

The Role Of Senses In Sensory Integration In The Context Of Child Nutrition

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ABSTRACT

Sensory integration: Integration is crucial in determining children's eating behaviours and nutritional outcome since eating is basically a multimodal experience integrating various sensory inputs e.g., taste, smell, touch, sight and sound. Children with sensory integration disorders (SID) could have an abnormal perception of sensory information with a food related consequence of persistent eating problems. This review is a synthesis of the existing literature on the importance of sensory integration in the nutritional development of children to identify the food selectivity and food neophobia as the major manifestation of sensory dysfunction. This literature review has revealed a significant correlation between hypersensitivity or hyposensitivity in certain sensory modalities, selective eating behaviours and the avoidance of nutritionally needed eating meals as well as an increase in anxiety during meals. Gustatory and olfactory sensitivity - Grossly results in aversion to bitter or aromatic foods and tactual defensiveness - results in the rejection of foods depending on texture. Visual and auditory sensitivities are also limiting the intake of food and have a negative impact on participating in meals. These sensory driven behaviours tend to have a small dietary diversity which is linked to micronutrient deficiencies and increased nutritional vulnerability. The review highlights the effectiveness of sensory based therapies based on the principles of multimodal learning. Methods of prioritising progressive exposure, sensory play and environmental changing rather than forceful feeding methods especially if it is done through parent led and school based initiatives. Incorporating sensory responsive methods in the domestic, educational and community environments promotes a long term improvement to eating behaviour and reduce stresses on carers. The results indicate a need for an appreciation of sensory integration being an important factor in nutrition of children. Integrating sensory informed assessment, intervention and policy initiatives are very important to address selective eating and increase inclusive healthy food habits among children with sensory integration problems.

Keywords: *Sensory-Based Interventions, Sensory Integration Disorders, Child Nutrition, Sensory Integration, and Food Selectivity*

1. INTRODUCTION

Proper nutrition in childhood is very important for good physical development, mental growth and long-term health effects. Eating problems including food selectivity, food refusal and food neophobia has been identified as a significant challenge for children with neurodevelopmental disorders, especially children with autism spectrum disorder (ASD) [1,3]. Such feeding difficulties often go beyond the normal type of picky eating that occurs with development, and may lead to a limited variety of foods, malnutrition, and increased carer stress [7,18].

Sensory integration refers to the neurological process through which the brain organisational and makes sense out of sensory information from the body and the environment and uses that information to produce appropriate adaptive responses. Effective sensory integration allows children to tolerate different sensory experiences related to eating; for instance, taste, smell, texture, sight, and sound of foods. Sensory integration dysfunction is characterised through abnormal sensory responsiveness including hyper-responsivity, hypo-responsivity or sensory-seeking behaviours which are quite common in children with ASD [8,21]. Epidemiologic studies found that sensory impairments affect the majority of children with ASD and are among its essential features [8,14].

Increasing research presents the presence of sensory processing challenges to play a large role in eating behaviours in children with ASD. Research has demonstrated often strong correlations between sensory sensitivity and dietary selectivity, particularly with the texture, taste, aroma and visual properties of foods [3,4]. Children with heightened tactile sensitivity often reject mixed / odd textured foods whilst hypersensitivities to smell and taste results in the avoidance of strongly

flavoured or aromatic foods [5,10]. Visual sensitivities may further restrict acceptability of foods based on colour, shape or presentation and so reinforce rigid eating behaviours [6, 23].

Food selectivity and neophobia not only represents a behavioural problem and has important nutritional and health implications. Meta-analyses and extensive research suggests that children with ASD have a lowered intake of fruits, vegetables and foods that are rich in proteins, increasing the risk of a micronutrient deficiency and a nutritional balance [9,43]. Such restrictive diets may create in turn gastrointestinal problems, imbalance in body mass index and long term metabolic issues [10,32]. In addition, gastrointestinal symptoms are often accompanying the feeding problem causing difficulties in quality of life for both child and carers [11, 28].

