivity and emotionality together in the context of food fussiness, it was tentatively hypothesised that sensory reactivity would be related to food fussiness even after controlling for emotionality. The moderation analysis was exploratory.

2 METHOD

Ethical approval for this study was obtained from the local Research Ethics Committee (UREC 2017/047/TT).

2.1 Participants

Preschool-aged children (3-4 years) were recruited as part of a larger study called the 'Watch Them Grow' (WTG) project (Dodd et al, 2020), which focused primarily on preschool predictors of anxiety when children start school. This age range was selected due to its association with increased parental perception of food fussiness (Carruth et al., 2004; Hafstad et al., 2013). Recruitment for the WTG project took place via local Facebook groups, advertising through nurseries and paid magazine advertising. Interested families were asked to visit a website which contained study information and register their interest to take part. They were then contacted by a member of the WTG team to participate in a baseline assessment which involved an eye tracking task. Children who had special educational needs were not eligible for the WTG project because their transition to school was likely to be atypical. Children were also excluded if mothers confirmed that they had lactose, nut or gluten intolerance as the study involved a taste reactivity taste where items which might contain these ingredients were offered to children. None of the mothers in the present study indicated that their child had an intolerance to lactose, nuts or gluten. Mothers had to be fluent in English to understand the instructions of the study and to give consent.

All 180 families who had completed the baseline assessment for the WTG project were invited to participate in the study described here. Recruitment for the present study took place between January 2017 and May 2018. Of the 180 families invited to participate in this study, 79 mother-child pairs responded and agreed to participate. According to power analysis conducted on G*Power (Faul, ErdFelder, Lang & Buchner, 2007), 79 participants were sufficient to obtain β Power of 0.92 for detecting an increase in R^2 when performing a regression analysis with three predictors, two independent predictors (emotionality and sensory reactivity) and one interaction term (emotionality x sensory reactivity), assuming a moderate effect size of F = 0.15. A medium effect size was assumed as this has been observed in previous studies that have examined associations between food fussiness with emotionality and sensory processing (e.g., Powell et al., 2011; Haycraft et al., 2011; Farrow & Coulthard, 2012; Nederkoorn et al., 2015).Children who participated in this study were aged from 3 to 5 years (M = 4 years, SD = 1 year) and the sample comprised of 45 girls and 35 boys. Children were described by their mothers as predominantly White British (84.7%) using the Office of Population Censuses and Surveys (OPCS; 2003) 17 group ethnic classification which combines ethnic and national group dimensions (e.g., White Irish, Black African, Asian Pakistan). Maternal age ranged from 24 to 44 years (M = 36 years, SD = 5 years). Of all the mothers taking part, 73.4% had a bachelor's degree or higher university level education, 87.8% were either married, in civil partnerships or cohabiting and over half (52.5%) were either in full or part- time employment. The number of mothers in full time employment seemed rather low, given the high levels of educational attainment. As mothers self-selected themselves to participate in the present study, it could be that mothers who were not in employment were more likely to participate given that they had more availability.

2.2 Measures

Mothers completed a background demographic questionnaire in addition to two measures of sensory reactivity, detailed below, a measure of food fussiness and a measure of emotional temperament.

We included two measures of sensory reactivity because each offered a specific benefit. The SSP was chosen as it is the most widely used parent report measure of sensory reactivity in early childhood. The SAND was chosen as it allows for independent observations of children's responses to sensory stimuli.

