JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

SENSORY PERCEPTION OF FRUIT IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER: SHAPE, COLOR AND TASTE ASSOCIATIONS

*Rogelio Berbel[1], Hanán Issa-Issa[2], Marina Martínez[1], Jordi Aracil[3], Enrique Roche[1,4,5,6], Lucía Vásquez[7,8,9], Javier Sáez-Valero[4,10,11], Javier Aranceta[12], Ángel Carbonell-Barrachina[*2], Elena García-García[*1,2]*

Address(es): Titul(s) Firstname Surname of the corresponding author
[1] Department of Applied Biology-Nutrition and Institute of Bioengineering. Miguel Hernández University, 03202-Elche (Alicante), Spain.
[2] Grupo de investigación "Calidad y Seguridad Alimentaria", Centro de Investigación e Innovación Agroalimentaria y Agroambiental (CIAGRO-UMH), Universidad Miguel Hernández, Carretera de Beniel, km 3.2, 03312-Orihuela (Alicante), Spain.
[3] Music Conservatory Francisco Casanovas, Torrevieja (Alicante), Spain.
[4] Alicante Institute for Health and Biomedical Research (ISABIAL). 03010-Alicante, Spain.
[5] CIBER Fisiopatología de la Obesidad y Nutrición (CIBEROBN), Instituto de Salud Carlos III (ISCIII), 28029-Madrid, Spain.
[6] Research Group "Nutrition and Physical Activity", Spanish Nutrition Society "SEÑ", 28010-Madrid, Spain.
[7] Ministry of Education, Directorate of Special Education (MINERD), Dominican Republic.
[8] Pedro Henríquez Ureña National University (UNPHU). Lecturer in Professional Ethics. Santo Domingo (Dominican Republic).
[9] University de la Costa (CUC), PhD student in Applied Cognitive Neurosciences. Barranquilla (Colombia).
[10] Instituto de Neurociencias de Alicante, CSIC-Universidad Miguel Hernández, Sant Joan d'Alacant, Alicante, Spain.
[11] Centro de Investigaciones Biomédicas en Red de Enfermedades Neurodegenerativas (CIBERNED), Sant Joan d' Alacant, Alicante, Spain.
[12] President of the Spanish Society of Nutrition. President of the Spanish Society of Comunity Nutrition (SENC). Spain.

*Corresponding author: angel.carbonell@umh.es and egarcia@umh.es

https://doi.org/10.55251/jmbfs.12911

ARTICLE INFO

Received 10. 6. 2025
Revised 15. 12. 2025
Accepted 9. 3. 2026
Published 1. 4. 2026

Regular article

OPEN ACCESS

ABSTRACT

The diagnosis of Autism Spectrum Disorder (ASD) involves three main areas: social interaction impairment, communication difficulties, and repetitive behaviors. Individuals with ASD may also experience challenges with food perception due to sensory sensitivities, affecting their eating habits and nutrition. This report analyzes how individuals with ASD perceive basic attributes of fruits such as shape, color, and taste through two tests. The first test included shape, color, and a fruit image, while the second replaced the image with the fruit's flavor. Additionally, the effect of music was studied. The results showed a 36 % discordance in the first test, increasing to 67 % when flavor was introduced. When music was added, discordant responses averaged 50 %. The findings suggest that children with ASD have difficulty associating fruits with their shape and color, particularly when yellow and triangle were present. Additional input such as music may influence their food choices and associations. Understanding these discrepancies can help develop better tools for improving eating behavior in this population.