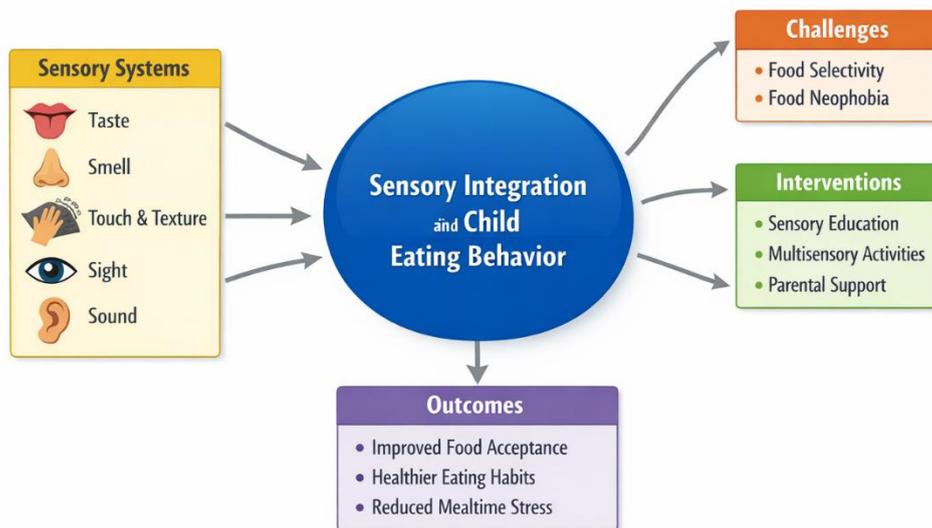


Figure 1 Sensory Integration and Child Eating Behaviours (Source: Author’s own derivation)

In addition to sensory factors unique to the child, the influences of the environment and the carer also plays a major part in the outcome of eating. Parents of children with ASD often report on the management of sensory driven food issues (e.g., in the absence of adequate professional support) leading to anxiety and stress [12, 44]. The lack of knowledge of educators and healthcare professionals was the reason that these issues worsened and showed the necessity of the development of organised educational and therapeutic programmes based on sensory [13]. It has been suggested that parental involvement and positive and regular meal-time behaviours can have a significant impact on children's food acceptance and adaptive eating behaviours [14].

Sensory therapies, such as multimodal food exposure, sensory play and Ayres Sensory Integration techniques have been found to have success in reducing food selectivity and increasing mealtime participation [15,38]. These methods emphasise with children incremental exposures to sensory stimuli in a non-threatening environment and enable children to develop tolerance and comfort with meals as well as a number of sensory modalities [16]. Systematic studies show that sensory learning procedures are most successful if they are tailor made to individual sensory profile needs in conjunction with the active collaboration of therapists, parents and educators [17].

Despite great advances in our understanding of sensory processing and feeding difficulties, deficits still exist in our synthesis of sensory systems, eating behaviour and nutritional outcomes and their integration into a coherent conceptual framework [18]. The bulk of the research today focuses on isolated sensory domains or clinical symptoms and very little is known about the overall effect of multisensory integration on infant nutrition. Furthermore, it is imperative to bring the empirical findings to an action-oriented approach and consequently the nutrition-oriented action-oriented approach to be implemented in the context of domestic, educational and public health [19]. This research looks to consolidate the current evidence regarding the influence of sensory integration on eating behaviours in children with a particular emphasis on aspects of food acceptance, selectivity and neophobia [20]. This research aims to synthesise findings of sensory systems, behavioural outcomes and intervention strategies in order to outline the effect of sensory integration on infant nutrition and emphasise implications for parents, educators and public institutions [21,37].

2. LITERATURE REVIEW

Sense Integration Disorders and Neuro Developmental

Sensory Integration is a fundamental neurological mechanism employed by the Central Nervous System (CNS) to organise or organise sensory inputs that come from the external environment and from the body in order to allow adaptive behaviour.

Sensory integration disorders (SID) or sensory processing dysfunction is when this mechanism fails and you react in an abnormal way to sensory stimuli [22]. SID is not listed as an independent diagnostic, however, it is widely recognized as a core feature of multiple types of neurodevelopmental disorders, such as autism spectrum disorder (ASD) [23,14]. Epidemiological research has shown that a significant percentage of children with ASD demonstrate clinically significant sensory abnormalities including hyper-responsivity, hypo responses and sensory seeking behaviours [21,24]. Clinical and neurobiological research has created evidence of sensory anomalies in the areas of touch, taste, smell, sight, and sound for persons with ASD [25, 30]. The neuroimaging research demonstrates structural and functional change in the portions of cortex associated with sensory processing in support of the biological underpinnings of SID [26]. The sensory problems are not transient - the problems of abnormal sensory responsiveness may persist into adolescence and adulthood [15,27] with implications for daily functioning, ability to interact with others and quality of life. Although there is increasing appreciation of the importance of SID as an essential element of ASD, most of the work is descriptive and focuses on prevalence, classification and symptomatology rather than functional results. Feeding and eating behaviours are an excellent example of a function for which sensory integration plays an important, albeit far from explored, role.

