Does Disgust Contribute to Picky Eating in Adults with Autism Spectrum Disorder?

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Problem Statement

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by difficulty with social reciprocity, impaired communication, and presence of repetitive restrictive patterns of behavior (American Psychiatric Association [APA], 2013). Autistic individuals have reported varying rates of gastrointestinal problems (Blenner et al., 2011). This coincides with data showing gastrointestinal disorders are one of the most common medical conditions that are associated with ASD (Madra et al., 2021). A study in 2009 found that autistic children displayed a higher incidence of constipation and food selectivity/feeding issues (Ibrahim et al., 2009). Another study found that autistic individuals, specifically children, are five times more likely to develop feeding problems including food selectivity, food refusal, and reduced nutrient intake (Madra et al., 2021). These gastrointestinal disorders can cause greater severity in sleep, behavioral, and psychiatric disorders, ultimately reducing the quality of life for these individuals (Ferguson et al., 2019). Furthermore, food allergies, reduced dietary nutrient intake, and metabolic disruptions have been found in autistic individuals (Hsiao, 2014).

Food selectivity issues, also called picky eating, have been associated with interference with family function during mealtimes (Mascola et al., 2010). Additionally, studies have shown that individuals with food selectivity issues replace fruits and vegetables with unhealthy processed foods, contributing to childhood obesity and reduced nutrient intake (Falciglia et al., 2000; Cermak et al., 2010). Autistic adults who identify as picky eaters were more likely to report anxiety about having food to eat when invited over to dinner and are less likely to organize leisure activities around food or

eating (Kauer et al, 2015). Given how many activities are centered around food, it makes sense that individuals with food selectivity issues struggle with food-related activities.

According to the CDC, about 1 in 36 children has ASD, with higher prevalence among boys (Maenner et al., 2023). Similarly, a recent study from the CDC estimated that 2.21% of adults in the United States have ASD, although the number may be higher as there is not an existing surveillance system to collect these data (Dietz, 2020). The high prevalence of ASD within the United States, in addition to the physical and social risks associated with picky eating, shows the need for research in this area.

Currently, food selectively issues focus on food category and/or texture aversion (Ahearn et al., 2001). A review showed that autistic children refused foods for more reasons than non-autistic children and consistency or texture issues were among the most common problems (Hubbard et al., 2014). As a result of food selectivity issues, autistic individuals may show a preference for carbohydrates and processed foods, decreasing possible nutrient intake (Ahearn et al., 2001). One prominent mechanism that is gaining traction as a driving force of picky eating in autistic individuals is disgust. Disgust is defined as a broad adaptive functional system protecting against pathogen infections and is also called the behavioral immune system. (Egolf et al., 2018). Similarly, it can also be defined as a food-related emotion that results in revulsion at the prospect of eating a contaminated object (Rozin et al., 1987). Results of a 2019 study showed that disgust is strongly associated with picky eating (Harris et al., 2019). The pairing of a taste with gastrointestinal discomfort may result in maintaining avoidance of a particular food, perpetuating food selectivity. In addition, the strong association of disgust with sensory features associated with eating (e.g., feel or smell) is expected since these features are

often associated with food contamination (Harris et al., 2019). In spite of this, there have not been studies examining the relationship between disgust (particularly food-related disgust) processing and picky eating in autistic individuals. Therefore, in this thesis, I plan to examine experiences of food-related disgust by autistic vs. non-autistic adults and the potential associations between food-related disgust processing and picky eating for these individuals.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social interaction and communication, as well as the presence of restricted and repetitive behaviors (APA, 2013). According to the DSM-5, children who meet diagnostic criteria must have deficits in three areas of social communication and two of four types of repetitive, restrictive behavior. Restricted, repetitive behaviors include repetitive motor movements, insistence on sameness (e.g., eating the same food everyday), fixated interests, and hyper- or hypo-reactivity to sensory input (e.g., adverse responses to textures) (APA, 2013). These restrictive, repetitive behaviors are often seen as choosing to eat the same food for every meal or only eating a specific food group and refusing to try other foods (Bandini et al., 2017). As such, highly restrictive eating habits such as picky eating are common for autistic individuals. Supporting this notion, according to one study, 67% of parents of an autistic child described their child as a picky eater and 6% reported their child had a poor appetite for most foods (Williams et al., 2000). Parents felt as though their child's food selection was based on texture (69%), appearance (58%), taste (45%), smell (36%), and temperature (22%). Problem eating behaviors ranged from refusal to try new foods to only eating a particular brand of food (Williams et al., 2000). Because of these problem eating behaviors, picky eating in autistic children is linked with significant parental stress, nutritional deficiencies, and poor dietary quality (Mascola et al., 2010; Cole et al., 2017). Similarly, picky eating in adults causes interference with daily activities revolving around food such as eating in the community and socializing with peers (Kauer et al., 2015). These concerns result in

autistic children and adults interacting with peers less and contribute to a variety of health issues.

Autism and Picky Eating

Picky eating is not uncommon among non-autistic children, particularly early in development, but autistic children are even more restrictive during early childhood and into early adolescence (Cermak et al., 2010). Picky eating is often defined as an unwillingness to try to eat familiar foods or try new foods (Taylor et al., 2015). Individuals who identify as picky eaters may have strong food preferences which should be of concern when these food sensitivities do not resolve themselves in early childhood. In addition to other significant health and social concerns, individuals with picky eating tendencies have reported gastrointestinal issues, not limited to chronic constipation, diarrhea, and abdominal pain, which result in metabolic disruption in addition to psychological issues (Williams et al., 2000; Blenner et al., 2011). Emotion dysregulation, anxiety, and symptoms similar to obsessive compulsive disorder may occur as a result of food selectivity in autistic individuals (Lafraire et al., 2016; Zickgraf et al., 2018; Bozzini et al., 2019).

Despite the research showing the effects of picky eating and although an increasing number of studies implicate these eating-related challenges in ASD during childhood, eating behaviors in ASD during adulthood are largely understudied. Thus, for example, it is unclear how many autistic adults consider themselves to be picky eaters. However, there is some research showing that food neophobia (i.e., fear of trying a new food), a construct related to picky eating, is common for adolescents and young autistic adults, particularly when compared to their non-autistic peers (Kuschner et al., 2015). As such, learning more about food selectivity issues in autistic adults is extremely important

as there could be substantial unmet needs that are not being addressed later in development and because food selectivity issues can affect quality of life.

