Rocz Panstw Zakl Hig 2024;75(4):313-321
https://roczniki.pzh.gov.pl/ https://doi.org/10.32394/rpzh/196996

REVIEW ARTICLE

THE ROLE OF SENSES IN SENSORY INTEGRATION IN THE CONTEXT OF CHILD NUTRITION

Anna Piotrowska, Eliza Kostyra, Rita Karaś

Department of Functional and Organic Food, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS), Poland

ABSTRACT

The growing problem of sensory integration disorders indicates the need to understand the role of the senses in children's food acceptance and to use this knowledge to determine actions to reduce food selectivity and neophobic attitudes. The paper analyzed the current scientific literature data concerning the impact of sensory integration disorders on children's eating behaviors. The influence of multisensory experiences and sensory education in shaping the proper eating habits of children with sensory integration disorders was also discussed. The importance of educational programs in public institutions and programs dedicated to parents' children with sensory integration disorders was emphasized. Analysis of current scientific literature data regarding the research topic (databases: Google Scholar, Web of Science, PubMed, Elsevier) was performed. Analysis of literature data indicates that sensory integration disorders affect children's eating habits and increase the risk of food selectivity and neophobic behaviors. Sensory learning-based interventions increase children's engagement and facilitate the formation of proper eating habits. Sensory education programs should be interactive and tailored to the individual needs of children with sensory integration disorders. It is extremely important to support parents in increasing their theoretical and practical knowledge.

Keywords: *sensory integration, child nutrition, senses, sensory integration disorders, sensory learning*

INTRODUCTION

The senses constitute the basis for communicating our nervous system with the outside world. We can effectively adapt to its requirements by establishing relationships with the environment. Sensory integration is the process of receiving and responding to information perceived through the senses. The ability to use the information provided is extremely important when performing various everyday activities with children. Difficulties in integrating this information trigger several processes and reactions affecting physiological, cognitive, motor and emotional functions, influencing social relationships and participation in everyday life.

Sensory integration disorders can lead to unusual eating behaviors, which are manifested by a change in the degree of liking food products, the occurrence of selective eating or neophobia. Although there are many causes of improper eating habits, it seems that too little attention is paid to the role of the senses in this regard. The increasing number of children with sensory integration disorders indicates the need for a deeper understanding of the senses' role in children's food acceptance. It will allow for better support for children affected by this problem in the context of reducing symptoms of selective eating and neophobic attitudes.

Effective forms of support should be developed for parents who are the first person to notice disturbing symptoms while observing their child's daily functioning. Theoretical and practical knowledge of sensory integration processes and disorders in this area will help them understand their child's inadequate behavior, reduce stress levels, and increase the possibilities of providing various forms of support.

THE ROLE OF SENSES IN SENSORY INTEGRATION

The senses enable us to respond to changing environmental conditions, affect our functioning in different situations and protect us. They also influence food consumption and the formation of eating habits. Seven sensory modalities work together: vision, hearing, touch (including oral touch), olfaction (smell/odor), gustation (taste), sense of balance (vestibular), and sense of proprioception (body awareness) [1].

Corresponding author: Anna Piotrowska, Department of Functional and Organic Food, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS-SGGW), Nowoursynowska 159c, 02-776, Warsaw, Poland; email: anna_piotrowska@sggw.edu.pl

Publisher: National Institute of Public Health NIH - National Research Institute

Sensory receptors capture external (environmental) stimuli (auditory, visual, tactile, gustatory and olfactory receptors) as well as internal stimuli originating in the body (vestibular, proprioceptive and tactile receptors). The receptors transform the captured stimulus into sensory information that is sent to the brain for processing, resulting in a specific motor and behavioral response [2]. Vestibular information is provided to many brain structures responsible for, among others, regulation of arousal, maintenance of a stable visual field, static and dynamic postural control, balance responses, bilateral coordination, and spatial perception [3]. Proprioception is the sense of body position and self-movement. Proprioceptors located within muscles, tendons, and joints transmitted signals to the brain, where they are integrated with information from other senses (vision, vestibular system) to create an overall representation of body position, movement, and acceleration [4].

Sensory Integration (SI) is a neurological process that enables the correct organizing and processing of information delivered to the brain from both the body and the environment. This process enables a person to receive sensory stimuli, interpret them, and respond appropriately to the situation. All information received by the senses must be integrated to provide a basis for the development of cognitive skills [1, 5, 6]. The sensory integration process includes four stages. In the first (registration), the brain receives sensory information from the senses. The second stage is modulation (regulating the stimulus intensity), and the third is discrimination (the stimulus is organized and interpreted to distinguish its relevance). The final stage is reaction – the brain integrates all the processed stimuli to generate an appropriate response that will lead to a specific behavior [2]. Sensory integration begins to develop in the mother's womb, through the movements of her body that stimulate the baby's brain [4].