Feeding Challenges, Dietary Selectivity and Food Neophobia in Children

Feeding problems are one of the most common problems reported by the carers of children with Autism Spectrum Disorder (ASD). The challenges include food aversion, narrow food variety, inflexibility towards foods and anxiety with meals [1,3,7]. Food selectivity, i.e., consistent rejection by the child of foods based upon sensory qualities rather than the nutrient content, is relatively frequent in children with ASD compared to the normal developing child [6,23,39]. Food neophobia has been defined as the reluctance or refusal to sample unfamiliar food and it adds to feeding difficulties [16,28]. Extensive and cross-cultural research has established that food neophobia in children with ASD is elevated with many children displaying increased neophobia extending beyond early childhood years, which hinders their dietary diversity [29,37]. These behaviours are unhealthy and as the systematic reviews and meta-analyses have repeatedly shown, food selectivity is accompanied by inadequate intakes of fruits, vegetables, protein sources and important micronutrients [31,43]. Clinical accounts continue about how eating difficulties are multifaceted in ASD including behavioural rigidity, gastrointestinal problems, parental stress and sensory processing anomalies [32]. Of these characteristics, sensory sensitivities have been repeatedly recognised as one of the most important markers of poor eating behaviours [33,34].

Table 1. Sensory Systems and Their Influence on Children’s Eating Behaviour

Sensory System	Primary Sensory Function	Common Sensory Challenges	Impact on Eating Behaviour
Taste (Gustatory)	Basic tastes (sweet, salty, sour, bitter, umami) determination.	Hypersensitivity or hyposensitivity of flavour.	Strong food preferences, intolerance to bitter/ambivalent food, limited food variety.
Smell (Olfactory)	Perception of food fragrance and intensity of tastes.	Asthmatic response to odors.	Shunning of ready-made food, unwillingness to taste new food, food neophobia.
Tactile (Oral–Somatosensory)	Feelings of touch, chill and mouth.	Hate soft, crunchy, sticky and composite texture.	Choosy eating, gagging, wish to have uniform textures.
Visual	Food color, shape and composition, determination.	Form sensitivity or colour of surgery.	Contempt toward dishes of visual peculiarity, tendency to visually homogenous foods.
Auditory	Food stuff auditory perception (crunching, chewing).	Hypersensitivity to sudden increase of sound or high sound level.	Suffering during a meal, avoiding hard foods.

Source: Authors own calculations based on (2,3,5,8,18,25,26)

Sensory Processing and Dietary Behaviour: Domain-Specific Evidence

Processing of the Taste Versus Smell

Taste and smell play a major role in accepting and perceiving flavours. Children with ASD exhibit strange gustatory and olfactory reactions, which have been described as oversensitivity to bitter tastes and strong smells [10,20]. Systematic studies shows altered perception of taste and processing of odours in Autism Spectrum Disorder (ASD) which may be the reason

for aversion to eating vegetables, mixed dishes and prepared foods [10,20]. There is scientific evidence from neurobiological research (experiments and animal models) for altered taste processing in aberrant signalling pathways of salt and flavour perception [20]. Nonetheless, although a number of studies have demonstrated the presence of sensory disparities, there are few studies that empirically associate gustatory and olfactory impairments with measurable nutritional outcomes, such as dietary sufficiency and/or growth measures.

Tactile - Oral-Somatosensory Processing

Tactile sensitivity, especially in terms of oral texture, is one of the most often reported sensory issues of children with ASD [5,13]. Children prefer to reject foods that are mushy, sticky, lumpy or have different textures & have a strong liking for uniform foods or processed foods [23,37]. Clinical studies show that there are considerable correlations between tactile hypersensitivity and food aversion, gagging and mealtime distress [13,34]. Despite substantial descriptive evidence, the majority of research are based on caregiver-reported questionnaires and rather than objective nutritional evaluations and as such, limit findings on long-term dietary implications.

Sensory Influences in Sight and Hearing

The visual attributes of food, for example, colour, shape and presentation have a significant impact on food acceptance in children with ASD. Studies show that items which are visually novel are more likely to get rejected consequently sticking to inflexible eating habits [23]. Auditory sensitivities such as chewing and crunching sounds might be an increasing source of discomfort at meals and avoidance of particular meals [21]. In comparison with taste and texture, the visual and aural domains are given less consideration and the individual impacts these have on nutritional outcomes are not sufficiently explored.

Nutritional and Health Effects of Sensory Driven Feeding Problems

The nutritional implication of sensory driven feeding challenges is beginning to be recognised as an issue of public health. There is evidence from meta-analytic study that children with autism spectrum disorder (ASD) have increased risks of micronutrient deficiencies and disordered macronutrients intake and gastrointestinal problems [39,43]. Restricted diets could also lead to abnormal body mass index profiles that include undernutrition as well as obesity [18]. Comorbid gastrointestinal issues that are commonly seen in children with ASD may worsen feeding issues and sensory sensitivities so that they form a reciprocal process between sensory processing and nutrition [4,25,32]. These findings underline the need for the feeding disorders to be approached not only as behavioural disorders but as complex issues with nutritional, physiological and also psychological elements.