Keywords: Autism, colors, fruits, sensory, spectrum disorders, tastes

INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurobiological condition characterized by unique developmental, communicative, social, and behavioral challenges **(American Psychiatric Association, 2013)**. Understanding ASD has evolved to recognize its complexity and diversity, impacting not only physical and emotional health but also social and educational inclusion. Individuals with ASD often face a higher risk of obesity and cardiovascular issues due to atypical eating habits and reduced physical activity. Given that individuals with ASD are at higher risk of obesity and cardiovascular problems due to atypical eating habits, fruits were selected in this study because of their association with a healthy diet. The literature indicates that fruit and vegetable consumption in this population is often insufficient; therefore, fruits were used as sensory stimuli both for their nutritional relevance and to establish a parallel with geometric shapes based on common and easily recognizable fruits. Recent studies emphasize the need to address both neuropsychiatric and physical aspects to enhance quality of life. Transitioning to adulthood poses additional challenges for individuals with ASD, who require appropriate support and employment opportunities **(Shattuck *et al.*, 2012)**. The symptoms of ASD include persistent deficits in social communication and interaction, such as difficulties with social-emotional reciprocity and forming relationships, alongside restricted and repetitive behavior patterns **(American Psychiatric Association, 2013; Wing, 2004)**. The etiology of ASD is multifactorial, encompassing genetic and environmental factors, with no definitive triggers identified. Historically, autism was misattributed to parental emotional detachment **(Kanner, 1968)**, but contemporary diagnostic criteria focus on impairments in social interaction, communication, and behavior **(Craig *et al.*, 2017)**. In Spain, studies indicate a prevalence of approximately 1 in 100 individuals with ASD, although this varies based on diagnostic criteria and research methodologies **(Ruiz-Lazaro *et al.*, 2009; Lopez-Espejo *et al.*, 2021)**. Additionally, individuals with ASD often exhibit altered sensory processing, which can manifest as either hyposensitivity or hypersensitivity, affecting their eating behaviors and leading to various emotional responses. The sensory processing sequence typically follows appearance, smell, texture, and taste **(Bandini *et al.*, 2017)**. Creating supportive environments, such as incorporating soft music, may positively influence neurodevelopment **(Bandini *et al.*, 2017)**. Music was chosen as an influential factor because several studies indicate that, in individuals with ASD, auditory stimuli can modulate attention, emotional regulation, and sensory response. Music therapy has been widely used in this population due to its ability to reduce anxiety, improve non-verbal communication, and facilitate interaction with other sensory stimuli, such as visual and gustatory cues. In this context, incorporating music allowed us to assess whether a structured auditory stimulus could influence the perception of shapes, colors, and flavors. Memorable string instruments were selected because they provide a soft, stable, and predictable timbre, characteristics that are generally better tolerated by individuals with ASD compared to abrupt, complex, or highly variable sounds. This type of sound promotes relaxation and reduces sensory overload, increasing the likelihood of obtaining more consistent responses during the tests. Although the age of the participants (under 25 years) may favor familiarity with this type of musical stimulus, the selection was not primarily based on age. Instead, it relied on previous evidence indicating that string sounds are particularly suitable for individuals with ASD due to their lower potential for triggering auditory hypersensitivity. In educational settings, recognizing the dietary preferences and aversions of students with ASD is vital for promoting proper nutrition and positive experiences during meals. Moreover, visual perception differences can impact

behavior and learning in the classroom **(Bandini *et al.*, 2019)**. Implementing visual aids and sensory activities can facilitate understanding and engagement among students with ASD. The collaboration of multidisciplinary teams is essential for effectively addressing the needs of individuals with ASD. The current report aims to explore how the perception of shapes, colors, and flavors affects individuals with ASD aged 7 to 25, highlighting the importance of early interventions to promote healthy eating and inclusive educational tool.

MATERIAL AND METHODS

This study was carried out with collaboration of the non-profit association ASPANIAS after a meeting entitled "Sensory Interest in Food in People with ASD and/or Intellectual and Functional Disabilities", conducted at University Miguel Hernández (UMH, Elche, Spain) in April 2024. Participants were mainly children, and legal guardians signed an informed consent to participate in the study and the Ethics Committee of the UMH approved the study protocol. A quantitative methodology was used, including a personal record sheet and a food perception test involving two shapes (circle and triangle), two colors (yellow and red) and two images/flavors (lemon and strawberry). The flavors lemon and strawberry were selected because they represent clearly differentiated taste profiles sour and sweet while the colors were chosen for being bright and easily recognizable. In individuals with ASD, clear and contrasting sensory stimuli, both gustatory and visual, facilitate identification and reduce sensory overload. Other flavors or colors were not used to avoid confusion or rejection, ensuring more consistent and comparable responses during the tests. Each test was conducted in one session, without and with music. For music selection, we sought evocative compositions with instrumentation primarily based on string instruments. In order to explain the qualitative methodology to be used during the tests with ASD children, the team of therapists, clinical psychologists and the coordinator from ASPANIAS Association maintained several meetings with the Department of Quality and Food Safety at UMH.