Sensory integration ability depends on the child's age and develops in four stages. At the first stage of development, the stimuli received by the tactile system are combined, the baby can suck and may establish a bond with parents because they perceive touch as a pleasant experience. Integrating information from the proprioceptive and vestibular systems enables the child to maintain proper muscle tension and coordinate eye movements. At the second stage of sensory integration, stimuli from the proprioceptive, vestibular and tactile systems are combined, affecting body perception and length of concentration time. The child acquires the ability to coordinate both sides of the body. At the third stage of development, visual, tactile and auditory stimuli are combined, and the child begins to learn speech. Eye-hand coordination enabling the child to perform many activities including independently dressing and eating. At the last level of development, stimuli from all senses are integrated. Sensory integration allows children to respond appropriately to specific sensory stimuli coming from the environment and from the body. The ability to use information provided by various senses during everyday activities, including consumption, is very important [1].

SENSORY INTEGRATION DISORDERS

Abnormalities in the process of sensory integration are referred as sensory processing disorders (SPD) or sensory integration dysfunctions/disorders (SID). They have neurological origins and cause the brain to incorrectly process sensory inputs. Sensory processing disorders are not related to damage to the brain or senses but involve abnormalities in the processing of sensory stimuli [4]. They are defined as a condition in which one or more phases of sensory integration are altered, resulting in unadapted behavioral and/or motor responses [2]. Sensory integration disorders strongly affect children's daily functioning including eating, and may lead to stress, anxiety or even depression. Children have difficulties in performing precise activities, react inappropriately to ordinary sensory experiences, get tired more quickly, have problems communicating with parents and function worse in peer groups. Difficulties with socialization may affect the pleasure of eating in the company of others. Sensory integration disorders may impede learning by imitation, and also acceptance of varied meals that are properly balanced in terms of nutritional value which may lead to dietary inadequacies in this population [2, 7-9].

According to Miller model, sensory integration disorders have three main forms that can co-exist combined: sensory modulation disorders, sensory based motor disorders and sensory discrimination disorders. The most common is sensory modulation disorder (SMD), which involves misinterpreting the intensity of sensory information. SMD includes 3 subtypes: sensory over-responsivity (SOR), sensory under-responsivity (SUR) and sensory craving (SC) [2, 6]. The classification of sensory processing disorder and subtypes is shown in Figure 1.

Children with sensory under-responsivity may need more intense or longer-acting stimulation because they do not experience it with the same intensity as typically developing children. In turn, over-responsivity to sensory stimulation can cause an excessively strong reaction to some harmless sensations as if they were dangerous or painful. Sensory craving children needs more stimulation than others and seek it out in a disorganized way – for example, they touch everything, are hyperactive, and

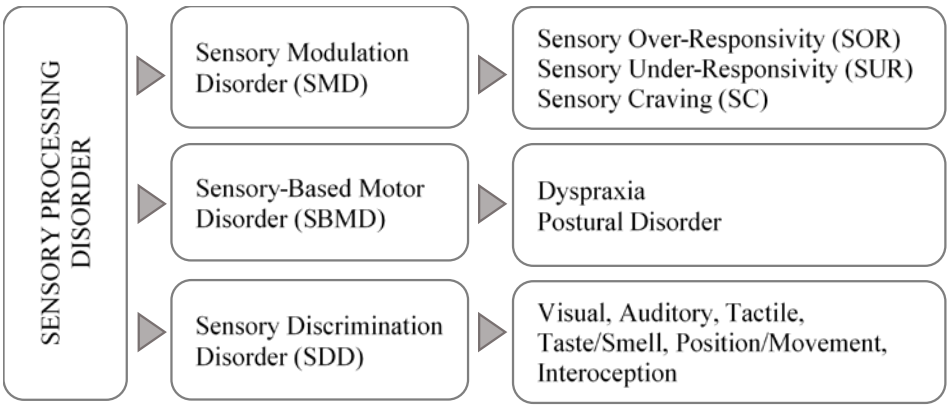

Figure 1. Type of sensory processing disorder
Source: Own elaboration based on Galiana-Simal et al., 2020 [2]

noisy [1, 3, 8, 10]. Children with sensory differentiation disorder have problems understanding the quality of sensory information. They experience difficulties identifying tastes, smells, food textures, and sounds. Sensory-based movement disorders (dyspraxia and postural disorders) mean difficulties in appropriate response to proprioceptive and vestibular stimuli. Children have problems performing coordinated movements, they seem clumsy, poorly grasp and manipulate objects [1, 4].

According to Schaaf's classification, sensory processing disorders include: poor sensory perception, sensory reactivity, somatodyspraxia (SD), vestibular and bilateral integration deficits (VBID) and visuodyspraxia (VP). Children with poor sensory perception are characterized by difficulties in identifying, differentiating, and interpreting sensory information in more than one sensory modality. Sensory reactivity, on the other hand, involves inappropriate responses to the stimulus's level, which interferes with the child's participation in daily activities. It can manifest as sensory hyper-reactivity or hypo-reactivity. In somatodyspraxia, poor sensory perception (especially tactile) is observed in combination with signs of poor motor planning. The child has problems with imitation and action planning. Vestibular and bilateral integration deficits refer to poor vestibular processing and difficulties in related motor functions, such as muscle tone, postural control, balance, visual motor skills, and bilateral coordination. Visuodyspraxia means poor visual perception with poor visual-motor skills and planning [2].