Instruments of Measurement and methodological Constraints

Numerous validated tools are known to assess sensory processing and mealtime behaviour including the Short Sensory Profile, and the Brief Autism Mealtime Behaviour Inventory [12,33,36]. Although the reliability and validity of these tools is satisfactory [26,42], they are mainly based on carer reports and are rarely used in combination with an objective evaluation of the individual's dietary/ nutritional status. As a result, at the present a substantial body of the work is not building empirical ties of some sensory domain and concrete nutritional end result, e.g. levels of nutrient in-take or development metrics. This methodological deficiency compromises translational efficacy of present research in regard to nutrient related therapies.

Sensory Based Interventions & Pedagogical Strategies

Sensory based therapies (e.g. Ayres Sensory Integration therapy, multisensory food exposure and sensory play), have shown potential in improving feeding behaviours [35,38]. Systematic investigations of efficacy of these interventions reveal mixed evidence to support the effects on reducing food selection and increasing engagement on mealtime [35,38]. Nonetheless, most of the intervention researches are in clinical or therapeutic settings and there are too few efforts on parent-led or school-based sensory education. Research shows that parental involvement and frequent sensory responsive feeding strategies are critical to maintenance of the effects of interventions [46]. Research has shown a lack of knowledge, by educators and carers, regarding sensory-related knowledge particularly in low-resource environments [41].

Table 2. Sensory Processing Patterns and Eating-Related Outcomes

Sensory Processing Pattern	Description	Typical Eating Behaviour
Sensory Over-Responsivity	Enhanced sensory hypersensitivity	Severe food aversion, restricted dietary intake, elevated food neophobia
Sensory Under-Responsivity	Reduced sensory awareness	Preference for robustly flavoured meals, excessive consumption, or pursuit of extreme sensations

Sensory Seeking	Proactive pursuit of sensory engagement	Preference for piquant, crisp, or robustly textured meals
Sensory Discrimination Difficulties	Sensory Sensibilities & Sensory Cognitive Symptoms	Erratic food acceptance and erratic eating behaviour

Source: Authors own calculations based on (,25,26,39,41,44)

Research Gap

While a significant number of research has been done on the topic of sensory integration disorders (SID) in children, particularly in relation to autism spectrum disorder, the majority of the research that has been done thus far has taken a clinical and descriptive approach. The bulk of the study is concerned with establishing the prevalence, categorisation and symptomatology sensory processing problems and is more concerned with the features of diagnosis than the functional implications of the disorder. Feeding challenges are commonly recognised whether really a primary behavioral cause which results in lack of comprehensive analysis the direct effect sensory integration disorder has nutritional outcomes. Food selectivity and food neophobia are very common among children with sensory processing issues, and a number of studies illustrated the prevalence of such problem among children in comparison to typically developing children. Nevertheless, most of this study talks about eating disorders as a generalised problem, and do not talk about the specific functions of specific sensory systems. Limited evidence is evident in the empirical associations of specific and relative modality of the senses (such as Gustatory, olfactory, tactile, visual and auditory processing) against specific eating behaviours/dietary patterns. The mechanisms involved in the development of low food intakes and nutritional imbalance in relation to sensory sensitivities are poorly described.

Numerous research have mostly relied upon caregiver-reported evaluation of sensory response and mealtime conduct and little blend of objective dietary intake data or nutritional measures. This methodological deficiency results in poor opportunities to draw explicit correlations between sensual motivated eating behaviours and real nutritional outcomes, as nutrient sufficiency, dietary diversity or the issues of growth-related health concerns. Moreover, even though the potential of sensory based therapies in reducing feeding problems is realized, most studies were done with clinic-based therapeutic techniques in addressing feeding problems. There is a gap in focus for practical and scalable therapies which could be used in daily situations particularly on parent initiated and school based sensory education programs. Insufficient emphasis to organising carers and educators sensory learning tools despite the research findings indicating that constant exposure and facilitative feeding situations are required for permanent behaviour modification.

Sensory-related feeding issues has not yet been given the attention it deserves from a policy and programmatic perspective. Although the significance of limited diets and nutritional deficiencies among children with sensory integration disorders are straightforward at the public health level, there are few studies linking empirical outcomes to recommendations for practice at children nutritional programs, educational systems, or public health initiatives. There is thus a very real need for research that will provide links between the theory of sensory integration and practical sensory learning methodologies and nutrition-oriented policy. Addressing these deficiencies is expected to increase understanding of the role sensory integration plays in understanding child nutrition and the development of inclusive, evidence-based interventions in clinical, educational and public health settings.