Workshop development

The workshop was conducted at the Elche Congress Center (Elche, Spain) Figure 1. A previous session with only therapists was maintained for timing control, breaks, gummy bean distribution and doubt resolution. Then test sessions with ASD children (n=16) aged between 7 and 25 years were conducted. The gender distribution of the children was determined to reflect the representativeness of the ASD population, in which a higher prevalence is observed in males. Including participants of both genders allowed us to assess potential differences in sensory perception of fruits, colors, and flavors, while the sample still reflects the typical proportion found in ASD studies. This approach ensures that the results are relevant and applicable to the general ASD population without introducing significant gender bias. Two children dropped out of the study, for safety threatening behavior and perceived emotional disturbances (anxiety). Perhaps this was due to being in an unfamiliar environment. The inclusion criteria were that children have to present ASD, be part of the ASPANIAS group, and present informed consent from their legal guardians. As exclusion criteria, all those who did not meet the inclusion criteria were excluded from the study. None of the children had X fragile disorder. Each child was in an individual booth to minimize interference and conduct the tests, as depicted in Figure 1. The control group consisted of 16 individuals without a diagnosis of ASD from Baix Vinalopó School. The inclusion criteria for this group were: no diagnosis of ASD or any other neurodivergent condition, active enrollment as students at the aforementioned school, and having informed consent from their legal guardians. Just like the experimental group, each control group participant completed the tests in an individual booth to minimize interference, following the same procedure.

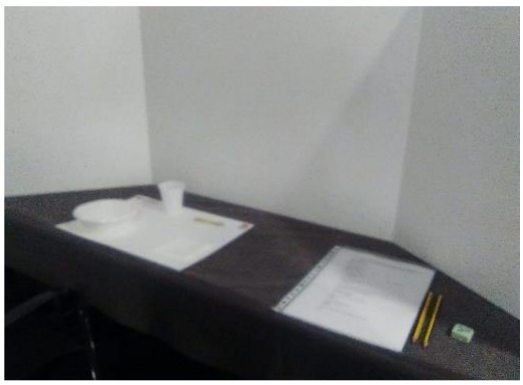

Figure 1 Cabin model where the tests with each ASD individual participating in the study was conducted

Gummy Bean Manufacturing Process

The confectionery products used (gummy beans) for this study were manufactured at the Polytechnic School of Orihuela (EPSO) (Orihuela, Spain) in accordance with quality standards for confectionery products (Figure 2). They are 100 % plant-based gummy beans, available in two shapes (round and triangular), two colors (yellow and red), and two flavors (lemon and strawberry). Confectionary products were manufactured according to Spanish legislation for "Natural Sweeteners and Derivatives". According to this legislation, gummy beans are food products made with sugars or sweeteners, to which other ingredients can be added. For this study, the following ingredients were used: agar-agar, food colorants, sweeteners and aromatic agents. The technological co-adjuvant agar-agar was used as a gelling agent. This ingredient is derived from algae Gellidium, Gracillaria, Gelidiella and Ptericiadia. Food coloring and saccharose were used as preservatives and sweeteners respectively. Aromatic agents included essential oils of lemon and strawberry, allowed by food legislation. Two prototypes of gummy beans were produced to find the optimal texture. For their preparation, the different raw materials used were first weighed (840 g of saccharose and 20 g of agar-agar for prototype 1, and 60 g for prototype 2). Saccharose was dissolved in 1.4 L of distilled water and heated to boiling. At this point, agar-agar was added to the mixture, and it was stirred until completely solved. At the same time, taste and color tests were conducted in two independent 100 mL beakers. Both the color and taste were decided through direct visual observation and flavor test. To this end, flavorings and colorants were mixed until the desired level was reached. Then, 24 mL (12 mL from each beaker) were added to the final agar solution. The optimal taste point was decided subjectively through direct flavor testing. For final color, food colorings were used, with red curcumin (E-100) and yellow tartrazine (E-102) being selected according to their association with the fruits used in the study. Once the final mixture was homogenized, the molds were filled, and finally, the gummy beans were refrigerated and stored. After obtaining the gummy beans and once refrigerated, it was found that the consistency of prototype 1 was too soft, making them difficult to demold and even causing breakage. On the other hand, the texture of prototype 2 was too hard, with a cartilaginous texture, complicating the chewing process. Therefore, a medium quantity of agar-agar (40 g) was decided as optimal and for future preparations.