It is critically important to bridge gaps in our knowledge around picky eating across development in ASD, primarily because it can result in a variety of concerns, including nutritional deficiencies (Williams et al., 2000) and gastrointestinal issues. Bloody stools, vomiting, and gastroesophageal reflux are elevated in some autistic individuals (Leader et al., 2020; Williams et al., 2000). As a result, picky eating may result in metabolic dysfunction or immune dysregulation (Hsiao, 2014). These concerns, when combined with other functional impacts such as meal time stress and disruption or interference with socializing, show the impact of picky eating in autistic individuals. Several factors have been linked to picky eating in ASD during childhood including sensory (e.g., oral texture) aversions (Ahearn et al., 2001; Zickgraf et al., 2022). However, these factors constitute only one of several likely contributors to picky eating in autistic individuals. Eating and feeding disorders such as Avoidant Restrictive Food Intake Disorder (ARFID) are highly comorbid with ASD and therefore play a key role (Koomar et al., 2021). ARFID is a relatively new diagnosis first appearing in the DSM-5 (APA, 2013) and is characterized by a feeding or eating disturbance which may result in significantly lower caloric intake that ultimately leads to failure to meet nutritional or energy needs (Koomar et al., 2021; Zimmerman et al., 2017). While a diagnosis such as ARFID contributes to picky eating, determining other factors which contribute to picky eating may provide individuals, families, and clinicians with the necessary tools to improve the health and social impacts of picky eating in autistic individuals.

Role of Sensory Sensitivities in Picky Eating

Only since DSM-5 (APA, 2013) has hypo- and/or hyper-sensitivity to sensory input or unusual sensory interests been included in the diagnostic criteria for ASD. Nevertheless, sensory issues are common in autistic individuals and were identified in early diagnostic descriptions in the 1940s (e.g., Kanner, 1943). There is now a solid evidence base to suggest that these issues likely contribute to picky eating (Cermak et al., 2010; Zickgraf et al., 2022). Children who showed preferences for certain textures showed significant differences in food choices, reduced appetite, and resistance to trying more foods compared to children who did not display texture preferences (Smith et al., 2005). These sensory issues may include aversions to strong flavors, smells, or textures (Harris et al., 2019). For example, children who are over-responsive to smells may become uncomfortable in a school cafeteria due to the range of food available (Cermak et al., 2010). Such sensory sensitivity may lead to picky eaters limiting their intake to certain textures, smells, and tastes (Twachtman-Reilly et al., 2008). Traditionally, alongside diagnostically inherent inflexibility and rigidity, these sensory issues are considered one of the primary driving forces behind picky eating observed in autistic children (Cermak et al., 2010). Other factors have been implicated (e.g., rigidity [Zickgraf et al., 2022]) but few have been investigated to date. One primary candidate yet to be studied is disgust processing, which is elaborated below.

Importance of Disgust Processing for Picky Eating

Disgust can be defined as revulsion at the prospect of oral incorporation of an offensive food (Rozin et al., 1987). Even if the food is an acceptable food, individuals may consider that food unacceptable due to factors which will be discussed below. Reasons for food rejection may include the belief that the object has negative sensory properties, anticipation of harm following ingestion, and ideation factors such as knowledge of origin or nature of food (Rozin et al., 1987; Goetz et al., 2013).

Disgust is primarily motivated by ideation factors. Individuals who reject food based on these factors assume that an item may taste bad and react by gagging, vomiting, and/or showing facial expressions of disgust (Rozin et al., 1987; Zickgraf, Murray et al., 2019). Research has shown that, similar to individuals with Obsessive Compulsive Disorder (OCD), picky eaters are more disgust-sensitive than non-picky eaters (Kauer et al., 2015; Bhikram et al., 2017). The use of cognitive strategies has been helpful in reducing disgust reactions and negative emotions related to disgust in individuals with OCD (Goetz et al., 2013).

Many theories have attempted to explain disgust as a construct particularly related to feeding and eating. Animalness is a theory that claims that almost all food disgust is based on foods with animal origin (Rozin et al., 1987). This theory states that all animals or animal products are potentially disgusting. Since humans are more similar to animals than plants, the theory associates food disgust with foods that have properties similar to humans or in close relations with humans (e.g., pets). However, this theory fails to explain food avoidance in foods that are not of animal origin. Another theory is based on spoilage and decay of foods. This theory assumes that because spoiled and decayed items

may be disease vectors, it is natural that these foods may elicit feelings of disgust (Rozin et al., 1987). While this theory may help to explain disgust processing, it is unlikely that it is the only reason for food avoidance.

Recent literature has suggested the anterior insula plays an important role in autism (Uddin et al., 2009; Avery et al., 2018). Similarly, the anterior insula has been implicated in disgust processing (Wright et al., 2004). Regardless of the psychological mechanism, the brain likely serves as a central mediator of the relationship between disgust processing and picky eating. One study which consisted of autistic adolescents and young males and age- and IQ-matched typically developing males showed that in ASD, like in non-autistic development, specific brain regions (e.g., the insula) respond preferentially to sweet vs. neutral tasting liquids (Avery et al., 2018). However, only the autistic participants showed a positive correlation between their self-reported taste sensitivity and activity in the insular cortex while being presented with sweet vs. neutral flavored fluids (Avery et al., 2018). Furthermore, increased taste sensitivity in the ASD group was associated with a lower healthy eating index based on their completion of a 24-hour food diary. Therefore, this brain basis of taste sensitivity is linked to eating patterns and behaviors, which could cascade to impact broader health. This pattern of results could also be at play for disgust processing. For example, increased insula activity has been documented in clinical groups who are particularly sensitive to disgust, such as those diagnosed with OCD, when shown disgusting stimuli during a task (Berle & Phillips, 2006).

Other studies have focused on the emotional, rather than the sensory-perceptual, components of disgust processing. One study shows that disgust processing may be

related to anxiety or negative consequences of eating such as choking or gagging (Harris et al., 2019). Unlike fear which is a response to a threat, disgust processing is perceived to be a response to potential contamination. As such, the emotional component of disgust processing may be accompanied by physiological reactions such as decreased heart rate (Woody & Teachman, 2000). A recent review indicated anxiety is one of the most common co-occurring conditions in autistic children (Ambrose et al., 2021). For this reason, anxiety may be a critical component when determining the relationship between disgust processing and picky eating. In one study, the Beck Anxiety Inventory (BAI) was used to study the relationship between disgust sensitivity and health/general anxiety. A strong emotional component of disgust is related to both health anxiety and general anxiety as disgust sensitivity scores were found to be significantly related to both health and general anxiety scores (Thorpe et al., 2003). Health anxiety is related to one's fear of acquiring a disease and has been linked to contamination fear as well as disgust. Anxiety disorders related to disgust (e.g., OCD) are not easily treated by exposure-based treatments. Although there is little explanation for this, researchers do know that emotional reactions occur as a result of intense sensory experiences including disgust. As such, these disgust-related experiences may result in greater sensitivity to different sensory modalities than other food-related avoidance disorders (e.g., ARFID) (Harris et al., 2019).

Given the clinical implications, knowing whether disgust processing, particularly food-related disgust processing, plays a role in picky eating for autistic individuals is crucial knowledge that we currently lack.