Role of Senses in Sensory Integration

Sensory integration refers to the Neurological mechanism by which sensory information form the environment and the body is collected, organized and processed to elicit appropriate behavioural responses. The process of eating is a complex one and requires the simultaneous integration of different inputs to the brain in form of taste, smell, sensations on your hands, visual appearance and above all sound. Effective sensory integration, allows youngsters to take the wide range of foods, textures and tastes and, consequently, helps promote good eating habits, as well as an adequate amount of nutrients. Each of the sensory systems has a special impact on the perception and acceptability of food. The gustatory system contributes to the recognition of basic tastes which accompanies the olfactory system which intensifies flavour perception and has an influence on the appetite. The tactile system, in the event of oral somatosensory processing, helps youngersters accept food textures and food determinations extremely well. Visual cues such as the hue, form and arrangement, influence food related anticipations, while auditory cues such as chewing and crunching sounds influence the comfort experienced during eating experiences. When functioning coherently, these systems of sensory information are met to increase youngsters's will to sample a variety of foods and build an adaptive eating behaviour. However, the way that sensory integration occurs is different for each individual child. Variations in sensory responsiveness can influence the perception and processing foods which can result in differences in food preferences and eating behaviours. These sensory based responses take on an importance of some degree in the presence of sensory integration issues.

Disorders That Affect the Sense of Integration

Sensory integration disorders (SID) are a type of sensory processing disorder sometimes referred to as sensory processing dysfunction whereby the brain finds it difficult to organise sensory information effectively which leads to the inability to have adaptive responses. Children with Sensory Integration Disorder (SID) may display a hypersensitivity, hyposensory or sensory seeking behaviours of different sensory modalities. These types of patterns often are seen in children affected with neurodevelopmental disorders particularly autism spectrum disorder, but may occur spontaneously as well. Clinically, children with Sensory Integration Disorder (SID) might have sensory hyper reactivity to sensory stimulation such as strong odours, specific textures or different tastes or have sensory hypo reactivity requiring a large amount of stimuli to trigger a reaction. Sensory-seeking behaviours by way of craving for intensely crunchy, spicy or robust flavoured foods. Significantly, SID does not occur within one sensory domain, but rather SID has often been linked with multimodal dysfunction and hence is interfering in daily activities such as eating. The presence of SID has been consistently found to be associated with challenges in day-to-day functioning, of which food, self care and social interaction are a component. Feeding problems are also an area of the first and more persistent problems noticeable by carers, that clearly points to the widespread relation between sensorial integration and nutrition.

How Sensory Integration Disorders Affect Paediatric Nutrition

Sensory integration problems have significant impact on children's eating behaviours, food acceptance and overall nutritional intake. Consumption is a sensory intense endeavour and disruption to sensory processing may present a greater dislike to specific attributes of foods. Children with Sensory Integration Disorder will often go off foods based on the flavour intensity, textural irregularity, olfactory features or visual unfamiliarity rather than the nutritional content. Hypersensitivities relating to both taste and smell stimuli can often lead to avoidance of any type of bitter vegetable, protein based diets or cooked dishes with strong smells. Tactile defensiveness leads to the rejection of foods that have mixed, soft and sticky textures whilst visual sensitivities may be causes of rejecting foods that differ in desired colours or shapes. Auditory sensitivity may include the inhibition of a meal, which can happen especially after youngsters are disturbed by the chewing or noises. These are sensory driven behaviours that converge the diversity of a diet and is given a narrow possibility to have exposure to a variety of potentially nutritious foods. Over time, limited meal options could be the compromise of nutrient intakes and thus consequent in deficiencies in essential vitamins, minerals and dietary fibre. As a result, the presence of sensory integration deficits are becoming more widely recognised as potential causes of behavioural difficulties, but potentially to contribute to nutritional susceptibility in children.

Table 3. Sensory-Based Interventions and Their Effects on Eating Behaviour

Intervention Type	Targeted Sensory System	Description	Observed Outcome
Multisensory Food Exposure	Gustation, olfaction, vision	Stepwise exposure to new foods using several different modalities of the senses	Increased food acceptability, acceptance of trying a new cuisine
Texture Desensitization	Relating to the sense of touch	Perceiving by touch sensation	Slow introduction of various textures
Sensory Play Activities	All sensory modalities	All sensory modalities	Exploration of food; none eating
Parental Sensory Education	Inter-sensory	Inter-sensory	Educating parents on sensory responsive eating methods

Source: Authors own calculations based on (1732,33,39,41,44)