2.2.1 **The Short Sensory Profile (SSP; Dunn, 1999)**

The SSP is a 38 item parent-report questionnaire used to measure children's sensory responses to sensory stimuli (Dunn, 1999). The SSP consists of seven subscales: Tactile sensitivity, Taste/Smell sensitivity, Movement sensitivity, Under responsive/Seeks Sensation, Auditory Filtering, Low energy/Weak and Visual/Auditory sensitivity. The present study made use of two subscales namely; Tactile and Taste/Smell as previous research has reported associations between food fussiness and sensory reactivity in taste, olfactory and tactile sensory modalities (e.g., Farrow & Coulthard, 2012; Nederkoorn et al., 2015; Zucker et al., 2015). Seven items of the SSP assess Tactile sensitivity (e.g., "Avoids going barefoot, especially in sand or grass") and four items assess Taste/Smell sensitivity (e.g., "Avoids certain tastes or food smells that are typically part of children's diets"). Parents indicate on a five-point Likert scale (1 = always to 5 = never) how well these statements describe their child's behaviours. Scores for each subscale are determined by computing the sum of the scores, with higher scores indicating typical levels of sensory processing. The SSP has good internal and external validity (Dunn, 1999) and has been validated in clinical and non-clinical samples of children (Tomchek & Dunn, 2007). In the present study, Cronbach's alpha for the taste/smell sensitivity subscale was 0.84 and 0.78 for the tactile reactivity subscale.

2.2.2 **Sensory Assessment for Neurodevelopmental Disorders (SAND; Siper et al., 2017)**

The SAND consists of an observation and corresponding caregiver interview designed to measure sensory hyperreactivity in children. Administration of the SAND consists of unstructured play with the child to acquaint him/her with the testing environment and the researcher, followed by the SAND observation. The observation involves direct presentation of sensory stimuli to the child with five stimuli presented within each sensory modality; visual, tactile, auditory, olfactory and taste (See Table 1). Children's responses are first dichotomised into absence or presence of behaviour in response to the stimulus; a score of 0 is given when a behaviour is not present and a score of 1 when a behaviour is present. If present, children's behavioural responses are further rated across sensory modalities into three DSM-V ASD symptom domains: sensory hyperreactivity, sensory hyporeactivity and seeking behaviours. For example, for SAND tactile sensory modality, being bothered by textures, having very little or no reaction to hot or cold temperatures and seeking opportunities to feel textures repeatedly constitute behaviours that reflect sensory hyperreactivity, sensory hyporeactivity and seeking behaviours respectively. The corresponding caregiver interview consists of 36 items and follows the same format. Caregivers are first asked to indicate whether their child shows signs of a given sensory behaviour or not. If the behaviour is present, caregivers are then asked to rate its severity (mild or moderate-severe) within each domain (e.g., Tactile hyperreactivity). Total SAND scores are derived by combining responses on the observation and caregiver interview. The SAND provides an overall total score (observed + caregiver reported), scores by sensory modality (visual, tactile, auditory, olfactory and taste) and scores by DSM-5 autism symptom domain scores (sensory hyperreactivity, sensory hyporeactivity and sensory seeking). Domain scores range from 0 to 30 with a total SAND score ranging from 0 to 150; higher scores indicate greater levels of sensory hyperreactivity symptoms. The observation is always conducted prior to the caregiver interview to avoid any bias that may result from prior knowledge of the child's sensory preference gleaned from the interview. As the present study was interested in associations between sensory reactivity, food fussiness and emotionality, only SAND hyperreactivity scores were used. Sensory hyperreactivity was indicated by stronger reactions to the presented stimuli during the observation and parent's indication that a behaviour is present in the corresponding interview (See Table 2). The present study focused on investigating associations for which there was evidence, namely between food fussiness and sensory reactivity in tactile, taste and olfactory sensory modalities. Data for sensory hyperreactivity in visual and auditory domains in the SAND were therefore excluded from the final analyses.

The SAND has been found to have very high internal consistency with an alpha value of 0.90 and good test-rest reliability with intraclass correlation coefficient (ICC) values of 0.97 for total scores, 0.82 for observed scores and 0.97 for reported scores (Siper, Kolevzon, Wang, Buxbaum, & Tavassoli, 2017) and can be used with both typical and non-typically developing children. In the present study, Cronbach's alpha for SAND taste, olfactory and tactile hyperreactivity subscales were 0.56, 0.60 and 0.61 respectively.

