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Eating behavior in autism: senses as a window towards food acceptance

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Atypical eating behaviors are common in autism. This article sheds light on the role of sensory processing on food acceptance and selectivity in autism. The role of the senses in eating behavior is described, suggesting that changes in liking to food sensory stimuli in autism occur and are linked to food neophobia. Interventions addressing sensory processes to improve eating behavior through familiarization are presented and discussed. Their results suggest that, in addition to other factors such as a social context, following a progression from unimodal to multimodal stimuli, the support of the child as an agent, and finally paying attention to the child's own rhythm, sensory familiarization may change food acceptance in autism.

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Autism spectrum disorder (ASD) is a common neurobiological developmental disorder, characterized by persistent deficits in social communication across contexts and the presence of restricted and repetitive behaviors, interests, and/or activities [1]. Hyper or hypo-reactivity to sensory input, as well as unusual interests in very specific types of environmental stimulation (e.g. *apparent indifference or adverse responses to pain/temperature/sounds and/or textures*, *atypical smelling or touching of objects*, *visual fascination with lights or movement*, and so on) are also characteristic features of autism. Atypical eating behaviors are extremely common in people with ASD [2,3]. Also known as food selectivity, picky/fussy eating (e.g. consumption of a limited number of foods) is the most common eating difficulty [4–6,7•]. Whereas the median prevalence is 62% in children and teens with ASD, it is usually estimated below 30% in TD individuals of the same age group [8].

Food difficulties experienced by people with ASD also include rituals surrounding meals, food refusal, rapid eating, chewing problems, difficulty to adapt eating behavior to other people present in the eating situation, pocketing food without swallowing for a prolonged period of time, filling up the mouth too much, vomiting and/or eating non-food substances [9–12]. Food refusal and/or selectivity in ASD children require carers to be particularly watchful [13]. These behaviors carry several risks for the child's nutrient balance and growth [14,15]. They can also spoil the pleasure that people with ASD can have during meal times and make them miss opportunities of social sharing, social participation, and of relaxing in the company of others, even though some, especially adults, develop strategies to deal with the social demands related to mealtimes, despite their selective behavior [16]. The serenity of the family can also be seriously threatened by educational tensions at these times [17].

Among children with ASD who have atypical eating behaviors, a quarter display three or more atypical eating behaviors [8]. Such altered eating behavior is often reflected in terms of food selectivity, which may be associated with a variety of deficits in social communication or repetitive behaviors (such as those mentioned above) but more importantly with peculiarities in sensory processing [18]. For instance, when asked, youths and adults with ASD themselves consider that their sensory sensitivity is strongly related to their eating behaviors [16,19]. The aim of this review is to shed light on eating behaviors in autism by clarifying the role of sensory processing on food acceptance. In order to do so, we will first present the behavioral manifestations of these peculiarities in autism. Then, the role of the senses on eating behavior in autism will be described. Finally, possible ways of improving eating behavior through sensory familiarization will be presented and discussed.

Behavioral manifestations of eating peculiarities in autism

A prominent behavioral manifestation of such eating peculiarities is food neophobia. In a large study involving 1462 children with ASD, almost all parents described their children as reluctant to try new foods [8]. Neophobia refers to aversive reactions or fear towards novel stimuli or situations by an organism, an animal or a person. Food neophobia may be displayed by refusal of new foods. Neophobia is considered an appropriate behavior 'when novel stimuli are true threats, but maladaptive when harmless' [20]. Novelty however can only be determined by considering the individual's subjectivity and the way in which they perceive and understand stimuli according to their sensorimotor functioning and acquired experience. Individuals with ASD are regularly challenged by the various constantly changing combinations of stimuli of the food and mealtime environment [7•]. Here, selectivity can be seen as a way of spontaneously dealing with these changes by reducing adaptation requirements.

Eating behavior peculiarities in children with ASD may also be displayed by strict preference for only one kind or even one brand of food, based on characteristics like texture, temperature, smell or taste [21]. Uniform texture, bland and neutral color foods are reported to be overwhelmingly preferred by more than 90% of children with ASD [8]. 'Crunchy' food is also a hit (as opposed to fruit and vegetables [22,23]). In the same line, a systematic qualitative review [24] showed a consistent correlation between food selectivity and impaired sensory processing, and emerging evidence that cognitive rigidity contributes to such feeding difficulties. The hypothesis of a link between food selectivity and sensory processing, whether over responsivity [25–27] or atypical responsivity to sensory stimuli [28] has been studied from several angles that we describe below.