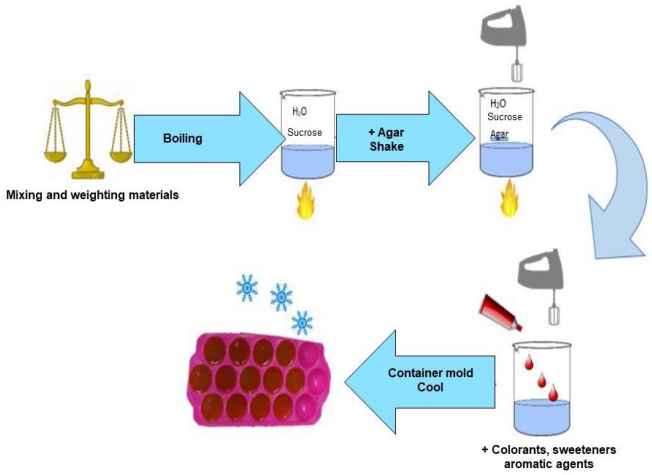

Figure 2 Graph of the jelly bean preparation process. Source: Own elaboration

Criteria for choosing the piece of music used in this study

As mentioned before, each test was conducted both with and without music. The chosen piece was "Fantasía para un gentilhombre" by Joaquín Rodrigo (first movement), written for guitar and orchestra. Taking in account, the preference of people with ASD for string instruments, especially the guitar and violin, this piece was considered very suitable. The music was played by a loudspeaker, ensuring in advance that the sound in the cabin was uniform and clear.

Types of tests used in this study

Training test

Before the children take the test in the workshop, they are prepared with a training test performed at ASPANIAS Association (Elche, Spain). This test does not provide results to analyze, but allowed to know personal preferences of each ASD child in order to make the participant selection for the future tests. The training test consisted of 4 questions about the personal preferences of candidate children. The questions were: *i*) Preferred flavor (strawberry, pear, kiwi), *ii*) Indicate the shape (round, triangle) for the corresponding fruits (strawberry, lemon), *iii*) Associate the fruits with colors (kiwi-brown, pear-green, apple-read/yellow), *iv*) Taste and indicate the preferred fruit (pear, tangerine, strawberry, banana, apple).

Image test

The test consists of sheets that alternate between shapes (triangle and circle) with 2 colors (yellow and red), including an image of the fruit (lemon and strawberry). A test example passed by participants is presented in Figure 3. Each ASD participant has to check for discrepancies in associating shape and color with the corresponding fruit. With the help of the therapist, the child answers the questions on the sheets.

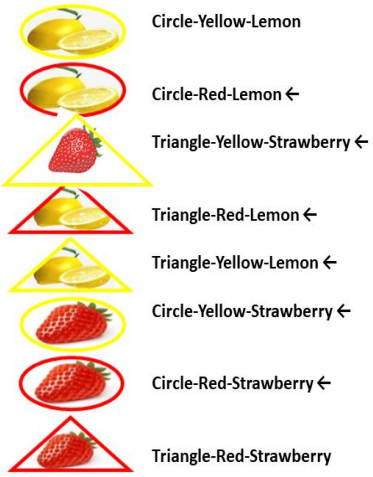

Figure 3 Example of "Image test" passed to ASD participants. Discrepant associations are indicated by an arrow

Sensory test

The test was performed in the presence of gummy candies with different shapes (triangle and circle) with 2 colors (yellow and red) and 2 flavors in mouth (lemon and strawberry). Before answering the questions, the gummy candy shapes are visually observed and must be tasted by each ASD participant, indicating discrepancies to the therapist that takes note of the answers. During the testing process and with the agreement of the therapists, it was decided not to have breaks between each test because it increased stress and led to a loss of concentration. The duration of each test was approximately 5-7 min.