Role of Sensory Sensitivities in Disgust

Given that the primary role of disgust is to help individuals avoid pathogens, certain sensory characteristics might be less appealing (Rozin et al., 1987). In other words, the relationship between food-related disgust processing and picky eating may be mediated by certain textures or smells which are deemed as repulsive or unacceptable for consumption. One study showed that picky eaters were more likely to reject foods with a slimy texture (Kauer et al., 2015). Similarly, another study showed that disgust processing was strongly associated with sticky and wet textures but only moderately associated with cold and lumpy textures, revealing that disgust processing may be particularly related to stickiness (Saluja & Stevenson, 2019). Heightened sensitivity to smells has also been associated with picky eating (Smith et al., 2020). Similar to the relationship mentioned previously, sense of smell plays a critical role in the rejection of disgusting and potentially threatening food (Schienle & Schöpf, 2017). For example, many foods (e.g., chicken) emit a foul odor when they are no longer safe to eat. Despite the independently established relationships between picky eating and disgust processing and between sensory sensitivity and disgust processing in the general population, these have not been examined in the context of ASD, and there has been little research to determine the relationship among all three in any samples.

Therefore, the following aims and accompanying hypotheses are provided to bridge our gaps in knowledge around food-related disgust-related processing and its potential correlates among autistic individuals.

Aims and Hypotheses

Aim 1: Examine the differences in food-related disgust processing between non-autistic adults and autistic adults.

Hypothesis 1: Autistic adults will report more gagging and feelings of food-related disgust when presented with new or disliked foods than will non-autistic adults.

Aim 2: Examine the relationship between food-related disgust processing and picky eating in autistic adults.

Hypothesis 2: There will be a positive correlation between food-related disgust processing and picky eating in autistic adults, such that greater food-related disgust ratings to new or disliked foods will be associated with increased reports of picky eating.

Aim 3: Examine to what degree the direct association between food-related disgust processing and picky eating is mediated by sensory (i.e., oral texture and/or olfactory) sensitivity among autistic adults.

Hypothesis 3: The relationship between food-related disgust processing and picky eating will be mediated by oral texture and/or olfactory sensory sensitivities. More specifically, the direct relationship between food-related disgust processing and picky eating will remain statistically significant, but the indirect relationship, which includes sensory (i.e., oral texture and/or olfactory) sensitivity as a mediator, will also account for a statistically significant portion of the shared variance between food-related disgust processing and picky eating.

Methods

Participants

Young autistic adults (n=252, 169 assigned female at birth; age: M=31.3, SD=5.59, range=20.58-41.33) were recruited via Simons Powering Autism Research (SPARK), Research Match as part of a follow-up study 1.5 years after initial data collection (see McQuaid et al., 2022). This follow-up study required the completion of an online battery of widely used and psychometrically sound questionnaires about eating-related behaviors and their potential correlates. All of these autistic adults had been given an ASD diagnosis by a medical professional. Participants completed the Autism Spectrum Quotient-28 (AQ28; Hoekstra et al., 2011) during the first wave of data collection 1.5 years before the current wave of data collection. The AQ28 is a 28-item self-report screening measure of autistic traits, with higher scores indicating more traits. The AQ28 has demonstrated good internal consistency in samples of autistic adults (alpha=.77-.86; Hoekstra et al., 2011). Of the participants in the current sample, 93.3% screened positive for ASD (AQ28>65). Only "independent" autistic adults, as specified by SPARK, were included in the current study. "Independent" adults are described by SPARK as adults ≥18 years of age who do not have a court-appointed legal guardian, and as a result, can consent for themselves. Due to these specific criteria, the individuals in this study were unlikely to have a co-occurring intellectual disability. Additionally, none of the participants reported having a diagnosis of intellectual disability currently or in the past when the medical history questionnaire was completed.

Additionally, non-autistic adults (n=145, 78 assigned female at birth; age: M=28.39, SD=6.26, range=18-39) were recruited via Qualtrics to serve as a comparison group for the autistic adults to address Aim 1 of the thesis. Non-autistic adults were excluded if they reported any history of an Autism Spectrum Disorder diagnosis or an eating disorder. See Table 1 for basic demographic information on both the autistic and non-autistic adult samples. See Table 2 for medical conditions and dietary practices of autistic adult participants.

Table 1. Participant demographic characteristics for autistic (ASD) and non-autistic (NA) adults.

Construct	**ASD n=252**	**NA n=145**
Age, years		
Mean (SD)	31.20 (5.59)	28.39 (6.26)
Range	20.58-41.33	18-39
Sex designated at birth, n (%)		
Female	169 (67.1%)	78 (53.8%)
Male	83 (32.9%)	67 (46.2%)
Gender Identity		
Gender diverse	38 (15.1%)	7 (4.8%)
Cisgender	214 (84.9%)	138 (95.2%)
Race and Ethnicity, n (%)		
Race*		
Asian	3 (1.2%)	15 (10.3%)
Black/African-American	5 (2%)	26 (17.9%)
More than one race	25 (9.9%)	6 (4.1%)
Native American/Alaska Native	2 (0.8%)	4 (2.8%)
White	213 (84.5%)	89 (61.4%)
Other	3 (1.2%)	0 (0%)
Unknown	1 (0.4%)	3 (2.1%)
Ethnicity		
Latinx	23 (9.1%)	23 (5.9%)
Not Latinx	226 (89.7%)	105 (72.4%)
Unknown	3 (1.2%)	17 (11.7%)
Educational Attainment		
Less than bachelor's degree	166 (66.9%)	90 (62.1%)
Bachelor's degree or higher	86 (34.1%)	55 (37.9%)
AQ28		
Mean (SD)	82.42 (11.60)	
Range	47-108	

Note: *Race, N=251.

Table 2. Dietary practices and medical conditions that could impact diet in autistic adults.

Construct	Autistic adults n=252
Dietary practices	
No dietary restriction	109 (43.3%)
1 or more dietary restrictions	143 (56.7%)
Observation of religious restrictions	8
Regularly fast	21
Currently or frequently dieting	57
Diet affected by medical conditions	39
Food allergy or sensitivity	92
Other dietary restriction	11
Medical conditions	
No medical condition	114 (45%)
1 or more medical conditions	138 (55%)
Gastroesophageal reflux/acid reflux/frequent heartburn	105
Irritable Bowel Syndrome	77
Crohn's disease	2
Ulcerative colitis	4
No medical condition	114

Measures

In the current study, I focused on assessing the constructs of disgust processing, picky eating, and both olfactory and oral texture sensory sensitivities. The Disgust Scale-Revised (Harris et al., 2019) was used to assess food-related disgust processing in adults. Picky eating was quantified using the Nine Item Avoidant/Restrictive Food Intake Disorder Screen (NIAS; Zickgraf & Ellis, 2018), the Adult Eating Behavior Questionnaire (AEBQ; Hunot et al., 2016), and portions of the Eating Habits Survey (Wildes et al., 2012). Lastly, oral texture and olfactory sensory sensitivities were assessed using items from the broader Eating Habits Survey (Wildes et al., 2012). Two items were asked of participants to assess dietary practices and medical conditions that could impact

eating behaviors. Participants were asked to select all of the following statements that apply to their diet: “I observe religious restrictions on my diet”, “I fast regularly for religious or health reasons”, “I am currently (or I am frequently but not always) on a diet to lose weight”, “My diet is affected by a medical condition”, “I do not eat a food or type of food because of an allergy or sensitivity”, “Other dietary restriction”, “None of the above.” Participants were also asked if they had ever been diagnosed with any of the following conditions: gastroesophageal reflux/acid reflux/frequent heartburn, irritable bowel syndrome, Crohn's disease, ulcerative colitis, or none of the above. Scores on this item will be utilized as covariate in analyses presented here.