Sensory processing and eating peculiarities in autism

Eating is a complex behavior that involves perceptual, emotional, cognitive as well as neurological processes. On the afferent perceptual level, the processes involved are distal (visual, auditory, orthonasal olfaction) and proximal (gustatory, retronasal olfaction, tactile) [29]. On the efferent responsive level, the construction of the person's behavioral eating decisions, for example, decision to ingest or reject a food, is strongly driven by sensory processing. The concept of internal action models refers to the general idea that the brain contains templates allowing both action initiation based on sensory expectations, and fine-tuned behaviors in accordance to the sensory input flow [30,31]. People with ASD may have difficulty constructing these templates, that is, difficulty in categorizing stimuli cognitively and hedonically from sensory inputs [32••]. On the behavioral level, this can be consistent with a low number of fine-tuned responses and behaviors polarized between total rejection or exclusive preference in ASD.

Studies in the chemosensory systems have revealed that gustation and olfaction are altered in ASD people at both perceptual [33,34] and neural levels [35]. In the olfactory modality, studies have shown results that do not always go in the same direction. For example, for olfactory detection abilities in adults, one study reported lower abilities in adult people with ASD [35], three studies found equivalent abilities in people with ASD and controls [36–38], while in another study odor detection was better in patients with ASD [39]. For olfactory identification in adults, it was reported to be impaired by three studies [35,36,38]. In children, while one study [40] reported poorer odor identification ability in ASD patients than in controls, another study [41] found poorer odor detection but no difference in identification between ASD children and healthy controls. A third study [42] found lower sensitivity and identification in ASD children compared to healthy controls. To date, the reasons for these differences between studies are not clearly identified. They are undoubtedly linked to the diversity of the screening methods and to the heterogeneity of the populations studied, which range from severe autism to Asperger-type forms. Future studies including larger samples considering the different forms of ASD and the use of more homogeneous methods should shed light on this problem. In hedonic terms, unlike typically developing (TD) children, children with ASD do not recruit the olfactory brain templates to adjust their sniff in accordance with odorant properties, for example, they do not make larger sniffs for pleasant in comparison to unpleasant odors [32••]. In a similar vein, significant hedonic discrimination between attractive and aversive food odors has been observed in TD, but not in ASD [43]. Moreover, hedonic discrimination level of these food odors was negatively correlated with food neophobia scores in ASD but not in TD.

Psychophysical studies focusing on gustation in ASD children are scarce. In comparison with TD, children with ASD showed lower sugar detection and higher preferences for juices with higher sucrose concentration [44]. In a different study, children and adolescents with high-functioning autism were significantly less accurate than matched controls in identifying sour and bitter tastes but did not differ in terms of taste detection [40]. In another study, adults with ASD, a majority of whom had IQ in the normal age range or higher, differed from TD controls in taste identification for sour, bitter, sweet, but not for salty taste [45]. Taken together, these studies on taste show a lack of consensus likely due — as for olfaction — to methodological differences. Moreover, one can note that these findings are not fully representative of the ASD spectrum since they mainly involve people with high-functioning autism.

In vision, when exposed to food images, children with ASD showed a specific pattern of temporal processing [46]. For instance, they explored food stimuli visually for longer than typically developing (TD) children. Moreover, whereas

TD children visually explored complex dishes with multiple items for longer than simple dishes (e.g. mix of carrot and peas versus peas only), children with ASD explored all dishes (whether simple or complex) in a similar way. They also gave more negative appreciation for most of the dishes they were exposed to. Interestingly and similarly to olfaction, unlike TD children, the hedonic ratings of children with ASD were negatively correlated with food neophobia scores, suggesting that — on an individual level — the more they manifest aversive reactions or fear towards novel food stimuli, the less the food was liked when presented visually.

Touch in ASD, especially oral touch, was mainly approached through self-reports or parent-reports. Introduced by Ayres [47], the concept of 'oral tactile defensiveness' describes the individual's over reaction to certain tactile innocuous stimuli coming into contact with the mouth or the oral area. This over responsivity, common in autism, manifests itself in avoidance or negative behavioral responses in relation with stimuli like food [48] and/or eating or oral care devices [49,50]. In comparison with TD, children with ASD are significantly more likely to refuse foods based on texture/consistency (77.4% versus 36.2%) [51]. Moreover, another study found that children with ASD with atypical oral sensitivity (tactile but also smell and taste) refuse more foods compared to those with typical oral sensitivity [52]. Finally, children with ASD usually prefer meals with uniform textures, either crunchy and dry, or smooth puree, while mixed textures may cause some resistance [53]. The role of temperature in food refusal has not been confirmed [51].