[Table 1 here]

[Table 2 here]

2.2.3 **Children's Eating Behaviour Questionnaire- Food Fussiness Subscale (CEBQ FF; Wardle, Guthrie, Sanderson & Rapoport, 2001)**

The CEBQ FF was used to assess mother's perception of their child's food fussiness. The subscale consists of six statements which evaluate whether the child eats a variety of foods, the child's interest in new foods and how difficult the child is to please with meals e.g., *my child decides he/she doesn't like a food, even without tasting it.* Respondents rate on a 5-point Likert scale (1= never, 5= always) how applicable each statement is to their child. Mean scores were calculated which ranged from one to five, with higher scores reflecting greater child food fussiness. The CEBQ FF has been demonstrated as having high reliability with a Cronbach's alpha value of 0.91 (Wardle et al, 2001) and has been found to correspond to behavioural measures of children's food rejection and acceptance behaviours (Rendall, Dodd & Harvey, 2020). For the current sample, Cronbach's alpha for food fussiness was 0.89.

2.2.4 Emotionality Activity Sociability Scale (EAS; Buss & Plomin, 1984)

The emotionality subscale of the EAS was used to measure emotional child temperament. This subscale comprises of 5 items to assess children's tendency to become easily and intensely aroused e.g., "*my child cries easily*". Respondents are asked to rate on a 5-point Likert scale (1= not characteristic or typical of your child to 5 = very characteristic or typical of your child) how well these statements described their child's behaviour. Mean scores were calculated and ranged from one to five, with higher scores indicating that the trait is more typical of the child. The EAS has been found to have good internal reliability with alpha values exceeding 0.70 (Ganiban, Saudino, Ulbricht, Neiderhiser, & Reiss, 2008; Saudino, McGuire, Reiss, Hetherington, & Plomin, 1995) and high test-retest correlations (Goodyer, Ashby, Altham, Vize, & Cooper, 1993). For the current sample, Cronbach's alpha for emotionality was 0.86.

2.3 Procedure

Children were tested individually at the University of Reading infant lab and were accompanied by their mother. Upon arrival, following greetings and introductions, the researchers encouraged the child to engage in unstructured play for several minutes with the aim of familiarising the child with the test environment. To mitigate the possibility that children's performance on the SAND would influence mothers' interview responses, mothers completed the demographic questionnaire, EAS, SSP and the CEBQ FF on an Apple iPad while the child took part in the SAND observation sensory hyperreactivity test, which was filmed. The child's behavioural responses to the presentation of the sensory stimuli were rated by the researcher for observed sensory hyperreactivity, hyporeactivity and seeking behaviours through live observations. Prior to rating children's responses, two researchers were trained by the study co- PI (TT) to identify sensory hyperreactivity, hyporeactivity and seeking behavioural responses. The two researchers rated the first 15 observations and compared their ratings by calculating percent agreement which ranged between 0.81 and 1 indicating high reliability based on suggested criteria (e.g., Landis and Koch, 1977). Following completion of the SAND observation, the child was allowed to resume unstructured play while the researcher obtained interview data from the parent (SAND caregiver interview). Finally, children were thanked and received stickers and a small gift for their participation. The present study focused on investigating associations for which there was evidence, namely between food fussiness and sensory reactivity in tactile, taste and olfactory sensory modalities. Data for sensory hyperreactivity in visual and auditory domains in the SAND were therefore excluded from the final analyses.

2.4 Data Analysis

The hypotheses and the data analytic plan were made prior to data collection and all data driven analyses are clearly identified and discussed accordingly. To test our hypotheses, correlation analyses were used to explore associations between sensory reactivity in taste, olfactory and tactile sensory domains with food fussiness. Moderated regression analyses were then used to investigate whether sensory reactivity explains a proportion of variance over and above emotionality in predicting food fussiness. Data were analysed using Statistical Package for Social Sciences (SPSS), version 24. Minimum and maximum values of all the study variables were within the expected range confirming data entry accuracy. The dataset contained 43 missing data points which were confirmed to be missing at random as indicated by significant Little's MCAR test, $p = 0.182$, therefore an Expectation

Maximization (EM) technique (Dempster, Laird, & Rubin, 1977) was used to estimate and impute missing data values. Significant Shapiro-Wilk's tests revealed non-normality in the distribution of majority of the study variables which were not improved using log, reciprocal or square root transformations. It was therefore decided to use a bootstrapping procedure to generate 95% bias- corrected bootstrapped confidence intervals of the correlation coefficients (1000 samples, N = 79) in all analyses. Statistical significance was set at $p < 0.05$, confidence intervals were reported for all bootstrapped correlations.