Nutritional Issues in Sensory Integration Disorder in Children

Children with sensory integration impairments are at an increased risk for any number of nutritional concerns as the result of continued food selectivity and avoidance. Restricted diets often focus on energy dense processed food that have consistent textures and leave out fruits, vegetables and food containing protein. Such dietary patterns may cause a jolt in the macronutrients intake and intake of the micronutrients. Prevalent problems with diet are iron deficiency, deficiency of calcium, vitamin A, Vitamin D and fibre. These deficits may effects on the psychological development, physical growth and skeletal health, immunological function and the cognitive development. Nutritional imbalance may cause anomalous result in calculating of body mass index; as undernutrition or overweight depending on the diet preferences. Moreover, eating problems associated with SID are often accompanied with problems with gastrointestinal systems, thus food aversion, bad experiences while eating are heightened. The reciprocal nature of the manner that sensitivity and gastrointestinal symptoms can increase one another increase can further the nutritional risk and interferes with therapeutic approaches. Carer stress and concern around feeding may also indirectly effect on the children's eating behaviours and therefore sustain inflexible food

patterns.

Support and Promotion to Selective Eating Children

Sensory based therapies have been helpful in improved food acceptance with the creation and non-threatening development of tolerance to sensory stimulation. These methodologies has focus on repetitive exposure, Sense of touch and multi modal education rather that feeding techniques with coercion. Parental guidance in sensory learning is of high importance as carers play an important role in influencing the eating settings of children. Information should be provided to parents regarding sensory processing and responsive feeding strategies that can serve to reduce the anxiety that may be present at mealtimes, and support the introduction of novel meals. Likewise, it may be used by the school-based sensory education programs to produce such an inclusive environment for helping children with selective eating behaviours at mealtime and at snack time. Public institutions are also involved, and the child nutrition programs in a change of difficulties for feeding related to sensory. This kind of integrating sensory friendly meal planning, flexible food presentation and carer education in child nutrition programs are ways that will have positive results as they will improve dietary diversity and can contribute to long term health outcomes. Timely detection and intervention is important to ensure development of adaptive eating behaviours and avoidance of long term nutritional consequences.

Table 4 Integrated Review of Sensory Integration, Eating Behaviour, and Nutrition in Children

Aspect	Description	Impact on Eating Behavior	Nutritional Implications
Sensory Systems	Gustatory, olfactory, tactile, visual and auditory perception processes involved in food perception	Influence food preferences, acceptance and aversion	Impact of dietary diversity on nutrient consumption
Sensory Integration Disorders	Atypical sensory responsiveness (hyper responsive, hypo responsive, sensory seeking behaviour)	Limited exposure to a variety of different types of cuisines	Heightened risk associated with restrictive diets
Eating Behaviors	Selective eating, refusal of specific textures or flavours	Suboptimal dietary quality	Deficiencies of Trace Elements
Nutritional Outcomes	Disproportionate, macronutrient and micronutrient	Increased food acceptance and increased availability of food to eat	Risks of growth and health
Support Strategies	Interventions based on sensory input, parental education, educational programs	Enhanced food acceptance and participation	Improved nutritional sufficiency

Source: Authors own calculations based on (20,25,41,44)

Intervention and discussion section

Feeding Challenges Strategies Related to Sense of Sight, Taste

The intervention for children with SID who have feeding problems has shifted from a predominately behavioural approach, to sensory based approach and then to the multisensory approach. This movement is the realization that selective eating and food neophobia are not opposites of each other, but perhaps adaptive responses to inappropriate sensory processing. Consequently, interventions that they make proper are based on the modification of sensory experiences rather than on the enforcement of consumption of food. Sensory-focused feeding therapies are based upon incremental, repetitive exposure to food-related sensory experiences in a non-threatening environment. Multisensory exposure techniques to food helps children to experience food through the senses of sight, smell, touch and sound before actually tasting the food which will help reduce their anxiety and increase their familiarity. These methodologies are congruent with the principles of sensory integration where sensory information assimilation ability of the nervous system is increased. Intervention studies suggest that repeated exposure to sensory stimuli cause more food acceptance, as well as decreased mealtime distress, especially if interventions are sensory profile driven by children.

Interventions based on Ayres Sensory Integration and allied methodologies of occupational therapy has been shown to have beneficial effects on feeding behaviours. These interventions are aimed at improving basic sensory processing, and are not only concerned with working on eating behaviour. Improvements in sensory control often results in development of greater

tolerance to textures, aromas and tastes, and so indirectly increases dietary diversity. However, the use of these methodologies are tending to take place in a clinical setting and as such may have limitations in offering these programs to many households. Parent-guided sensory learning is an important and sensible advancement over "health care" therapies. Parents play an important role in the mealtime environments of children and their responses to sensory driven behaviours may either amplify our food choice or counteract food choice. Educating parents on recognition on sensory sensitivities, responsive feeding techniques and sensory learning activities at mealtime when the child is at home has shown decrease in the stress in mealtime and increase in child involvement in mealtime. Home-based sensory activities of the and systematic exposure to foods, and regular routines enable the generalization of the outcome of intervention outside of the therapy session.