In sum, the above literature suggests that changes in liking to food sensory stimuli in ASD occurred in many sensory modalities, and that they are linked to food neophobia for some of them. Note that some eating behaviors improve with development [54,55], but food selectivity difficulties may persist into adolescence or adulthood in some people with ASD, especially in those who have not received support [4,11,56]. The question of how to solve this issue is an important one. Up to now, research into the eating behavior of people with ASD has considered each sensory modality separately. However, such selective eating behavior involves the processing of sensory information with various senses simultaneously [29,57], and perceptual modalities involved in eating share some anatomical-physiological substrates, for example, the insular gustatory cortex shows a heightened sensitivity not only to taste stimulation, but also to olfactory, somatosensory, and even visual stimulation [57]. Beyond the multisensory processing, the context of experimentation and in particular its real-life character are important to consider, particularly in autism [27]. A series of interventional protocols (detailed below) have been recently tested by scientists from different fields to evaluate how sensory exposure (through unisensory or multisensory familiarization with or without context) may change food selectivity and/or acceptability.

Helping individuals with autism to circumvent such eating alterations using sensory exposure

Kim *et al.* [58] examined the effect of various unisensory/multisensory exposures (visual and/or tactile) of vegetables among preschool children with ASD with moderate level of food selectivity. The 3-phase program lasted six months with a 5–10 min daily vegetable exposure, four days a week. The staff conducted one play activity per day putting children in contact with three different vegetables (from a set of 12). The activities of the first phase involved visual exposure but no direct tactile contact with the vegetables (i.e. find and match the veggies); that of the second phase involved visual and tactile exposure, with tactile contact only during half of the activity time (i.e. veggie-necklace making). Finally, activities of the third phase involved visual and tactile exposure for the whole duration of the activity (i.e. mash the veggies). The authors observed a significant increase in vegetable consumption in the exposed group compared to the control one after six months of activities but no significant group differences in terms of touching and tasting the vegetables. Results also show no significant differences in nutritional intakes between the two groups.

In the same vein, Luisier *et al.* [59•] observed that olfactory familiarization can render food more attractive to children with ASD. Here, the familiarization was unimodal (only smell presented) but in a real-life and relational context. Twenty-five children (range: 5–13 years) were exposed to one olfactory food stimulus four times in a time window of five weeks. Stimuli used for familiarization were selected for each participant individually during an olfactory pretest assessment. Two odors for which each child showed the least hedonic reactivity ('low-hedonic' odors) were selected, one in the familiarization procedure, the other as control stimulus. During familiarization, children paid attention to the olfactory stimulus and were engaged in social warm interactions with the experimenter. Participants were encouraged to be active agents while interacting with both the material and the experimenter. Results showed an effect of familiarization on emotional reactivity to odors in ASD children: participants reacted facially more positively to the odor after having been familiarized with it. More interestingly, when faced with a food choice after familiarization, more than two-thirds of the ASD children chose the food with the 'familiarized odor'.

Galpin *et al.* [60•] provided a 12-week sensory-based feeding intervention to 19 ASD children (3 girls and 16 boys; aged 4 years 10 months to 10 years 7 months). All of the children had communication difficulties and most of them exhibited challenging behaviors. This targeted food selectivity intervention was conducted at school during snack time by regular school personnel after being trained and supervised. The interventions followed a specific procedure and were based on the Sequential Oral Sensory (SOS) approach based on sensory texture desensitization in an emotionally positive context. Results showed that, after the intervention, the children tasted and ate a greater variety of foods during snacks within the four following food categories, that is, carbohydrate, fruit and vegetable and sauce. Moreover, some mealtime behaviors (including food refusal, food selectivity, disruptive mealtime behavior score) also improved.