INFLUENCE OF SENSORY INTEGRATION DISORDERS ON CHILDREN NUTRITION

Sensory integration disorders strongly affect nutrition. Eating is a complex behavior which involves perceptual, cognitive, emotional and neurological processes. A meal is a complex multisensory experience requiring the combination of information from different senses, enabling the assessment of the appearance of food, its smell, texture, and taste. Usually, a meal is eaten in the presence of other people, so conversations at the table, music, or food preparation sounds engage the sense of hearing. Motor planning is also necessary to control posture and manipulation of cutlery. All these factors pose a considerable challenge for children with sensory integration disorders. For these reasons, children with sensory processing disorders would have more eating difficulties resulting from disturbances in the integration particularly tactile, olfactory, and visual/auditory information, than their typically developing peers of the same age [2, 8].

Although eating problems are not limited to children with sensory integration disorders, they are very common in this population. According to literature data, during the early years of life, approximately 25% of all children experience eating problems. This number may rise to 80% in children with developmental difficulties especially with autism spectrum disorders (ASD) [8]. A common problem is selective or picky/fussy eating, defined as eating a limited variety of food, as well as neophobia, which means rejecting unknown foods and restricting intake to known and familiar products [8, 11-14]. According to Wallace et al. (2018) children with ASD are more neophobic than children without ASD [15]. It is recognized that children with ASD demand meals to be prepared in the same way at every presentation [16]. Moreover, children consume food in the same ritualistic or obsessive way. Almeida et al. (2022) [17] point out that food neophobia (FN) is a complex problem, where a multidisciplinary-trained team should cooperate to face the situation. Researchers stressed that in the context of ASD, FN alone and in combination with other factors such as behavioral, metabolic and pharmacological affect a risk of overeating palatable

foods (e.g. high-carbohydrate, high-fat), resulting in overweight or obesity [15]. Food neophobia can cause lower BMI in children, whereas the interaction of FN and ASD traits (social, communication, and restricted/repetitive behavior) may evoke significantly higher BMI. It implies that ASD traits in combination with food neophobia have opposing influences on weight to FN alone. Further research is necessary to explain the health implications (both short-term and long-term) of FN and related food selectivity in ASD [15]. Low dietary variety in children can lead to nutritional deficiencies – among others, inadequate intake of iron and zinc (associated with low meat consumption) and dietary fiber, resulting from low consumption of fruit and vegetables, is observed [18]. Extreme food selectivity is observed in children with ASD, who may strongly prefer only one type or even one brand of food based on cues such as consistency, temperature, smell or taste [11]. Children with sensory processing disorders rarely eat the same meals as the rest of the family, have aversions to certain tastes and textures, refuse to eat certain foods because of their smell, and do not like extremes of temperature [8]. Hypersensitivity can cause the child to seek stronger stimuli, which can lead to overconsumption. Regarding taste sensitivity, overuse of salt and sugar may be observed [19]. Studies have shown that texture is the primary reason for food refusal in autistic youth. Smooth creamy textures (e.g. mashed potatoes), foods with lumps (e.g. oatmeal), and foods that require chewing are particularly problematic [12].

Research suggests that tactile hypersensitivity plays a significant role in eating problems. There is a link between tactile defensiveness and food selectivity. Exploration through touch is an essential preliminary step in introducing new foods to young children's diets. Children who demonstrate tactile defensiveness avoid exploring food with their hands. Older children have difficulties handling cutlery, other children's proximity, or routine cleaning after meals [7, 8, 20]. Children with sensory integration disorders may also have oral tactile defensiveness, which causes them to overreact to harmless tactile stimuli that come into contact with the mouth or oral cavity. They often spit out food or vomit, if they do not accept its consistency or temperature [19]. This over-reactivity, common in autism spectrum disorders, manifests as avoidance or negative behavioral responses to stimuli such as food. Compared to typically developing peers, children with ASD are much more likely to refuse food because of its texture/consistency [11]. Studies conducted among children with autism showed that those with oral sensory oversensitivity refused more foods, including whole grain products, and ate fewer vegetables compared to children with typical oral sensory sensitivity. It can impact the quality of the child's diet, leading to deficiencies in fiber and other valuable nutrients. In turn, oral under-sensitivity, in which the child does not adequately perceive stimuli, may result in consuming large amounts of food and stuffing mouth [7].