School based sensory education programs are an important - and underutilised - intervention strategy. Organised meal and snack environment is available in the educational institutions where the children tend to get exposed to food. Implementing sensory friendly measures for example flexible food presentation, decreased aural stimulus and sensory exploration activities can assist to children with selective eating behaviours. Training for Educators is important as the lack of knowledge for sensory integration issue could prove a damaging in misdiagnosing feeding challenges being like behavioural noncompliance. Public health and nutritional programmes for the kid may add sensorial reaction methods instantly in its present framework in a bigger size. Sensorio-inclusive meal plan, sensitising carers and early screenings for sensory related feeding challenges help in nutritional hazard relief. Program-level therapies are of particular relevance in the context of community and resource limited settings where there may be limitation of access to specialised therapy.

Table 5 Sensory Challenges and Nutritional Implications

Sensory Issue	Eating Behavior Outcome	Potential Nutritional Risk
Taste hypersensitivity	Not interested in vegetables and proteins	Mineral supplementation Deficiencies in micronutrients
Texture aversion	Restricted dietary diversity	Diet with reduced amounts of proteins and calories
Olfactory sensitivity	Rejection of prepared meals	Lack of sufficient diet diversification
Visual selectivity	Limited dietary options	Inadequate dietary diversity

Source: Authors own calculations based on (9,12,19,26,39,41,44)

3. DISCUSSION

This results of this review show the importance of the crucial role that sensory integration has in shaping children's eating behaviours and nutritional results. In a number of research the sensory processing anomalies have repeatedly emerged as an important factor which contributes to food selectivity and neophobia with the perspective that feeding problems in children with Sensory Integration Disorder (SID) are sensory in nature and not purely behavioural. This way of looking at things has significant ramifications to the formulation of interventions and formulation of policy. This is a major contribution as it helps to bring together the individual sensory systems as well as specific eating behaviours. Gustatory and olfactory hypersensitivity is associated in a strong way with food rejection to bitter, strongly flavoured or olfactory food items whereas tactile defensiveness is mostly associated with food avoidance of food items associated with textures. Visual and auditory sensitivities may be less commonly studied, but do have one more bearing on food acceptability, and engagement at mealtime. These results again emphasize the importance of multisensory evaluation and intervention as focusing on one aspect of sensory processing may miss out on the cumulative effects of sensory integration disorder.

Although there is a lot of record of feeding issues, it's still not very much the most common or you see actual connections between sensory processing and measurable nutritional consequences. Most studies have been from caregiver reported behavioural measures, as opposed to direct dietary or nutritional assessment. This disparity implies the need for some research to establish in order to measure the full impact on long term health that comes from sensory-motivated selective eating. Nonetheless, available data suggests that restrictive diets associated with SID increases risk of micronutrient deficiencies and poor dietary diversity and gastrointestinal problems and hence the need for nutrition-oriented intervention measures. The intervention literature has found that the use of sensory-based approaches is more successful and sustainable than forceful feeding approaches. Strategies for sensory learning which emphasize small steps of incremental exposure and play-oriented interaction and modification of the environment are particularly helpful. Significantly, treatments involving parents and educators are then likely to have more predictable effects in the possibilities that feeding problems are dealt with in the child's natural environments. This discovery supports the shift away from the clinic-centered paradigms and into the family- and school-centered paradigms.

The results provide an important perspective of the need for sensory considerations in the planning of child feeding and early development programs on a policy level. Sensory integration is rarely incorporated in traditional nutrition programs although the effect it has on acceptance of foods and adequacy of diets can only be ignore. Integrating sensory screening and assure carer education and sensory responsive meal planning in paediatric health efforts might increase inclusion and efficacy. Estimate of sensory related feeding issues in timely manner may also prevent the development of selective eating to chronic nutritional issues. This review is consistent with a conceptual model in which sensory integration represents a mediation link between sensory input and nutritional outcome. Utilising multimodal, context specific therapies to deal with sensory integration issues can help improve eating behaviours; reduce stress to carers and prepare healthier eating patterns for the diet.