To examine whether any sociodemographic factors should be controlled for in the main analyses, preliminary two-tailed bootstrapped Pearson's correlations were conducted to explore associations between child and maternal sociodemographic factors measured on a continuous scale (child and maternal age) on the one hand and food fussiness, emotionality, SAND and SSP reactivity on the other. Bootstrapped independent samples t-tests were carried out with categorical sociodemographic variables (child sex, child ethnicity, maternal education, marital status and maternal employment) to ascertain if there were significant group differences in food fussiness, emotionality and sensory reactivity scores. There was a significant negative correlation between maternal age and child food fussiness (r =. -229, 95% CI -.438 – -.014, p = .042). With increasing maternal age, there was a decline in maternal perception of child food fussiness. Child age was not related to any of the study variables. Results indicated that for the categorical variables, there were no significant differences between groups for food fussiness, emotionality, SAND and SSP sensory reactivity. Maternal age was therefore controlled for in all further analyses involving food fussiness (see Tables 1 and 2 in supplementary materials for non-significant results).

Correlation analyses were used to examine relationships between emotionality and sensory reactivity. Correlation analyses were also carried out to examine relationships between

SAND hyperreactivity and SSP reactivity across sensory domains as well as relationships between SAND hyperreactivity measured via observation and SAND hyperreactivity measuring using maternal interview.

Prior to performing regression analyses, two-tailed bootstrapped Pearson's partial correlations controlling for maternal age were performed to explore associations between sensory reactivity measured by the SAND and SSP across taste, olfactory and tactile sensory domains with food fussiness. To control for the increased risk of Type 1 error due to multiple analyses, statistical significance was set at a more stringent Bonferroni corrected p-value of $p < 0.01$ (0.05/5), only significant correlations meeting this criterion were included in the regression analyses. There was a significant positive correlation between food fussiness and taste hyperreactivity measured via the SAND, t = .36, $CI^{95\%}$ .18 - .53, $p < 0.001$. There were significant negative associations between food fussiness and SSP taste/smell reactivity, t = -.58, $CI^{95\%}$ -.72- - .43, $p < 0.001$ and between food fussiness and SSP tactile reactivity, t = -.37 , $CI^{95\%}$ -.55 - -.17, $p < 0.001$. The negative association observed in the association between food fussiness and the SSP occurs because of the scoring of the SSP where higher scores on the taste/smell (SSP) sensory reactivity scale indicate less reactivity. The correlations between food fussiness with SAND tactile hyperreactivity and SAND olfactory hyperreactivity were non-significant at t = .23, $CI^{95\%}$ -.004 - .46, $p = 0.04$ and t = .29, $CI^{95\%}$ .07-.40 , $p = 0.03$ respectively.

Based on these results, three separate bootstrapped hierarchical regression analyses were planned to investigate whether taste (SAND), taste/smell (SSP) and tactile (SSP) reactivity respectively would independently explain a proportion of variance over and above emotionality in predicting food fussiness. The hierarchical regression analyses also explored whether each of these sensory variables interacted with emotionality to predict food fussiness. Significance level for the regression analyses was set at $p < 0.05$ as variables had been selected on an alpha criterion of 0.01.

Before performing the regression analyses, the predictor variables were centred. An interaction variable was subsequently created from the product of the centred variables. In each analysis, the dependent variable was food fussiness, maternal age was entered in Step 1 to control for its effects, emotionality was entered in Step 2, and then the relevant sensory reactivity variable was entered in Step 3 to determine if it explained any unique variance over and above emotionality in predicting food fussiness. The interaction term was entered in Step 4. The results for model 3 of each regression analysis are shown in Table 4. Model 3 is presented given that inclusion of the interaction terms in Model 4 did not significantly increase the variance accounted for in any of the models.