In the case of visual hypersensitivity, children often prefer products with little variety of colors, and an colorful appearance of the served meal may cause its rejection [19]. Children with hyperreactivity to sound may avoid eating meals, especially in kindergarten,

Table 1. Main characteristics of sensory modulation dysfunction for the senses

Senses	Hyposensitivity	Hypersensivity
Auditory	Children tend to be very noisy during various tasks. They listen to music at high volume and like noisy objects, often shout to stimulate themselves	Children are disturbed by loud noises such as thunderstorms, rockets and human noises. They feel uncomfortable in crowds
Visual	Children like lights, reflections and bright colors	Children are sensitive to light, they tend to look down. They have very sharp eyesight
Olfactory	Children tend to smell food before eating. They are influenced by strong smells	Children can avoid various odors
Taste	Children eat anything, they tend to put everything in their mouth	Children tend to eat very little. They reject different tastes/flavours and easily vomit
Tactile	Children seek to touch, cuddle or caress	Children have difficulties with hyperreactivity during dressing and eating. They try to avoid bodily contacts
Vestibular	Children poorly register vestibular stimuli. Difficulties are observed in attention, fine motor skills and laterality	Children avoid games and exercises that involve movement and balance, such as swings, climbing, slides
Proprioceptive	Children present poor body control. They feel that their body is heavy	Children are constantly on the move and have problems with attention

Source: Own elaboration based on Vives-Vilarroig, Ruiz-Bernardo and García-Gómez, 2022 [9]

child care or school, because the noise level is too high for them. Even sounds accompanying their own consumption (crushing the product in the mouth, chewing, crunching) may be a problem in particularly sensitive children. Excessive visual sensitivity may cause children to react more strongly to the visual stimuli of foods that may evoke unpleasant memories of their taste or texture [8]. Sensory modulation dysfunction for the senses are shown in Table 1.

Research suggests that children with autism may demonstrate atypical reactions to tastes and odors that strongly influence their eating behavior. This can manifest in both the difficulty of identification (higher sensitivity threshold) as well as very strong aversive reactions caused by hypersensitivity. Scientific studies show that children and adolescents with high-functioning autism had difficulty identifying sour and bitter taste as well as common odors compared to their typically developing peers. However, there were no differences in recognizing sweet and salty taste [7, 21].

NUTRITIONAL PROBLEMS OF CHILDREN WITH SENSORY INTEGRATION DISORDERS

Problems with sensory integration affect diet and nutritional status. Between 46% and 89% of children with ASDs exhibit nutritional challenges [22]. They often prefer junk food calorie-dense, carbohydrate-dense with high sodium, and reject fruits, vegetables as well as whole grains products [22-24]. Low intake of antioxidants, which are abundant in fruits and vegetables, can lead to the accumulation of oxidative radicals and cause a deterioration in the mental and physical condition of children with ASD [24]. Consuming foods with high-calorie density can lead to excessive weight gain. Children with ASD have higher rates of obesity than children without ASD [25]. This may also be due to a sedentary lifestyle and the side effects of medications. Children with ASD are less likely to participate in any physical activity, leading to overweight and obesity. Many medications, such as antipsychotics, stimulants, and antiepileptics, play a significant role in weight gain. Encouraging children with ASD to engage in physical activity adapted to their abilities is extremely important, not only in weight management. If it is properly organized, it helps release stress and also provides social interactions [23, 24, 26]. Apart from obesity, children with ASD are at risk for malnutrition. This may result from inadequate energy intake and the problems caused by improper absorption of nutrients from the intestines [27]. Most studies indicate that the protein intake by children with ASD is adequate. Data on fat and carbohydrates are ambiguous – both too high and correct intake in the diet are found. Children with ASD are a population group particularly vulnerable to deficiencies in fibre as well as certain vitamins and minerals. Too low intakes of vitamins A, D, and C, folic acid, as well as calcium, iron and zinc are often observed [23, 25, 27-30].

Abnormal intake of some dietary nutrients observed in children with ASD may also result from gastrointestinal disorders, intolerances and allergies. A significant percentage of children with ASD follow a gluten-free or casein-free diet, which increases the risk of calcium and fibre deficiencies [25]. Many children with ASD show abnormalities in gastrointestinal physiology, including increased intestinal permeability, overall microbiota alterations, and gut infection [25, 27, 29]. A diet high in carbohydrates and low in fibre often observed in children with ASD, may exacerbate or determine gastrointestinal symptoms (e.g. constipation) – fibre supports intestinal transit, and its low supply in the diet increases the risk of constipation. Constipation and diarrhoea are often associated with an altered gut microbiota composition. Intestinal dysbiosis is often associated, in the ASD population, with an alteration of the barrier of the intestinal mucosa with a consequent increase of the intestinal permeability to exogenous substances of alimentary or bacterial origin, in some cases even neurotoxic [25]. Gastrointestinal disorders, like diarrhoea or constipation, occur in nearly half of ASD children, and their incidence increases with age [27]. They can affect the absorption and utilization of nutrients from the diet. In addition, imbalances in different types of gut flora may result in decreased synthesis of some B vitamins, worsening nutritional deficiencies [28]. Scientific research indicates a close relationship between the functions of the intestines and the brain, the so-called "gut-brain axis", including neural, immunological, hormonal and metabolic pathways [25]. Appropriate dietary treatment of gastrointestinal symptoms can bring major relief to the symptoms of autism [27]. Scientific research indicates that the use of a diet adapted to the individual needs of a child with ASD can alleviate its symptoms and also the accompanying diseases. There is a need for supporting parents by doctors, dieticians, and specialists in the field of sensory therapy because changing the way of eating in this group of children is a special challenge.