Table 1 Workshop working outline

FIRST GROUP (n=9)	**SECOND GROUP (n=7)**
Starting time: 10 AM	Starting time: 11:40 AM
Image test	**Image test**
No music	No music
With music	With music
Sensory test	**Sensory test**
No music	No music
With music	With music
End time: 10:50 AM	End time: 12:18 AM

Then, both tests (image and sensory) were carried out the same day but with the indicated piece of music. Overall, participation was positive. Only 2 children dropped out of the study, one due to resistance to participate and the other due to being out of time. At the end of the tests, each participant received a gift. Both the participants and the therapists felt happy and satisfied regarding this experience and were eager to carry out further studies that deepen our understanding to improve the quality of life of individuals with ASD. Table 1 shows the outline of the development of the workshop.

RESULTS

The study investigated sensory perceptions associated with different color and shape combinations among participants. Notably, the combination of red color and circular shape was found to evoke a pleasant sensory experience. This finding aligns with existing literature suggesting that rounded shapes, particularly when combined with warm colors like red, are associated with positive emotions and increased appeal **(Barrett & Bar, 2009; Spence & Ngo, 2012)**. Participants reported feeling more at ease and positive when presented with red circular stimuli, reinforcing the hypothesis that specific visual attributes can enhance sensory enjoyment. During the first interview, families expressed a significant interest in better understanding their children's behaviors. Many shared concerns related to specific behaviors they have observed in their children during everyday situations, particularly in the context of feeding and sensory processing. This quest for understanding reflects a genuine desire to support their children and enhance their well-being. This collaboration underscores the importance of involving parents in the research process, recognizing their key role as informants and allies in understanding their children's needs. The first specific objective explores the influence of sensory processing on the perception of the basic attributes of fruit. The discordant answers were differentiated into two categories, shapes (triangle and circle) and color (red and yellow), which were used in the tests. Only participant N°3 presents a notable difference This suggests that visual stimuli could be affecting his performance, as evidenced by poor modulation. In contrast, the other participants show a typical development, with no apparent obstacles interfering with their performance. In the context of sensory perception and food preferences, "discordances" refer to the mismatches or inconsistencies between the expected sensory attributes of a food item and the actual experience of those attributes. These discrepancies can arise from various factors, including color, shape, flavor, and texture associations. In the questions where the image of a circle appears in the picture test, the rate of discordant answers is 26 %, while the rate of discordant answers when the triangle appears is 48 %. The rate of discordant responses obtained in the jelly bean test (sensory test) is 39 % with the circle, while the rate of discordant responses when the triangle appears is 61 %. The shape results for the first question of both tests reveal that 69 % of the children's preferred shape is the circle. In the questions where the shape is yellow in the picture test, the rate of discordant answers is 43 %, while the rate of discordant answers when the shape is red is 27 %. In the sensory test, the rate of discordant answers in the questions where the figure is yellow is 54 %, while the rate of discordant answers when the figure is red is 46 %. In contrast, the combination of yellow color and triangular shape elicited a less favorable sensory perception. Participants indicated that this pairing led to discomfort or confusion regarding expected flavors. Research supports the idea that angular shapes, such as triangles, can evoke negative emotions or discomfort, especially when combined with colors that convey caution **(Bakroon & Lakshminarayanan, 2016)**. The sharpness and tension of the triangular shape may detract from the overall sensory experience, leading participants to perceive this combination less favorably. These findings underscore the significant role that visual stimulus, particularly color and shape, play in shaping sensory perceptions and preferences among consumers. The positive response to the combination of red and circular shapes highlights the psychological impact of visual design elements on sensory experience. Research indicates that color and shape can significantly influence consumer behavior, with certain combinations eliciting stronger emotional responses and preferences **(Spence, 2015)**. Chi-square test (χ^2) was used to analyze whether the differences in responses (Discrepant vs Correct) in Table 2 across the four test conditions are statistically significant.