Disgust

The Disgust Scale-Revised (Harris et al., 2019) is composed of four items derived from portions of the broader Eating Habits Survey (Wildes et al., 2012) and was used here to assess food-related disgust in adults. The items from this scale are focused on assessing disgust and gagging associated with new or disliked foods (Harris et al., 2019). The four items are as follows (in self-rating format for adults): “Do you gag when tasting a new food?”, “Do you gag when tasting a disliked food?”, “Do you feel disgusted when presented with a new food?”; “Do you feel disgusted when presented with a disliked food?” Items were presented on a 5-point Likert scale (1=always, 2=more than half the time, 3=about half the time, 4=less than half the time, 5=rarely or never). This 4-item scale has good internal consistency (Cronbach’s alpha=.83; Harris et al., 2019) and strong face validity given the transparency of item content. A summary score is calculated by

summing the 4 items. For specific aim 1, this summary score serves as the dependent variable for Aim 1, but the independent variable for Aims 2 and 3.

See Table 3 for questions used to assess food-related disgust in adults.

Table 3. Questions from the Disgust Scale-Revised (Harris et al., 2019).

Disgust Scale-Revised Items
1. Do you gag when tasting a new food?
2. Do you gag when tasting a disliked food?
3. Do you feel disgusted when presented with a new food?
4. Do you feel disgusted when presented with a disliked food?

Picky Eating

Three indices of picky eating will be used in the current study including one rating of overall picky eating, one rating of food fussiness, and one rating of dietary variety/intake.

Overall Picky Eating

The Nine Item Avoidant/Restrictive Food Intake Disorder Screen (NIAS; Zickgraf & Ellis, 2018) was used to assess picky eating. Specifically, the picky eating subscale, which is composed of 3 items (see Table 4) from a broader 9-item questionnaire that is rated on a 6-point Likert scale (0=strongly disagree, 1=disagree, 2=slightly disagree, 3=slightly agree, 4=agree, 5=strongly agree) was chosen. The picky eating subscale reflects good internal consistency (Cronbach's alpha=.86; Zickgraf & Ellis, 2018) and good construct validity as shown by positive correlation between screening positively on NIAS subscales and high association with an ARFID diagnosis (Murray et al., 2021). The

subscale is scored from 0 to 15, with a higher score indicating higher levels of the stated metric. The resulting score serves as the independent variable for Aim 1, but the dependent variable for Aims 2 and 3.

Food Fussiness

The self-rated Adult Eating Behavior Questionnaire (AEBQ; Hunot et al., 2016) was also used to assess picky eating. Specifically, the Food Fussiness scale from the AEBQ, which is composed of 5 items (see Table 4) from a broader 35-item questionnaire that is rated on 5-point Likert scales (1=never, 2=rarely, 3=sometimes, 4=often, 5=always) was chosen. The food fussiness scale for adults reflects good internal consistency (Cronbach's alpha=.88; Zickgraf & Rigby, 2019) and good construct validity when compared to the Three-Factor Eating Questionnaire which also measures eating behaviors in the adult population (Jacob et al., 2022). A summary score is calculated by averaging the 4 items. This summary score serves as the independent variable for Aim 1, but the dependent variable for Aims 2 and 3. See Table 4 for questions used to assess picky eating from the AEBQ and NIAS.

Table 4. Picky eating-related items from the Nine Item Avoidant/Restrictive Food Intake Disorder Screen (NIAS) and Adult Eating Behavior Questionnaire (AEBQ).

NIAS Overall Picky Eating Items	*AEBQ Food Fussiness Items*
1. I am a picky eater.	1. I refuse new foods at first.
2. I dislike most of the foods that other people eat.	2. I enjoy tasting new foods.
3. The list of foods that I like and will eat is shorter than the list of foods I won't eat.	3. I enjoy a wide variety of foods.
	4. I am interested in tasting food I haven't tasted before.
	5. I often decide that I don't like a food before tasting it.

Dietary Variety/Intake

Dietary variety/intake was assessed using questions from the food frequency portion of the Eating Habits Survey (Wildes et al., 2012). Participants were asked to "indicate which of the following foods and beverages would be easy for you to try a bite or two if you were given these foods or drinks" based on a 5-point Likert scale (1=always, 2=more than half the time, 3=about half the time, 4=less than half the time, 5=rarely or never). Food types included fruit/fruit juice, vegetable/vegetable juice, salty bread products (e.g., crackers), sweet bread products (e.g., cake), unprocessed/processed meat (e.g., steak and pepperoni, respectively), and dairy products (e.g., cheese).

Sensory Sensitivity

Oral texture and olfactory sensitivities were assessed using 8 total items adapted from the Eating Habits Survey (Wildes et al., 2012). The scales specifically assessing smell and food texture sensitivities used 4 items for oral texture and 4 items for olfactory (see Table

5) which come from a broader 39-item questionnaire that are rated on a 5-point Likert scale (1=always, 2=more than half the time, 3=about half the time, 4=less than half the time, 5=rarely or never; Zickgraf et al., 2022). These scales showed strong face validity and good internal consistency for smell sensitivity (Cronbach's alpha=.90) and oral texture sensitivity (Cronbach's alpha=.91; Zickgraf et al., 2022). Summary scores for both oral texture and olfactory sensitivities are calculated by summing the 4 items for each category independently. Each of these summary scores serve as a mediator for Aim 3. See Table 5 for questions used to assess oral texture and olfactory sensitivities.

Table 5. Eating Habits Survey questions assessing oral texture sensory sensitivity and olfactory sensory sensitivity.

Eating Habits Survey items assessing oral texture sensitivity	*Eating Habits Survey items assessing olfactory sensitivity*
1. Are you sensitive to the textures of food?	1. Are you sensitive to the smells of food?
2. Does sensitivity to the textures of food keep you from trying new foods?	2. Does sensitivity to smells keep you from trying new foods?
3. Does sensitivity to food textures keep you from eating a variety of foods?	3. Does sensitivity to smells keep you from eating a variety of foods?
4. Does sensitivity to the textures of foods keep you from participating in social gatherings with food?	4. Does sensitivity to smells keep you from participating in social gatherings with food?