Table 6 Integrated Summary of Sensory Systems, Eating Behaviours, and Nutritional Implications in Children

Sensory System	Sensory Processing Challenge	Typical Eating Behaviour	Sensory-Based Intervention	Nutrition-Related Implication
Taste (Gustatory)	Hypersensitivity to gustatory stimuli (bitter, sour)	Extreme dislike of food, limited choice of vegetables and compound dishes	Incremental taste exposure, repeated sampling, sensory educational activities	Risk of Vitamin A and Iron Deficiency
	Reduced sensitivity	Inclination towards brisk/ spicy flavours, excessive eating	Strategies for enhancing and improving flavour	Excessive use of salt or sugar
Smell (Olfactory)	Heightened sensitivity to odours	Rejection of cooked or strongly aromatic foods, food neophobia	Controlled and exposed experience to smell activities, multi sensory interaction with food	Lower amount of calories and protein eaten
Tactile (Texture / Oral-Somatosensory)	Aversion to texture (soft, sticky, crunchy)	Gagging, dietary selectivity, and aversion to diverse textures	Desensitisation of texture, gradual progression of texture	Consumption of fibre and absence of variation in the diet
Visual	Sensitivity to hue, form, or visual characteristics	Denial to accept new or pictorial complex meals	Visual acclimatisation, presentation tasks from cooking cuisine	Eating of fibre and lack of variations in diet Little variation of food in the diet
Auditory	Heightened sensitivity to auditory stimuli associated with eating	Abstaining from eating crunchy foods, pain on eating	Change in environment when eating	Decreased satisfaction of meals & decreased intake
Multisensory Integration	Sensory over-responsiveness or inadequate integration	High levels of food selectivity, neophobic behaviours	Multi-sensory culinary Exposure, play based sensory pedagogy	Suboptimal dietary quality
Caregiver & Environment Factors	Inadequate parental awareness or assistance	Erratic feeding responses	Parent's training and initiatives in educational institutions	Bad habits of eating foods for a long period of time

Source: Authors own calculations based on (9,12,17,19,23,26,33,37,39,41,43,44,45,46)

4. CONCLUSION AND IMPLICATIONS

The sensory integration plays an important role in children's eating behaviours and nutritional outcome. This review demonstrates that eating is a complex multisensory experience that involves and requires integration processing of gustatory, olfactory, tactile, visual and aural stimuli. Disruption of sensory integration, as is experienced among children with sensory

integration disorders (SID), can result in sensory inputs about the food being experienced as overpowering or aversive, which may result in chronic food selectivity and food neophobia. These behaviours are not temporary developmental phases but rather long-lasting tendencies which have a profound impact on dietary intake and overall nutritional well being. This article reviews the synthesised research. This article identifies the following points about sensory driven feeding problems: Sensory driven feeding problems are primarily linked to unusual sensory responsiveness, and not behavioural disobedience. Hypersensitivity to taste and smell (common causes of this are avoidance of bitter, fragrant and/or mixed foods) and tactile defensiveness cause food refusal of foods with complex textures. Food enjoyment are further restricted, visual and auditory sensitivities, and have a negative effect on the participation of the mealtime. These sensory issues combined lead to a limitation in the variety of food intake putting children with Sensory Integrative Disorder (SID) at a greater risk of nutritive imbalance and shortage of nutrients and adverse growth and health outcomes.

The review highlights some of the limitations of more typical methods of feeding, that is, based on coercion or behavioural regulation. Such tactics, however, often overlook the basics of sensory based behavior of selective eating and serves as another compromiser of anxiety and food avoidance. On the other hand, sensory-based therapy which follows the principles of multi-mode learning has shown more promise with regard to a sustained development. Gradual exposure, sensory play and changing context helps youngsters to develop tolerance and familiarity with foods in a supportive context. Interventions including parents and educators are particularly helpful because of transferability of sensory learning to everyday exposure to situations affecting eating behaviours away from clinical settings. Based on a practical perspective, these findings have important implications for practice in child nutrition, education and policy. Sensory integration must be mentioned as an important factor in the acceptance of food in childhood. In fact early screening for sensory processing abnormalities can contribute to the early identification of children at risk for nutritional issues and to the preventive intervention. The inclusion of sensory-responsive approaches to the conventional nutritional counselling and advice for feeding children might be helpful to achieve better nutritional outcome and to reduce the stress experienced by carers.

Educational institutions such as school food interventions and early childcare centres should be sensory inclusive by responding to the needs of sensory variety. Teacher training and carer education programs need to include basic understanding of sensory integration and its impact upon eating behaviour in order to promote this understanding and help reduce the misconception of selective eating as behavioural rebellion. At the policy level, both child nutrition and public health programmes must shift away from a one-size-fits-all policy to promote feeding patterns, and instead include flexible and sensory-aware programming to promote inclusive and equitable nutrition. Addressing sensory integration issues through multimodal, family-focused and contextualized based interventions are exciting strategies to help address eating behaviours and nutritional health in children with selective eating patterns. The identification of sensory bases of feeding difficulties is important both for the development of effective interventions, as well policy and long-term well-being of children with sensory integration problems. Future studies will need to focus on longitudinal and intervention studies and incorporate sensory evaluation with objective nutritional measures in order to strengthen the evidence base of sensory responsive child nutrition programs.

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