SUPPORT AND DEVELOPMENT OF CHILDREN WITH SELECTIVE EATING HABITS

Yamane, Fujii and Hijikata (2020) [31] investigated the relationship between developmental assessment and type of support for autistic children with selective eating habits. They stated that developmental assessment is key to selecting optimal support

strategies. Four groups of children with different factors in the selection of foods such as sensory, visual, familiarity and environmental stimulation were identified (Figure 2). Special meals have been developed for three groups (without the group with environmental stimulation) based on research results. The children assigned to group one tended to select foods based on touch or a preference for crunchy products (e.g. snacks). In this case, support was related to the offering of foods that reflected the preferences for texture, smell, taste, temperature and color. The children of group two tended to prefer foods with thin shapes or meals with their favorite seasonings or sauces (e.g. mayonnaise, ketchup). In contrast, children of group three preferred to consume familiar foods. Considering this, support consisted of serving foods that imitated family recipes. Furthermore, the researchers encouraged the children to consume new foods by rewarding them with their favorite meals. A critical issue in the research was the support of the children's families. In this insight, key information on used recipes or ingredients was provided to the family. In addition, the family was supported by helping them to prepare the proposed meals. The research highlights that it is difficult to determine which type of diet would be appropriate for each child at an early stage. According to researchers, an assessment of the developmental and sensory factors of each group would be useful to determine the type of support needed for each child [31].

Yamane, Fujii and Hijikata (2020) [31] emphasized the importance of the following aspects related to the support: 1) creation of a consumption environment that provides comfort and ease of eating, preparing food the child can eat, alleviating the anxiety associated with consuming a meal, progressive inclusion of less favorite foods, 2) preparation favorite foods, developing child's interest eating, preparing products the child prefers and encouraging the child to try new foods by touching or licking them, 3) cognitive development or social interaction of children, improvement of individual level of their development, improving the food-related behavior through the consumption of unfamiliar foods in the presence of favorite persons and 4) making sure that the child's hunger is not satisfied only with favorite foods and to arouse interest in trying new meals.

The literature emphasizes that living and caring for a child with an eating sensory disorder was described as a lonely, difficult and unsupportive journey for many parents. The research found that raising awareness and improving parental support was key to understanding children's consumption problems [13]. On the other hand, parents realized that improvement would come through a long-term effort involving patience, persistence, strength and optimism. Acceptance of a child's sensory integration disorder by the parent, family and wider community can affect a positive relationship with solving various problems and coping with challenges. In the study by Cunliffe, Coulthard and Williamson (2022) [13] parents gradually adopted a positive and accepting attitude regarding their child's eating. The acceptance process determined positive food-related interactions with the child (e.g. cooking and playing with food). This indicated that experience-based interventions serve an important purpose in this population. It was stressed that further research should determine the impact of parental interventions

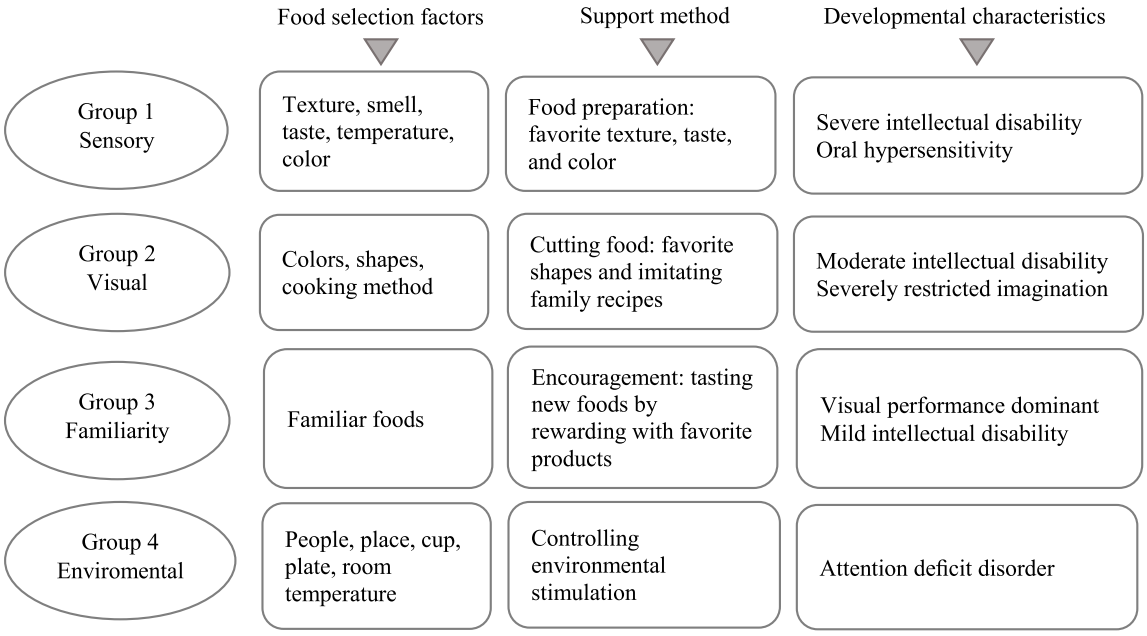

Figure 2. Support type and the developmental characteristics of children with autism
Source: Yamane, Fujii and Hijikata, 2020 [31]