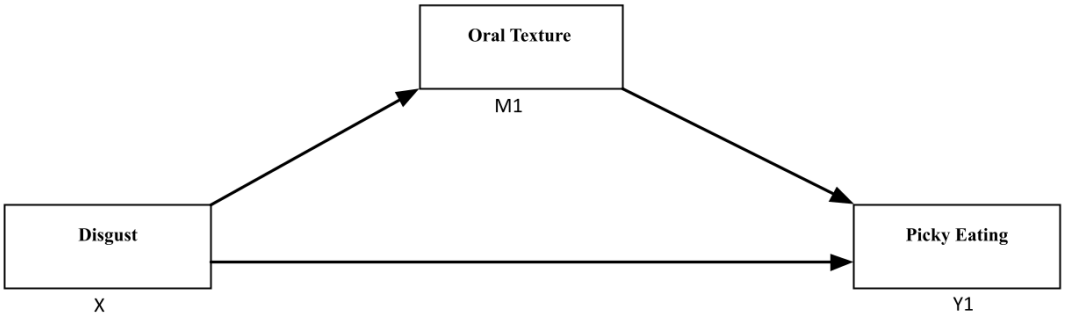
Data Analysis

Aim 1: Analysis of covariance (ANCOVA) was used to examine the differences in disgust processing between non-autistic and autistic adults. These analyses were implemented in SPSS, version 28.0.

Aim 2: Hierarchical linear regressions were utilized to examine associations between disgust processing (step 2) and picky eating among autistic young adults after accounting for the potential influences of age, sex assigned at birth, and autistic traits (step 1). As with Aim 1, the regression analyses were implemented in SPSS, version 28.0.

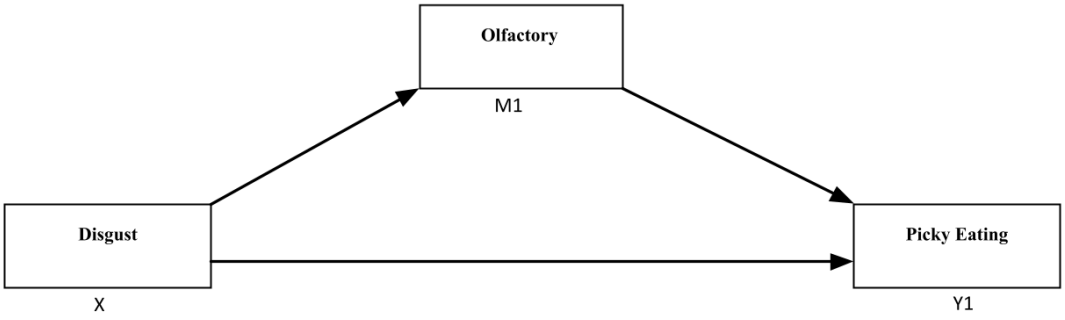
Aim 3: Mediation analyses were used to examine to what degree the direct association between disgust processing and picky eating was mediated by sensory (i.e., oral texture and/or olfactory) processing. These analyses were implemented using the PROCESS package (Hayes, 2022) in R (version 4.2.0). In total, six simple mediation models (See Figures 1 and 2 for visual depictions of the proposed mediation models) were tested (PROCESS Model 4). In all six models, the disgust mean score was the independent variable. Dependent variables included the NIAS picky eating mean, AEBQ Food Fussiness mean score, and the willingness to try vegetables/vegetable juice mean score. Mediator variables were either olfactory or oral texture sensory sensitivity mean scores. Covariates in all models were age, educational attainment, dietary restrictions, and sex assigned at birth. Modeling implemented bootstrap confidence intervals using 10,000 bootstrap samples. To assess the indirect effect or mediation, confidence intervals that did not include zero were considered significant.

Figure 1. Schematic mediation model of oral texture sensitivity as a mediator of the association between food-related disgust processing and picky eating in autistic adults.



Covariates = age; sex; educational attainment; dietary restrictions

Figure 2. Schematic mediation model of olfactory sensitivity as a mediator of the association between food-related disgust processing and picky eating in autistic adults.



Covariates = age; sex; educational attainment; dietary restrictions

Results

Prior to performing primary analyses, I examined the internal consistency reliability of the 4-item food-related disgust scale among autistic adults to ensure adequate basic psychometrics. Just as in prior research conducted with neurotypical adults (Harris et al., 2019), I found good internal consistency (Cronbach's alpha=0.85) for this scale among autistic adults.

Aim 1: Examine the differences in food-related disgust processing between non-autistic adults and autistic adults.

An ANCOVA was run with group (autistic vs. non-autistic adults) as the between subject factor, age, sex assigned at birth, educational attainment, and dietary restrictions as covariates, and mean food-related disgust processing scores as the dependent variable. After accounting for covariates, autistic and non-autistic adults did not differ in their mean food-related disgust processing ratings (ASD: M=3.54, SD=1.07; NA: M=3.46, SD=1.00; F=1.26, p=.26).

Aim 2: Examine the relationship between food-related disgust processing and picky eating in autistic adults.

Linear regressions revealed significant associations between food-related disgust processing and the three measures of picky eating (overall picky eating, food fussiness and dietary variety/intake). They are each examined separately below.

Overall Picky Eating

The covariates, entered in step 1 of the regression (age, sex assigned at birth, educational attainment, and dietary restrictions), accounted for 7% of variance in overall picky eating (F= 4.39, p=.002). This relationship was driven by sex assigned at birth such that autistic adults assigned female at birth rated themselves as experiencing more overall picky eating than those assigned male at birth (t=3.40, p<.001), and to a lesser extent age, such that older age among these young adults was associated with more picky eating (t=2.29, p<.05). When food-related disgust processing ratings were added to the model in step 2, disgust processing accounted for an additional 24% (F=119.96, p<.001) of the variance in overall picky eating beyond the covariates (see Table 6).

Food Fussiness

Again, the covariates, entered in step 1 of the regression (age, sex assigned at birth, educational attainment, and dietary restrictions), accounted for 7% of variance in food fussiness (F=4.33, p=.002). This association was driven by sex assigned at birth with greater food fussiness reported by autistic adults assigned female at birth (t=3.35, p<.001). When food-related disgust processing ratings were added to the model, disgust processing accounted for an additional 27% (F=143.56, p<.001) of the variance in food fussiness beyond the covariates (see Table 6).

Table 6. Regressions of the overall picky eating and food fussiness questionnaires on control variables and food-related disgust processing for autistic adults.