Table 2 Percentages of discrepant and correct answers in the 4 tests carried out in the present study (people with a neurodivergent profile)

Answers	**Image test (without music)**	**Sensory test (without music)**	**Image test (with music)**	**Sensory test (with music)**
Discrepant	36 %	67 %	51 %	53 %
Correct	64 %	33 %	49 %	47 %

In the neurotypical control group (Table 3). the results showed a higher overall accuracy in all conditions. In the image test without music, the percentage of correct responses was 95 %, with only 5 % discrepancies. A similar result was observed in the sensory test without music (95 % correct, 5 % discrepant). Under the condition with music, accuracy in the image test decreased slightly to 90 % (10 % discrepant), while in the sensory test it remained at 95 % (5 % discrepant).

Table 3 Percentages of discrepant and correct answers in the 4 tests carried out in the present study (people without neurodivergent conditions)

Answers	*Image test (without music)*	*Sensory test (without music)*	*Image test (with music)*	*Sensory test (with music)*
Discrepant	*5%*	*5%*	*10%*	*5%*
Correct	*95%*	*95%*	*90%*	*95%*

The Chi-square test of independence to determine whether the discrepancy and correctness of responses depend on the experimental conditions (image/sensory and with/without music). It is observed that in people with a neurodivergent profile the proportion of discrepant responses is higher in the sensory test without music (67 %) than in the picture test without music (36 %). When music is present, the discrepancy decreases in the sensory test (53 %) and increases in the picture test (51 %). Correct answers are inversely proportional to discrepant answers. Whereas in neurotypical persons, discrepancy values are much lower in all conditions (between 5 % and 10 %), which means that correct responses are consistently high (90 % - 95 %). In the group of people with (ASD), there is greater variability in discrepant/correct responses by experimental condition, suggesting that music and test type may be influencing the results. In the second group (neurotipical persons), correct response rates are very high and consistent, indicating that the effect of music or test type may be minimal. The results of the Chi-square test indicate a statistically significant difference in the proportions of Discrepant and Correct responses across the different test conditions ($p < 0.001$). This suggests that the type of test condition (whether it was an image or sensory test, with or without music) has a significant effect on the participants' performance (Table 2). On the other hand, scientific evidence highlights that music facilitates increased attention and non-verbal expression in individuals with ASD **(Quintin *et al.*, 2012)**. The results from the image test indicate that 51 % of the discordant answers are with music, while 53 % of the discordant answers occur in the sensory test with music. These results differ from those obtained by other authors **(Gold *et al.*, 2006)**, arguing that the benefits of music can enhance social interaction and interaction with the environment for people with ASD. The results obtained in this study differ slightly from previous findings, particularly regarding the sensory perception and color associations in individuals with ASD. It is critical to highlight that anticipation of events plays a crucial role for these individuals, as they often rely on clear, predictable cues to process sensory information effectively. Unfortunately, during the session in question, the facilitators overlooked the importance of maintaining this anticipation, potentially impacting the participants' engagement and responses. This lapse emphasizes the need for future studies to thoroughly investigate the influence of structured anticipatory cues in sensory-based experiments, especially when working with this population. These findings emphasize the critical importance of color and shape in influencing consumer choices, particularly regarding healthy and sustainable eating. Research shows that appealing colors can enhance the attractiveness of healthy foods and promote positive associations, encouraging consumers to make better dietary choices **(Hagtvedt & Brasel, 2016; Spence, 2015)**. Additionally, the use of shapes can influence perceptions of freshness and quality, impacting overall food preferences. In summary, a strategic focus on color and shape in product design and marketing can significantly enhance consumer engagement, ultimately leading to healthier and more sustainable choices. This underscores the need for continued research to understand the interplay of visual elements in food selection, which can aid in the development of effective marketing strategies and promote better dietary habits among consumers.