based on acceptance of the child's eating behavior and engagement in gradual positive eating interactions on parent-child support strategies [13].

It was noted that a sensory diet could improve executive functions in children with ADHD [32]. According to Motahari-Muyed, Asgari and Gharebaghi (2015) [33] sensory integration therapy was effective in symptoms of ADHD: attention deficit, hyperactivity, and impulsivity. In the study of Khanahmadi at al. (2023) [34] the effect of using a sensory diet smartphone application by mothers on the main symptoms of children with ADHD (attention deficit, impulsivity, hyperactivity) was examined. It was stressed sensory diet smartphone applications may be an effective approach for reducing attention deficit experienced by children with ADHD.

THE ROLE OF INTERVENTIONS IN SENSORY INTEGRATION DISORDERS

The intervention protocols have been proposed by scientists from different fields to determine the effect of sensory exposure such as unisensory and multisensory familiarization (with or without context) on the selectivity of food and/or their acceptability by children with sensory integration disorders [11]. For example, the researchers measured the impact of different unisensory and multisensory exposures (visual and/or tactile) on vegetable consumption among preschool children with ASD having a moderate level of food selectivity [35]. The program was carried out for six months (with a 5–10 min daily vegetable exposure, four days a week). There was a significant increase in vegetable consumption in the exposed group to the control group after six months of intervention. There were no differences between the examined groups in terms of tasting and touching vegetables.

Luisier et al. (2019) [36] stated that olfactory familiarization could positively influence the perception of food attractiveness in children with ASD. In the study, the stimulus was unimodal (odor) and presented in the context of real life and relational context. Twenty-five children (aged 5–13 years) were exposed to one olfactory food stimulus four times by five weeks. The results revealed an effect of familiarization on emotional reaction to odors in ASD children. It was found that children reacted facially more positively to the odor after familiarization with it. Furthermore, more than two-thirds of children with ASD chose foods with a familiar odor.

In another study, a 12-week sensory-based consumption intervention was conducted with 19 children with ASD [37]. All the children showed communication problems and most of them had challenging behavior. The regular school personnel following training and supervision performed a targeted food selectivity intervention in school. The interventions followed the developed procedure according to the Sequential Oral Sensory (SOS) approach with sensory texture desensitization in an emotionally positive context. The study results found that after the intervention, the children tried and ate a greater variety of foods during snacks within the examined food categories (e.g. fruit and vegetables and sauces). Furthermore, the researchers observed improvements in some mealtime behaviors, including no refusal to eat, less selective eating, and a reduction of disruptive consumption behavior.

The researchers highlighted that unisensory and multisensory interventions may be useful in improving food selectivity in children with ASD [8]. It was suggested that progressively working on the hedonic properties of sensory stimuli could influence openness to the consumption of new products and meals in children with ASD through sensory familiarization. However, it is important to note that children reacted differently to the intervention. Therefore, it becomes necessary to analyze each situation individually to meet the child's needs. It was noted that tolerance to food stimuli could be mediated and corrected by support and sensory interventions. Graduated exposure therapy is one of the key elements to achieving positive consumption outcomes in children with various disorders and problems.

According to Nadon et al. (2011) [8], the caregiver should "assess 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 the sense of smell, taste and touch, starting by exploring familiar foods or objects outside of the mealtime context if the anxiety levels are too high.

CONCLUSIONS

With the growing problem of sensory integration disorders, it is becoming important to understand the role of the senses in children's recognition of the sensory characteristics of different foods, their acceptance and, consequently, the reduction of neophobic attitudes.

Sensory learning-based interventions support children's engagement and facilitate the formation of appropriate eating habits. Sensory education programs should be interactive and involve children in a variety of practical tasks (e.g. educational stories, drawing, games, cooking and food consumption). These approaches give children an incentive to try unfamiliar foods through increased awareness, curiosity and interaction with their peers.

It is pointed out that repeated exposure of new products to children is not a technique widely used

by parents at home despite the proven positive effects in this respect. There is potential for unisensory and multisensory intervention to influence children's willingness to eat new foods. Researchers emphasize that hands-on activities with unfamiliar products (fruit and vegetables) can increase children's willingness to try them especially those with sensory integration disorders. It is crucial to support parents who have children with sensory integration disorders by increasing their theoretical as well as practical knowledge. The experience of eating more enjoyable and accessible needs intrinsic motivation, sensory functioning and understanding from a social environment.