	NIAS Picky Eating Subscale					**AEBQ Food Fussiness Subscale**				
	B	SE	95% CI for B	b	t	B	SE	95% CI for B	b	t
Step 1	R^2=0.07, *F*=4.39, *p*=.002					R^2=0.07, *F*=4.33, *p*=.002				
Age	0.12	0.05	[0.02, 0.22]	0.15	2.29[b]	0.10	0.06	[-0.02, 0.22]	0.11	1.72
Sex at Birth	2.05	0.60	[0.86, 3.23]	0.21	3.40[d]	2.31	0.70	[0.95, 3.67]	0.21	3.35[d]
Education[a]	-0.28	0.61	[-1.47, 0.91]	-0.03	-0.47	0.06	0.70	[-1.32, 1.43]	0.01	0.08
Dietary Restriction	0.42	0.58	[-0.73, 1.57]	0.05	0.72	1.41	0.67	[0.09, 2.72]	0.13	2.10[b]
Step 2	ΔR^2=0.31, ΔF=119.96, Δp<.001					ΔR^2=0.34, ΔF=143.56, Δp<.001				
Control Covariates										
Disgust Scale	-2.49	0.23	[-2.94, -2.05]	-0.59	-10.95[d]	-3.05	0.25	[-3.56, -2.55]	-0.62	-11.98[d]

[a] Completed a Bachelor's degree vs. did not complete a Bachelor's degree
[b] p<0.05
[c] p<0.01
[d] p<0.001

Dietary Variety/Intake

Overall, linear regressions revealed significant associations between food-related disgust processing and dietary intake/variety (i.e., a willingness to try food from a variety of food groups). Each food group is examined separately below.

The covariates, entered in step 1 of the regression (age, sex assigned at birth, educational attainment, and dietary restrictions), accounted for 2% of variance in willingness to try fruit/fruit juice ratings; however, this was a non-significant association. When food-related disgust processing ratings were added to the model in step 2, disgust processing

accounted for an additional 8% (F=21.90, p<.001) of the variance in willingness to try fruit/fruit juice ratings beyond the covariates (see Table 7).

In contrast, step 1 covariates accounted for a statistically significant amount of variance (5%) in willingness to try vegetable/vegetable juice ratings (F=2.92, p=.02), which was driven by sex assigned at birth (t=2.95, p<.05). Autistic individuals assigned female at birth were less willing to try vegetables/vegetable juice than those who were assigned male at birth. When food-related disgust processing scores were added in step 2, they were also a significant predictor of (accounting for 18% of variance in) willingness to try vegetables/vegetable juice ratings, after accounting for covariates (F=54.76, p<.001). See Table 7.

Table 7. Regressions of willingness to try fruits and vegetables onto covariates and food-related disgust processing for autistic adults.

	Fruit/Fruit Juice					**Vegetable/Vegetable Juice**				
	B	SE	95% CI for B	b	t	B	SE	95% CI for B	b	t
Step 1	R^2=0.02, *F*=1.02, *p*=.40					R^2=0.05, *F*=2.92, *p*=.02				
Age	0.01	0.01	[-0.02, 0.03]	0.03	0.52	0.002	0.13	[-0.02, 0.03]	0.01	0.19
Sex at Birth	0.17	0.13	[-0.09, 0.44]	0.08	1.31	0.46	0.15	[0.15, 0.76]	0.19	2.95[b]
Education[a]	0.18	0.13	[-0.09, 0.44]	0.08	1.30	0.03	0.16	[-0.28, 0.34]	0.01	0.19
Dietary Restriction	0.04	0.13	[-0.22, 0.29]	0.02	0.27	0.29	0.15	[-.004, 0.59]	0.12	1.94
Step 2	ΔR^2=0.08, ΔF=21.90, Δp<.001					ΔR^2=0.18, ΔF=54.76, Δp<.001				
Control Covariates										
Disgust Scale	-0.28	0.06	[-0.39, -0.16]	-0.30	-4.68[d]	-0.48	0.07	[-0.61, -0.35]	-0.44	-7.4[d]

[a] Completed a Bachelor's degree vs. did not complete a Bachelor's degree
[b] p<0.05
[c] p<0.01
[d] p<0.001

The covariates, entered in step 1 of the regression (age, sex assigned at birth, educational attainment, and dietary restrictions), accounted for 1% of variance in willingness to try salty bread products ratings; however, this was a non-significant association. When food-related disgust processing ratings were added to the model in step 2, disgust processing accounted for an additional 5% (F=12.34, p<.001) of the variance in willingness to try salty bread products ratings beyond the covariates (see Table 8).

Similarly, step 1 covariates were non-significant correlates of willingness to try sweet bread products ratings, accounting for 2% of variance. But again, in step 2, food-related

disgust processing was a significant predictor of willingness to try sweet bread products ratings (F=6.78, p=.01), accounting for 3% of variance in scores (see Table 8).

Table 8. Regressions of willingness to try bread products onto covariates and food-related disgust processing for autistic adults.

	Salty Bread Products					**Sweet Bread Products**				
	B	SE	95% CI for B	b	t	B	SE	95% CI for B	b	t
Step 1	R^2=0.01, F=0.30, p=.88					R^2=0.02, F=0.97, p=.43				
Age	0.003	0.01	[-0.02, 0.03]	0.02	0.24	0.02	-0.01	[-0.01, 0.04]	0.07	1.09
Sex at Birth	-0.12	0.15	[-0.41, 0.17]	-0.05	-0.84	-0.10	0.16	[-0.41, 0.21]	-0.04	-0.65
Education[a]	-0.03	0.15	[-0.32, 0.26]	-0.01	-0.20	-0.05	0.16	[-0.36, 0.27]	-0.02	-0.28
Dietary Restriction	-0.10	0.14	[-0.38, 0.18]	-0.05	-0.69	-0.21	0.15	[-0.51, 0.09]	-0.10	-1.40
Step 2	ΔR^2=0.05, ΔF=12.34, Δp<.001					ΔR^2=0.03, ΔF=6.78, Δp=.01				
Control Covariates										
Disgust Scale	-0.23	0.07	[-0.36, -0.10]	-0.23	-3.51[d]	-0.19	0.07	[-0.33, -0.05]	-0.17	-2.60[c]

[a] Completed a Bachelor's degree vs. did not complete a Bachelor's degree
[b] p<0.05
[c] p<0.01
[d] p<0.001

Step 1 covariates accounted for a statistically significant amount of variance (7%) in willingness to try unprocessed/processed meat ratings (F=4.81, p<.001), which was driven by sex assigned at birth (t=3.87, p<.001). Autistic individuals assigned female at birth were less willing to try unprocessed/processed meats than those who were assigned male at birth. When food-related disgust processing scores were added in step 2, they were also a significant predictor of (accounting for 6% of variance in) willingness to try

unprocessed/processed meat ratings, after accounting for covariates (F=17.79, p<.001). See Table 9.

Finally, step 1 covariates were non-significant correlates of willingness to try dairy products ratings, accounting for 3% of variance. But again, in step 2, food-related disgust processing was a significant predictor of willingness to try dairy products ratings (F=15.78, p<.001), accounting for 6% of variance in scores (see Table 9).