3 RESULTS

3.1 Descriptive Statistics

Descriptive statistics for the study measures can be seen in Table 3. Mean scores on the CEBQ FF and the emotionality subscale of the EAS for children in this sample are comparable to previous studies that have used these measures with children of a similar age group (e.g., Ashcroft et al., 2008; Holley, Farrow & Haycraft, 2018; Powell et al., 2011; Rendall et al., 2020). Mean scores for taste, olfactory and tactile reactivity measured using the SSP in the current sample of children are comparable with previous studies that have used these measures with typically developing children and reflect typical levels of sensory reactivity (e.g., Farrow & Coulthard, 2012). There are no available norms to compare means for taste, olfactory and tactile hyperreactivity measured via the SAND.

3.2 Relationships between emotionality and sensory reactivity

Emotionality was significantly negatively correlated with tactile reactivity measured via the SSP, t = -.31, $CI^{95\%}$ -.49 - -.06, p < 0.05. Emotionality was not significantly related to SSP taste/smell reactivity and SAND hyperreactivity in taste, olfactory and tactile sensory domains (See Table 3 in supplementary materials for non-significant results).

3.3 Relationships between SAND and SPP reactivity across sensory domains

Taste hyperreactivity measured via the SAND was significantly negatively correlated with Taste/Smell reactivity measured using the SSP, t = -.33, $CI^{95\%}$ -.54 - -.07, *p* <0.01. Similarly Tactile hyperreactivity measured via the SAND was significantly negatively correlated with tactile reactivity measured using the SSP, t = -.26, $CI^{95\%}$. -.44 - -.005, *p* < 0.05. Olfactory hyperreactivity measured via the SAND was not significantly related to taste/smell reactivity measured using the SSP. Lower scores on the SSP are an indication of higher sensory reactivity (See Table 4 in supplementary materials for non-significant results).

3.4 Relationship between SAND observation and SAND Interview hyperreactivity

SAND hyperreactivity measured via observation was unrelated to SAND hyperreactivity measured via maternal interview across tactile, olfactory and taste sensory domains (See Table 4 in supplementary materials).

[Table 3 here]

3.5 Predictors of food fussiness

3.5.1 <u>Taste hyperreactivity measured via the SAND</u>

In Step 1, maternal age contributed significantly to the regression model, *F* (1, 77) = 4.26, *p* = .04 explaining 5.2% of variance in food fussiness. Introducing emotionality in Step 2 resulted in a significant change in R^2, *F* (2, 76) = 11.54, *p* = .001, explaining an additional

12.5% of variance in food fussiness. In Step 3, taste hyperreactivity (SAND) explained 8.2% of variance in food fussiness and this change in R^2 was also significant, F (3, 75) = 8.36, p = .005. The introduction of the emotionality x taste hyperreactivity (SAND) interaction term in Step 4 did not result in a significant change in R^2, F (4, 74) = 0.04, p = .85.

3.5.2 Taste/smell reactivity measured via SSP

Step 1 and 2 are identical across models so are not repeated here. In Step 3, adding taste/smell reactivity (SSP) to the model explained an additional 26.3% of variance in food fussiness and this R^2 change was also significant F (3, 75) = 19.64, p < 0.001. Finally, the introduction of emotionality x taste/smell reactivity (SSP) interaction term in Step 4 only explained 1.9% of the variance in food fussiness and this R^2 change was non-significant, F (4, 74) = 15.72, p = .11.

3.5.3 Tactile reactivity measured via SSP

Adding tactile reactivity (SSP) to the model in Step 3 explained an additional 7.2% of variance in food fussiness and this R^2 change was also significant F (3, 75) = 8.31, p = 0.009. Finally, the introduction of emotionality x tactile reactivity (SSP) interaction term in Step 4 only accounted for 2% of the variance in food fussiness and this R^2 change was non-significant, F (4, 74) = 6.8, p = .16.