DISCUSSION

The increase in discordant responses during the sensory test compared to the image test suggests that sensory perception plays a crucial role in how individuals with ASD process multisensory information **(Reynoso *et al.*, 2017)**. Gummy beans require the integration of multiple sensory inputs, such as appearance, taste, smell, and texture, to form a cohesive perception. The heightened sensory stimuli may have contributed to difficulties in associating the gummy candy with the corresponding fruit flavor, potentially linked to a rejection of gelatinous textures. This aligns with the hypothesis that sensory inputs processed by the hypothalamus influence the hedonic value of food, affecting individuals' responses to food stimuli **(Koch & Koch, 2003)**. The sensory response to food is not merely a reaction to isolated stimuli but a complex process involving the central nervous system, which integrates multisensory inputs to shape overall food perception **(Koch & Koch, 2003)**. Understanding this integration is essential for addressing dietary choices and eating behaviors in children with ASD, where sensory hypersensitivities may lead to atypical responses to food textures, tastes, or appearances.

Regarding shape preferences, our findings indicate a higher rate of discordance with triangle-shaped stimuli compared to circles, which were favored by the children. This aligns with cognitive theories suggesting that the brain prefers simple, symmetrical shapes like circles, which are easier to process than angular shapes such as triangles **(Spence, 2015)**. Previous studies have shown that round shapes are associated with positive sensory experiences, such as sweetness, while angular shapes evoke associations with more intense or negative flavors, like bitterness or sourness **(Manippa & Tommasi, 2023)**. This cross-modal correspondence may explain the children's preference for circles, as these shapes align with expectations of pleasant sensory experiences. Additionally, **Bar and Neta (2007)** suggest that circular shapes are evolutionarily associated with safe, nutritious foods, such as fruits, reinforcing this preference. The familiarity and simplicity of circular shapes may also reduce stress in children with ASD, enhancing their sensory processing abilities and decreasing discordant reactions. In terms of color, the discordant response rate was higher for yellow compared to red, with red being the most favored color. This is consistent with findings from **Grandgeorge and Masataka (2016)**, who reported that children with ASD exhibit a stronger preference for primary colors like red. The aversion to yellow may stem from its association with less appealing sensory qualities, such as bitterness or sourness, which can negatively impact sensory perception and increase stress, leading to higher discordance rates **(Velasco *et al.*, 2016; Wan *et al.*, 2018)**. The combination of a circular shape and red color likely creates a more favorable sensory environment for individuals with ASD, as both stimuli are simpler and more predictable, reducing stress and fostering more consistent responses.

The impact of music on test outcomes suggests that it did not provide the anticipated benefits for participants with ASD, contrary to previous findings **(Wigram & Gold, 2006)**. This discrepancy may be due to participants not being informed in advance about the use of music during the test, potentially causing additional stress. The importance of preparing individuals with ASD for changes in their environment is highlighted, as unfamiliar stimuli can increase anxiety and negatively affect performance. Future research should explore the role of sensory stimuli, such as music, in a more controlled and predictable context to better understand its effects on sensory processing in individuals with ASD. Our results indicate that the combination of red color and circular shape generates a more pleasant sensory perception compared to yellow and triangular shapes. Additionally, the lack of improvement in responses when music was introduced suggests that additional research on the interplay between color, shape, and flavor of foods could be instrumental in promoting healthy food preferences in children with ASD. The findings further suggest that music influences cognitive processing in neurodivergent individuals, emphasizing the importance of anticipating sensory stimuli. The improvement observed in the second set of tests could be attributed to greater adaptation, aligning with previous studies on sensory regulation in autism and other neurodivergent conditions **(Robertson & Baron-Cohen, 2017; Pellicano & Burr, 2012)**. Music, as an inclusive tool, has been shown to benefit cognitive and sensory processing in neurodivergent individuals. Research demonstrates that music modulates neural plasticity and enhances multisensory integration, aiding attention and emotional regulation **(Wan *et al.*, 2018; Koelsch, 2014)**. In individuals with autism, music supports sensory modulation, helping to reduce perceptual overload. Additionally, rhythmic synchronization has been found to improve focus and impulse control **(Chen *et al.*, 2022)**. These findings reinforce the need for protocols that consider sensory sensitivity in neurodivergent populations. The anticipation of musical stimuli could optimize cognitive processing and performance in perceptual and attentional tasks, further supporting the use of music as a therapeutic tool in educational and clinical settings. The effects of the tests might have been enhanced if individuals with ASD which were already familiar with a specific type of music. Literature suggests that people with ASD respond better to familiar auditory stimuli, as known music can reduce anxiety, increase attention, and facilitate sensory integration. However, in this study, a standard musical stimulus was used for all participants to maintain consistency and comparability of the results, avoiding individual biases related to prior musical preferences. Moreover, music has been shown to enhance social interaction and emotional expression, areas often challenging for individuals with autism. By fostering social skills, nonverbal communication, and emotional expression, music serves as an accessible medium for interaction and connection.