There is no doubt that the problem of sensory integration disorders in children is growing, and cooperation between specialists from various fields is needed – doctors, dieticians, psychologists, and therapists. Appropriate diet and medications or supplements can increase the effectiveness of helping children with ASD. Multidisciplinary intervention strategies are needed to minimize food avoidance behaviors of children with sensory integration disorders (e.g. ASD), which may affect their nutritional status as well as cognitive and social-behavioral outcomes.

Funding sources

This work was financed by the Polish Ministry of Science and Higher Education within funds of the Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS) for scientific research.

Disclosure conflict of interest

The authors declare that they have no conflicts of interest concerning this article.

REFERENCES

1. Nosek- Kozłowska K. Sensory integration disorders - a problem for children in the modern world. Rozpr Społeczne. 2024;18(1):269-80. doi: 10.29316/rs/186804.
2. Galiana-Simal A, Vela-Romero M, Romero-Vela VM, Oliver-Tercero N, García-Olmo V, Benito-Castellanos PJ, et al. Sensory processing disorder: Key points of a frequent alteration in neurodevelopmental disorders. Cogent Med. 2020;7(1):1736829. doi: 10.1080/2331205X.2020.1736829.
3. Lane SJ, Mailloux Z, Schoen S, Bundy A, May-Benson TA, Parham LD, et al. Neural foundations of ayres sensory integration®. Brain Sci. 2019;9(7):153. doi: 10.3390/brainsci9070153.
4. Dudzińska M. Wspomaganie terapii dziecka z zaburzeniami przetwarzania sensorycznego w kontekście koncepcji integracji sensorycznej – implikacje praktyczne. Niepełnosprawność Dyskursy Pedagog Spec. 2020;(37):102-23.
5. Allen S, Knott FJ, Branson A, Lane SJ. Coaching Parents of Children with Sensory Integration Difficulties: A Scoping Review. Occup Ther Int. 2021: 6662724. doi: 10.1155/2021/6662724.
6. Kaniewska-Mackiewicz E. Wpływ zaburzeń integracji sensorycznej na codzienne funkcjonowanie oraz naukę w szkole. Zesz Nauk WSG. 2020;36(5):91-117.
7. Chistol LT, Bandini LG, Phillips S, Ave H, Cermak SA. Sensory Sensitivity and Food Selectivity in Children. J Autism Dev Disord. 2018;48(2):583-91. doi: 10.1007/s10803-017-3340-9.
8. Nadon G, Feldman DE, Dunn W, Gisel E. Association of Sensory Processing and Eating Problems in Children with Autism Spectrum Disorders. Autism Res Treat. 2011;2011:541926. doi: 10.1155/2011/541926.
9. Vives-Vilarroig J, Ruiz-Bernardo P, García-Gómez A. Sensory integration and its importance in learning for children with autism spectrum disorder. Cad Bras Ter Ocup. 2022;30:e2988. doi: 10.1590/2526-8910.ctoAR22662988.
10. Miller LJ, Nielsen DM, Schoen SA, Brett-Green BA. Perspectives on sensory processing disorder: A call for translational research. Front Integr Neurosci. 2009;3:22. doi: 10.3389/neuro.07.022.2009.
11. Petitpierre G, Luisier AC, Bensafi M. Eating behavior in autism: senses as a window towards food acceptance. Curr Opin Food Sci. 2021;41:210-6. doi: 10.1016/j.cofs.2021.04.015.
12. Baraskewich J, von Ranson KM, McCrimmon A, McMorris CA. Feeding and eating problems in children and adolescents with autism: A scoping review. Autism. 2021;25(6):1505-19. doi: 10.1177/1362361321995631.
13. Cunliffe L, Coulthard H, Williamson IR. The lived experience of parenting a child with sensory sensitivity and picky eating. Matern Child Nutr. 2022;18(3):e13330. doi: 10.1111/mcn.13330.
14. Cermak SA, Curtin C, Bandini LG. Food Selectivity and Sensory Sensitivity in Children with Autism Spectrum Disorders. J Am Diet Assoc. 2010;110(2):238-46. doi: 10.1016/j.jada.2009.10.032.
15. Wallace GL, Llewellyn C, Fildes A, Ronald A. Autism spectrum disorder and food neophobia: clinical and subclinical links. Am J Clin Nutr. 2018;108(4):701-707. doi: 10.1093/ajcn/nqy163.
16. Marshall J, Hill RJ, Ziviani J, Dodrill P. Features of feeding difficulty in children with Autism Spectrum Disorder. Int J Speech Lang Pathol. 2014;16(2):151-8. doi: 10.3109/17549507.2013.808700.
17. de Almeida PC, Zandonadi RP, Nakano EY, Vasconcelos IAL, Botelho RBA. Food Neophobia in Children with Autistic Spectrum Disorder (ASD): A Nationwide Study in Brazil. Children (Basel). 2022;9(12):1907. doi: 10.3390/children9121907.
18. Taylor CM, Emmett PM. Picky eating in children: Causes and consequences. Proc Nutr Soc. 2019;78(2):161-9. doi: 10.1017/S0029665118002586.
19. Głodzik B. Nawyki żywieniowe dzieci z zaburzeniami integracji sensorycznej. Lublin Pedagog Yearb. 2013;32:25-34.