[Table 4 here]

4 DISCUSSION

The aim of this study was to investigate associations between food fussiness and sensory reactivity in children across taste, olfactory and tactile sensory domains. In addition, the present study aimed to evaluate whether these associations remained after controlling for the effects of emotionality. This study further explored whether emotionality might moderate the association between sensory reactivity and food fussiness.

Consistent with the hypothesis, the present study found greater taste, olfactory and tactile sensory reactivity to be significantly related to greater food fussiness. These results corroborate previous findings of a positive relationship between parent- reported sensory reactivity in taste, olfactory and tactile sensory domains and food fussiness (e.g., Farrow & Coulthard, 2012; Zucker et al., 2015). It has been suggested that children with higher levels of sensory reactivity have lower thresholds for detecting sensory information and are able to easily detect subtle changes in the sensory properties of food (Farrow & Coulthard, 2012). Children tend to reject food on the basis of the taste, look, smell and texture of food (Coulthard, Palfreyman, & Morizet, 2016). Fussy eaters have been observed to reject food based on certain sensory properties, for example, to spit out food due to a dislike of the taste and/or texture (Rendall et al, 2020; Fries, Martin & van der Horst, 2017; Luchini , Lee & Donovan, 2016). It makes sense therefore that children who are able to easily detect the taste, olfactory and tactile properties of food might be more likely to be fussy eaters.

The present research extended previous research by examining whether taste, olfactory and tactile sensory reactivity explained variance in fussy eating over and above emotionality. The findings indicated that taste, olfactory and tactile sensory reactivity explained up to an additional 8.2- 26.3% variance in food fussiness that was not due to emotionality, although this was not consistent across both measures. These results provide some suggestion of the importance of sensory reactivity in taste, olfactory and tactile sensory domains in explaining child food fussiness. Importantly, the effect of emotionality remained significant after sensory reactivity was included as a predictor. Taken together, these results therefore indicate that children with higher emotionality and sensory reactivity are more likely to be perceived by their mothers as fussy eaters. Mealtimes could be particularly challenging for children with higher emotionality who are also highly sensitive. Such children are likely to find various foods aversive due to their sensory properties and may be more likely to reject these foods and/or resist trying or eating them when offered. Given the likely challenges arising from these characteristics, parents may find mealtimes very difficult, and this may lead them to use a range of strategies to encourage food consumption including controlling feeding practices such as use of pressure, food rewards and prompts. Previous studies have reported controlling feeding practices to be associated with food fussiness in cross-sectional studies (e.g., Jansen et al., 2012; Webber, Cooke, Hill, & Wardle, 2010), although it is difficult to establish the direction of causality. A longitudinal study, however found that at age seven, mothers' use of pressure predicted food fussiness at age nine (Galloway, Fiorito, Lee & Birch, 2005), suggesting that controlling feeding practices could exacerbate food fussiness (Blissett, 2011; Dovey et al., 2008). Alternatively, some parents may try to avoid the conflict associated with pressuring children with higher emotionality and sensory reactivity to eat disliked foods and may adapt a more permissive approach, offering foods that their children prefer, which in turn may reinforce food fussiness as children are not exposed to a variety of foods, and may also result in greater parent perception of food fussiness.

The present study found no significant interactions between emotionality and sensory reactivity across taste, olfactory and tactile sensory domains in predicting food fussiness. This finding indicates that emotionality and sensory reactivity independently influence food fussiness in an additive way. The relationship between each of these variables and food fussiness is not dependent on the level of the other variable.

While we found an association between taste reactivity and food fussiness, it should be noted that some of items assessing taste reactivity in the SSP include statements such as "my child is a picky eater" which overlap with food fussiness items. It is therefore possible that associations between SSP taste reactivity and food fussiness may be as a result of item overlap between food fussiness and this sensory measure. Consequently, the relationships between food fussiness and taste reactivity must be interpreted with caution because the items measuring taste reactivity in the SSP are so closely related to food fussiness. This closeness may explain the high correlations between SSP taste/smell reactivity with food fussiness and the large proportion of variance explained by taste/smell reactivity assessed through the SSP in food fussiness scores.