Taken together, these observations support the notion that unisensory/multisensory interventions could be useful to improve food selectivity in children with ASD [61]. They suggest that it is possible to operate progressively on the hedonic characteristics of sensory stimuli and thus to expand the food repertoire of children with ASD through sensory familiarization. It should be noted that in all these experiments, the children react differently to the intervention and each one has his or her own singularity, which is important to analyze to meet the child's individual needs. The child's functioning, even if singular or atypical, must be considered as a variable, that is, the product of the interaction between the organism and the environment. Here, tolerance for stimuli such as food can be mediated, and improved, by supports and sensory interventions, and graduated exposure therapy is one of the means by which this can be achieved. Moreover, one should provide to the individual the best possible conditions for meals. In this context, Nadon *et al.* [62] recommend that the caregiver 'assesses the child's overall level of arousal before mealtime and may intervene to ensure an optimal state for eating'. The child must have the opportunity to explore new foods through touch, smell, and taste, starting with the exploration of familiar foods or items outside the mealtime situation if his or her anxiety level is too high. Supports provided in ecological contexts are particularly beneficial to facilitate transfer and generalization.

Regardless of the mode of sensory intervention, a question that deserves to be raised is whether children with ASD may have specific needs given that their eating disorders are relatively similar to those seen in other pathological conditions. In fact, when compared to TD and other clinical comparison groups (picky eaters, children with avoidant restrictive food intake disorder), children with ASD have significantly greater behavioral problems and particular sensitivity to social and non-social stimuli [25]. They also differ on the extent of their restrictive interests, that systematically characterizes the relationship with their environment. Both aspects must therefore be taken into consideration to adapt the intervention.

Conclusions and future directions

Sensory particularities attested by neuroimaging studies in both humans and animals can be considered as fundamental and primary characteristics of the neurobiology of autism [63,64••]. These neurobiological specificities would even be at the origin of the social problems encountered by people with an ASD. Given the importance of sensoriality in the act of eating and its role in the appreciation of food attested to by first-hand experience, that is, by people with ASD themselves [65], it is not surprising that interventions addressing sensory processes in their singularity are effective. The future success of the interventions presented may also be partly linked to the following conditions:

First, working on the emotions felt during meals could help reduce challenging behaviors. Indeed, several studies [3–5] have shown that the emotions experienced by children with ASD when faced with familiar foods stimuli are more negative than those experienced by typically developing children. In order to reach the child in his or her singularity, a playful social and relational context favoring positive emotions seems to help the child to gradually accept new stimuli.

Second, another element that also seems to contribute to the success of the interventions is an initially unimodal approach and then a multimodal approach. This method could overcome the difficulty of children with ASD in encoding multisensory information [66] which requires integration of information provided by the different sensory streams in order to coordinate unified percepts or sensory impressions [67]. In a unimodal approach, the child is supported to focus his or her attention on a single salient and 'standardized' sensory dimension such as the aroma of food in order to avoid local visual functioning, which is prominent in autism [5,7•]. Such attention towards food aroma could lead him/her to create salient memory traces in which the sensory traces would be linked to the positive emotions felt during the activities involving this food. The salience of these traces could support the creation of categorical knowledge, a skill that is not systematically privileged in ASD [68,69••]. That would allow the child to recognize a food carrying the memorized sensory feature and to associate this food with a positive emotion and subsequently to accept to consume it. Indeed, children eat what they like and like what they know [70].

In a recent qualitative review, Kim [71] highlights the importance of self-determination, namely agentivity, on the quality of life of people with ASD. In another qualitative study, Robertson and Simmons [12] conducted a focus group on sensory experience with a sample of adults with a diagnosis of autism or Asperger's syndrome. These participants highlighted the importance to control sensory stimuli themselves in order to make them more predictable. Thus, the acquisition and long-term maintenance of open behaviors towards foods could be based on learning self-determination in the sensory domains. It means that the adult should support the child to pay attention to sensory stimulations, to test them out in different ways, to develop individual strategies to integrate them in the food context, and finally to have confidence in his or her skills to consume a food carrying these sensory stimulations.

Numerous studies confirm, in relation to sensory specificities and their impact on daily life including eating [13,14], the atypical temporal processing of sensory inputs by individuals with ASD [14,72]. This atypical treatment is expressed at different levels of stimuli processing — attention time to sensory stimuli, time needed before being able to make a subjective, emotional appraisal or to perform a motor activity, and so on [73–75]. The temporal particularities of sensory-motor processing should also be taken into account in food education activities in order to enable the child to express his or her strengths [76] and to conduct the entire stimuli processing sequence with positive emotion and, then, to develop effective strategies and sustainable skills.

Given their sensitivities, the construction of eating behavior is not easily acquired for people with ASD. However, research shows that when there is food selectivity, they can fully benefit from adapted support aimed at both enhancing their intrinsic motivation and sensory functioning, and on optimizing the physical and social environment, in order to make the experience of eating more enjoyable and more accessible.

Conflict of interest statement

Nothing declared.

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