Table 9. Regressions of willingness to try meat and dairy products onto covariates and food-related disgust processing for autistic adults.

	Unprocessed/Processed Meat					**Dairy Products**				
	B	SE	95% CI for B	b	t	B	SE	95% CI for B	b	t
Step 1	R^2=0.07, F=4.81, p<.001					R^2=0.03, F=1.93, p=.11				
Age	0.02	0.01	[-0.01, 0.04]	0.10	1.56	-0.02	0.02	[-0.05, 0.01]	-0.07	-1.004
Sex at Birth	0.56	0.15	[0.28, 0.85]	0.24	3.87[d]	0.20	0.17	[-0.14, 0.54]	0.07	1.16
Education[a]	0.01	0.15	[-0.28, 0.30]	0.003	0.05	0.20	0.18	[-0.54, 0.15]	-0.07	-1.12
Dietary Restriction	-0.05	0.14	[-0.33, 0.23]	-0.02	-0.36	-0.36	0.17	[-0.69, -0.03]	-0.14	-2.16
Step 2	ΔR^2=0.06, ΔF=17.79, Δp<.001					ΔR^2=0.06, ΔF=15.78, Δp<.001				
Control Covariates										
Disgust Scale	-0.27	0.07	[-0.40, -0.15]	-0.27	-4.22[d]	-0.31	0.08	[-0.47, -0.16]	-0.26	-3.97[d]

[a] Completed a Bachelor's degree vs. did not complete a Bachelor's degree
[b] p<0.05
[c] p<0.01
[d] p<0.001

Aim 3: Examine to what degree the direct association between food-related disgust processing and picky eating is mediated by sensory (i.e., oral texture and/or olfactory) processing.

Results for Aim 2 established the association between food-related disgust processing and picky eating across a variety of metrics. Next, I used mediation analysis to examine if (either oral texture or olfactory) sensory sensitivity mediates the relationship between food-related disgust processing (independent variable in all models) and picky eating (one of the three dependent variables of NIAS mean score, AEBQ Food Fussiness mean score, or willingness to try vegetables/vegetable juice mean ratings) across six models. Across all six models, the pattern was essentially the same. Namely, the direct relationship between food-related disgust and picky eating, regardless of metric, remained robust. This relationship, in turn, was mediated by sensory sensitivity (either olfactory or oral texture) as indicated by the bootstrap 95% confidence intervals not overlapping with 0. For detailed results, please see Figures 3 and 4.

Figure 3: Results for olfactory sensitivity as a mediator of the association between food-related disgust processing and picky eating, including a) overall picky eating using the NIAS mean score, b) food fussiness using the AEBQ mean score, and c) likelihood of trying vegetable/vegetable juice mean score. All indirect effects were significant as indicated by bootstrap confidence intervals not overlapping with 0. **p<.0001, *p<.01

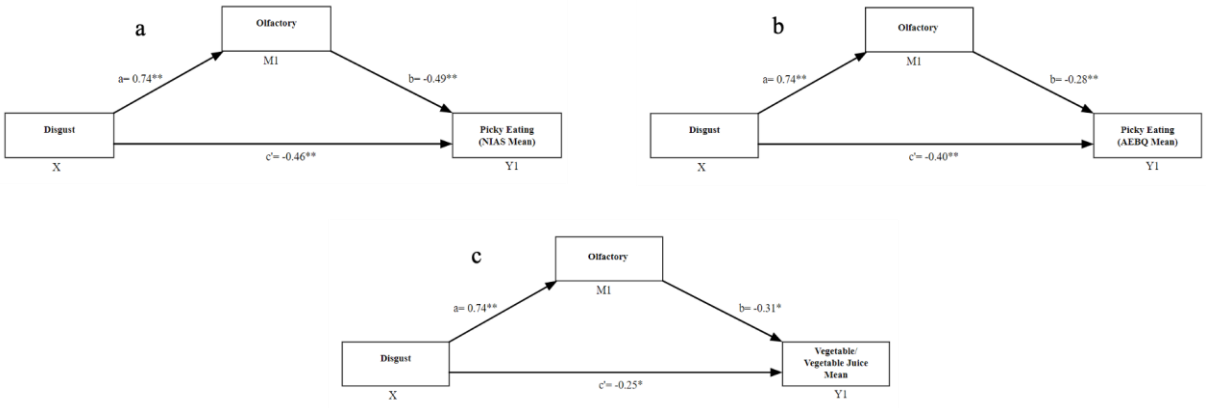
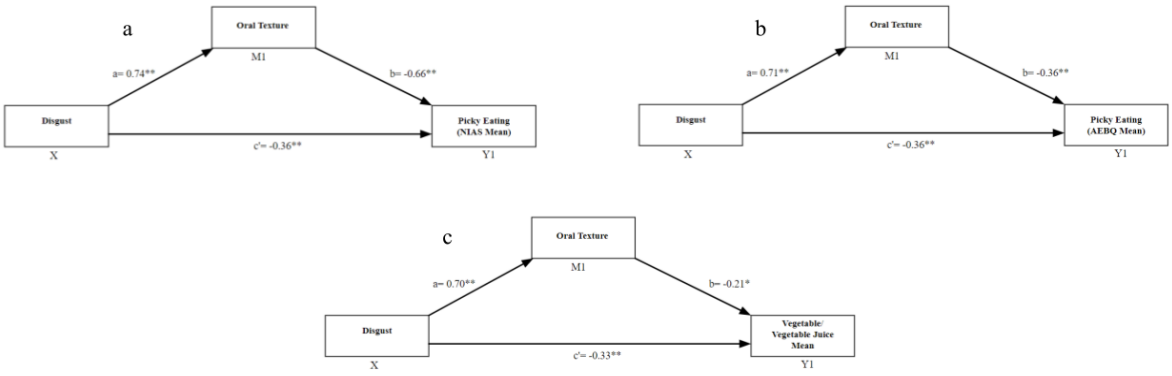


Figure 4: Results for oral texture sensitivity as a mediator of the association between food-related disgust processing and picky eating, including a) overall picky eating using the NIAS mean score, b) food fussiness using the AEBQ mean score, and c) likelihood of trying vegetable/vegetable juice mean score. All indirect effects were significant as indicated by bootstrap confidence intervals not overlapping with 0. **p<.0001, *p<.01



Discussion

Our knowledge of picky eating, including its etiology, is limited in autistic adults because picky eating is viewed as a challenge experienced primarily by young children. Furthermore, most existing research has linked picky eating in ASD to sensory issues, often neglecting other possible contributors, such as disgust processing. Therefore, the present study attempted to build on the limited research base by examining the differences in food-related disgust processing between autistic and non-autistic adults, examining associations between food-related disgust processing and various metrics of picky eating as well as determining to what degree, if any, the association between food-related disgust processing and picky eating is mediated by sensory sensitivities among young autistic adults.