A strength of this study is the inclusion of a behavioural measure of sensory reactivity in conjunction with parent- report which addresses the limitations of previous research in this area where sensory reactivity has solely been assessed via self-report. Although total SAND hyperreactivity scores were significantly related to SSP scores, when the SAND hyperreactivity scores were split into observation and interview, only SAND hyperreactivity across tactile, olfactory and taste sensory domains measured via maternal interview were significantly related to SSP taste/smell and SSP tactile reactivity, SAND hyperreactivity measured via observation were unrelated to SSP taste/smell and SSP tactile reactivity. This suggests that the significant association between SAND and SSP scores was driven by SAND interview scores. This finding highlights the importance of including a behavioural measure of sensory reactivity as maternal report are not always accurate reflections of their children's behaviours which was observed in the lack of association between SAND hyperreactivity observation and interview scores in the present study.

While the findings contribute to our understanding of the relationships between sensory processing and food fussiness, this study is not without its limitations. In common with other studies of this kind, the generalizability of the findings is limited to predominantly white British children from two-parent households with highly educated mothers as is typical of research in this field (e.g., Fernandez et al., 2018; Holley et al., 2020). Further research is needed to explore whether the present findings can be replicated with children from other ethnic and demographic backgrounds and with children of mothers with lower educational attainment. It is also important to note that the cross-sectional nature of the present study prevents any inferences about causality. While emotionality and sensory reactivity have been identified as potential risk factors for the development of food fussiness, further research exploring these relationships using longitudinal designs is required to determine whether they are causal factors.

Despite these limitations, the present study demonstrates that highly sensory hyperreactive children who also have higher emotional temperaments are most likely to be fussy eaters. This finding is important because interventions could focus on targeting these characteristics as a mechanism for decreasing fussy eating. While emotionality is enduring and not easily modified, it may be possible to target maladaptive parenting feeding styles that have been found to interact with emotionality to predict food fussiness (Kidwell, Kozikowski, Roth, Lundahl, & Nelson, 2018). To target reactivity, several studies have used multi-sensory techniques to increase food acceptance through exposure to the sensory properties of food (e.g., Houston-Price, Butler & Shiba 2009; Coulthard & Ahmed, 2017; Coulthard & Sealy, 2017; Nederkoorn, Theiβen, Tummers & Roefs, 2018; Houston-Price, Owen, Kennedy & Hill, 2019). The principle behind these techniques stem from the mere exposure hypothesis (Zajonc, 1968) which proposes that the outcome of familiarisation with a stimulus is a positive attitude towards the particular stimulus. These studies have shown that familiarizing children with food through multi-sensory exposure increased food acceptance and liking. There are also feeding programs that focus on exposing children to the sensory properties of food address child feeding problems including food fussiness. For example, the sequential oral sensory (SOS) approach to feeding (Toomey, 2002) is a play-based program to assess and treat children with feeding problems. The SOS approach allows children to interact with food in a playful, non-stressful way through exploring and learning about the different properties of food such as texture, smell and taste. The goal is to increase the range and volume of foods children will eat through a play-based intervention (Toomey & Ross, 2011). The SOS approach has been found to be successful at increasing the number of foods consumed by children aged 18-61 months who participated in a 12-week program (Boyd, 2007).

5 CONCLUSIONS

This study provides a novel investigation of the association between emotional temperament, sensory reactivity and food fussiness in young children. Our findings provide some suggestion of greater parental perception of food fussiness in children with emotional temperament and sensory reactivity in taste, olfactory and tactile sensory domains. These characteristics could be targeted to address food fussiness, moreover, children with these characteristics identified as being at risk could be prioritised for existing interventions aimed at addressing food fussiness.