20. Smith AM, Roux S, Naidoo NT, Venter DJL. Food choices of tactile defensive children. Nutrition. 2005;21(1):14-9. doi: 10.1016/j.nut.2004.09.004.
21. Bennetto L, Kuschner ES, Hyman SL. Olfaction and Taste Processing in Autism. Biol Psychiatry. 2007;62(9):1015-21. doi: 10.1016/j.biopsych.2007.04.019.
22. Hill AP, Zuckerman KE, Fombonne E. Obesity and autism. Pediatrics. 2015;136(6):1051-1061. doi: 10.1542/peds.2015-1437.
23. Ranjan S, Nasser JA. Nutritional status of individuals with autism spectrum disorders: Do we know enough? Adv Nutr. 2015;6(4):397-407. doi: 10.3945/an.114.007914.
24. Doreswamy S, Bashir A, Guarecuco JE, Lahori S, Baig A, Narra LR, et al. Effects of Diet, Nutrition, and Exercise in Children With Autism and Autism Spectrum Disorder: A Literature Review. Cureus. 2020;12(12): e12222. doi: 10.7759/cureus.12222.
25. Ristori MV, Quagliariello A, Reddel S, Ianiro G, Vicari S, Gasbarrini A, et al. Autism, gastrointestinal symptoms and modulation of gut microbiota by nutritional interventions. Nutrients. 2019;11(11):2812. doi: 10.3390/nu11112812.
26. Zheng Z, Zhang L, Li S, Zhao F, Wang Y, Huang L, et al. Association among obesity, overweight and autism spectrum disorder: A systematic review and meta-analysis. Sci Rep. 2017;7(1):11697. doi: 10.1038/s41598-017-12003-4.
27. Kawicka A, Regulska-Ilow B. How nutritional status, diet and dietary supplements can affect autism. A review. Rocz Panstw Zakl Hig. 2013;64(1):1-12.
28. Xia W, Zhou Y, Sun C, Wang J, Wu L. A preliminary study on nutritional status and intake in Chinese children with autism. Eur J Pediatr. 2010;169(10):1201-1206. doi: 10.1007/s00431-010-1203-x.
29. Dubourdieu PM, Guerendiain M. Dietary Intake, Nutritional Status and Sensory Profile in Children with Autism Spectrum Disorder and Typical Development. Nutrients. 2022;14(10):2155. doi: 10.3390/nu14102155.
30. Sharp WG, Berry RC, McCracken C, Nuhu NN, Marvel E, Saulnier CA, et al. Feeding problems and nutrient intake in children with autism spectrum disorders: A meta-analysis and comprehensive review of the literature. J Autism Dev Disord. 2013;43(9):2159-2173. doi: 10.1007/s10803-013-1771-5.
31. Yamane K, Fujii Y, Hijikata N. Support and development of autistic children with selective eating habits. Brain Dev. 2020;42(2):121-8. doi: 10.1016/j.braindev.2019.09.005.
32. Kumari Sahoo S, Senapati A. Effect of sensory diet through outdoor play on functional behaviour in children with ADHD. Indian J Occup Ther. 2014;46(2):49-54.
33. Motahari-Muyed M, Asgari M, Gharebaghi S. The effectiveness of group-based sensory integration intervention on attention, hyperactivity and impulsivity of elementary students with ADHD. J Clin Psychol. 2015;7:11-20. doi: 10.22075/jcp.2017.2205.
34. Khanahmadi S, Sourtiji H, Khanahmadi Z, Sheikhtaheri A. Effect of a sensory diet smartphone application on the symptoms of children with attention deficit hyperactivity disorder (ADHD): A feasibility study. Heliyon. 2023;9(8):e19086. doi: 10.1016/j.heliyon.2023.e19086.
35. Kim SY, Chung KM, Jung S. Effects of repeated food exposure on increasing vegetable consumption in preschool children with autism spectrum disorder. Res Autism Spectr Disord. 2018;47:26-35. doi: 10.1016/j.rasd.2018.01.003.
36. Luisier A-C, Bérod AC, Bensafi M, Petitpierre G. L'éducation à l'alimentation dans le trouble du spectre de l'autisme. Enfance. 2019;2:201-222. doi: 10.3917/enf2.192.0201.
37. Galpin J, Osman L, Paramore C. Sensory Snack Time: A School-Based Intervention Addressing Food Selectivity in Autistic Children. Front Educ. 2018;3:77. doi: 10.3389/feduc.2018.00077.

Received: 05.11.2024
Revised: 04.12.2024
Accepted: 07.12.2024
Published online first: 13.02.2025