For the first aim, differences in food-related disgust processing between autistic and non-autistic adults were examined. In contrast to my prediction, autistic adults and non-autistic adults did not differ in food-related disgust processing. Due to the lack of research on this topic in autistic adults, previous research does not dispute or align with these findings. Overall, these findings suggest that there are no inherent differences in food-related disgust processing among autistic adults, unlike picky eating and sensory sensitivities, which are both experienced by autistic adults much more commonly than by non-autistic adults. However, the scale used here (The Disgust Scale-Revised [Harris et al., 2019]) was a bespoke measure of self-reported food-related disgust processing. Future research should further interrogate both food-related and nonfood-related disgust processing in ASD. For example, the broader research literature suggests there are two components of disgust: 1) disgust sensitivity or how distressed an individual becomes by

disgust-related experiences and 2) disgust propensity or the likelihood that an individual responds to stimuli with disgust. Future research should expand upon the current study's findings to compare self-reported disgust sensitivity versus disgust propensity (for both food and nonfood items) between autistic and non-autistic adults. The current study represents only an initial foray into this line of inquiry.

Although group differences were not found in this first study to examine food-related disgust processing in autistic adults, a positive correlation between disgust processing and picky eating across numerous metrics was robustly documented. More specifically, food-related disgust processing was linked with picky eating using both broad measures (NIAS picky eating and AEBQ Food Fussiness scales) and more narrow measures of willingness to try foods organized by food group (e.g., willingness to try vegetables/vegetable juice, fruits/fruit juice, etc.). Although documenting this association in a relatively large group of autistic adults is novel, prior studies have established this correlation in non-autistic adults. For example, prior studies have shown that both general disgust propensity and disgust sensitivity play a role in picky eating in non-autistic adults (Brown et al., 2022; Egolf et al., 2018). In one study associations between disgust and picky eating were specific to food-related disgust processing in non-autistic adults (Brown et al., 2022). This aligns with previous studies which found that non-autistic adults, who identify as picky eaters, have shown that they have higher disgust sensitivity (Kauer et al., 2015). Moreover, recent studies have shown that there is a positive correlation between meat disgust and meat avoidance in neurotypical adults (Becker et al., 2022). Moreover, a large study of adult self-identified 'picky eaters' using the same measure of food-related disgust as the current study, found a moderate to large positive

association between self-ratings of disgust and picky eating (Harris et al., 2019). While the magnitude of the relationship Harris et al. (2019) reported (b=0.4) was similar to what was found here (b=0.6) among autistic adults, it is slightly smaller. Taken together, these findings show the importance of investigating the role that disgust processing plays in commonly occurring picky eating for autistic people.

Additionally, this data suggest that all metrics of picky eating, both global measures and willingness to try certain foods, differ by sex assigned at birth among autistic adults. Autistic adults assigned female sex at birth rated themselves as more selective in their eating overall and as less willing to try foods from all of the food groups queried. Concordant with these results, studies show that non-autistic females show higher levels of food neophobia, as they are less willing to try new or a wide variety of foods (Frank et al., 1994; Lopes et al., 2006). Similarly, recent studies indicate greater picky eating in autistic females, than in autistic males (Lundin Remnélius et al., 2022; Spek et al., 2020). The current study's findings therefore corroborate a pattern of findings established in both autistic and non-autistic adults of greater food selectivity in women. Whether this sex difference is even more pronounced in autistic adults remains an open question.

Finally, analyses demonstrated that the association between food-related disgust processing and picky eating is mediated by both olfactory and oral texture sensory sensitivity. Models of picky eating in autism, particularly in childhood, are dominated by the central role that sensory processing and sensitivity plays in the development of food selectivity (e.g., Ahearn et al., 2001; Hubbard et al., 2014; Nederkoorn et al., 2019; Zickgraf et al., 2022). However, these results indicate that food-related disgust remains a

significant predictor of picky eating even after accounting for sensory sensitivities in autistic adults. This suggests that additional factors beyond sensory processing, namely food-related disgust, could contribute to picky eating in autistic people. Therefore, intervention approaches that focus on not only sensory processing, but also disgust processing are likely needed to address picky eating in autistic people.

Limitations

This study has limitations that should be considered when contextualizing these findings. For example, this study was conducted online with a sample of autistic adults that included mostly individuals assigned female sex at birth. However, an online study allowed the recruitment of a large sample, which provided ample statistical power to test hypotheses, and particularly to evaluate mediation models. In addition, although the sample of autistic adults was predominantly female based on sex assigned at birth, women are underrepresented in the autism research literature. Therefore, this study represents an important contribution by including the often underrepresented female voice. Lastly, this study did not include autistic adults who had a co-occurring intellectual disability. Because the study relied on independent completion of self-report questionnaires, people with intellectual disabilities were largely excluded from this study. Therefore, findings may not apply to this subgroup of autistic adults. In spite of these limitations, this study represents a critically important starting point in understanding the role that food-related disgust plays in picky eating in autistic people.

Implications

Prior to this study, links between disgust processing and picky eating had not been examined among autistic adults. The current study demonstrates strong associations between disgust processing and picky eating. Moreover, this relationship is mediated by sensory processing challenges in autistic adults, though the direct relationship between disgust and picky eating remains robust as well. Therefore, targeting factors related to disgust processing (in addition to sensory processing) may have important implications for improving dietary variety and may engender positive impacts on downstream physical health for autistic adults.

Currently, a majority of feeding treatments, such as the SOS Approach to Feeding, are focused on the sensory aspect of eating (Toomey & Ross, 2011). Additionally, most of these treatments are geared towards treating feeding difficulties in children rather than adults. Given these findings and others emerging in the literature, clinicians treating feeding disorders should consider the role food-related disgust plays in picky eating and approach these challenges from a lifespan perspective. Researchers focused on disgust processing in non-autistic individuals have suggested that psychological based treatments may be effective. Since learned food aversions may be formed before food preferences emerge, reversing feelings of disgust may be challenging (Legget et al., 2015). In one study, researchers aimed to reduce aversions to insects as potential food items in Western countries. In addition to changing sensory characteristics, such as making aversive food more visually appealing, psychological factors such as renaming the food, presenting the food differently, and cooking the aversive food item with other preferred foods reduced aversive experiences (Deroy et al., 2015). In a recent

case study, acceptance-based interoceptive exposure increased food intake in an adolescent with anorexia nervosa (Plasencia et al., 2019). This treatment targeted the adolescent's ability to withstand discomfort generated by food-related disgust. Similar to other research focusing on food-related disgust, this case study focused on a specific eating disorder rather than food-related disgust related to picky eating in autistic individuals. Continuing research related to food-related disgust and picky eating in autistic individuals could help to pinpoint the role that disgust plays in the pathway to developing picky eating, which will in turn spur development of more effective strategies for feeding treatment.

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