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Stella Rendall: Conceptualization, Methodology, Software, Formal analysis, Investigation, Visualization, Writing- Original Draft. **Kate Harvey**: Project administration, Conceptualization, Supervision, Writing- Review & Editing. **Teresa Tavassoli:** Conceptualization, Investigation, Resources, Writing- Review & Editing. **Helen Dodd:** Project administration, Conceptualization, Resources, Supervision, Writing- Review & Editing

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Table 1: Items used in SAND observation**.**

Sensory Modality	Sensory Stimuli
Visual	Spiral disc Handheld sparkle wheel Flashing lights Bubble wheel Fluorescent tubes
Tactile	Vibrating toy Inside-out prickly ball Mouldable goo Toothette Paint Brush
Auditory	Musical toy Buzzer Brass cymbals Whistle CD with music
Olfactory	A variety of oils in vials Lemon Garlic Rose petals Cinnamon Lavender
Taste	Lemon sherbet (sour) Strawberry yoghurt (sweet) Salty pretzels (salty) Tonic water (bitter) Sweet chilli crackers (spicy)

Table **2.** Examples of observed and reported sensory hyperreactivity items in the SAND.

Sensory Modality	Observed Hyperreactivity	Interview
Tactile	Rubs skin or is bothered by different textures	Does your child ever appear bothered by different textures, (i.e., sirens), refuses to wear certain clothes?

Olfactory	Bothered by smells, holds nose	Does your child turn away from ordinary smells?
Taste	Bothered by different food properties, removes food from mouth	Does your child gag in response to ordinary food?

Table 3: Descriptive statistics for child food fussiness, emotionality and sensory reactivity (N= 79).

Measure	**Mean (SD)**	**Median (IQR)**	**Range**	**Min/max**
CEBQ FF	2.89 (0.75)	3.00 (1.00)	1-5	1.33/5.00
EAS (Emotionality Subscale)	2.53 (0.90)	2.40 (1.20)	1-5	1.00/4.80
SAND Hyperreactivity				
Taste	2.46 (1.68)	2.00 (2.00)	0-10	0.00/8.00
Olfactory	2.26 (1.79)	2.00 (2.00)	0-10	0.00/7.00
Tactile	1.95 (1.69)	2.00 (2.00)	0-10	0.00/6.00
SSP reactivity[1]				
Taste/Smell	17.14 (3.26)	18.00 (4.00)	4-20	8.00/20.00
Tactile	30.42 (3.60)	31.00 (4.00)	7-35	13.00/35.00

Note. IQR = interquartile range, SD = standard deviation. SAND = Sensory Assessment for Neurodevelopmental Disorders (Siper et al., 2017), SSP = Short Sensory Profile (Dunn, 1999)

[1] Higher scores on the SAND hyperreactivity measure indicate greater levels of sensory reactivity while higher scores on the SSP sensory reactivity measure indicate less reactivity.

Table 4: Predictors of food fussiness using hierarchical regression analyses- final model

Step 3	**β**	**SE**	**CI$^{95\%}$**
Taste hyperreactivity (SAND)			
Maternal Age	-.21*	.02	[-.07, -002]
Emotionality	.30*	.09	[.08, .42]
SAND taste hyperreactivity	.29*	.05	[.04, .22]
Taste/smell reactivity (SSP)			
Maternal Age	-.13	.02	[-.06, .008]
Emotionality	.26*	.073	[.07, .36]
SSP taste/smell reactivity	-.53**	.02	[-.16, -.09]
Tactile reactivity (SSP)			
Maternal Age	-.13	.02	[-.07, .02]
Emotionality	.28*	.09	[.06, .40]

SSP tactile reactivity	-.36*	.03	[-.12, -.02]

**p <0.05; ** p <0.001*, *$CI^{95\%}$ = 95% confidence interval lower, upper bound values.* β = *regression estimates (mean slopes), SE = standard error*. SAND = Sensory Assessment for Neurodevelopmental Disorders (Siper et al., 2017), SSP = Short Sensory Profile (Dunn, 1999)