In conclusion, music appears to influence results differently depending on the type of test. Sensory tests may be more prone to discrepancies due to their subjective nature. The control group shows less discrepancy. These results emphasize the need for further research into the sensory preferences of children with ASD, particularly regarding their interactions with food. Understanding how multisensory integration impacts eating behaviors can inform better strategies for nutritional intervention. Additionally, educating the school community to recognize and address sensory challenges is essential for creating a more supportive and inclusive environment for students with ASD. Insights into sensory discrepancies could provide effective educational tools for addressing eating disorders in children with ASD.

CONCLUSIONS

The color and shape of foods can influence food perception in children with autism spectrum disorder (ASD). In this way, it has been observed that red color and circular shape seemed to produce a pleasant emotion while yellow color and triangular shaper seemed to produce a negative reaction in these children. Thus, further studies are needed to identify factor that can be used to improve food habits and to somehow control food choices in children and teenagers with ASD.

Acknowledgments: Authors want to thank ASPANIAS for participation in the study.
Project CIAICO/2023/198 financed by the Autonomous Community (Comunidad Valenciana) through Consellería de Educación, Cultura, Universidades y Empleo. CIBEROBN is an initiative of Instituto de Salud Carlos III, Madrid (Spain).

REFERENCES

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington: American Psychiatric Publishing.
Bakroon, A., & Lakshminarayanan, V. (2016). Visual function in autism spectrum disorders: a critical review. *Clinical & Experimental Optometry*, *99*(4), 297-308. https://doi.org/10.1111/cxo.12383
Bandini, L., Curtin, C., Phillips, S., Anderson, S. E., Maslin, M., & Must, A. (2017). Changes in food selectivity in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *47*(2), 439-446. https://doi.org/10.1007/s10803-016-29636&#8203
Bandini, L. G., Curtin, C., Eliasziw, M., Phillips, S., Jay, L., Maslin, M., & Must, A. (2019). Food selectivity in a diverse sample of young children with and without intellectual disabilities. *Appetite*, *133*, 433–440. https://doi.org/10.1016/j.appet.2018.11.016
Bar, M., & Neta, M. (2007). Visual elements of subjective preference modulate amygdala activation. *Neuropsychologia*, *45*(10), 2191–2200. https://doi.org/10.1016/j.neuropsychologia.2007.03.008
Barrett, L. F. & Bar, M. (2009). See it with feeling: Affective predictions during object perception. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1325–1334. https://doi.org/10.1098/rstb.2008.0312
Craig, F., Fanizza, I., Russo, L., Lucarelli, E., Alessandro, L., Pasca, M. G., & Trabacca, A. (2017). Social communication in children with autism spectrum disorder (asd): Correlation between DSM-5 and autism classification system of functioning-social communication (ACSF:SC). *Autism Research: official journal of the International Society for Autism Research*, *10*(7), 1249–1258. https://doi.org/10.1002/aur.1772
Chen, W. G., Iversen, J. R., Kao, M. H., Loui, P., Patel, A. D., Zatorre, R. J., & Edwards, E. (2022). Music and Brain Circuitry: Strategies for Strengthening Evidence-Based Research for Music-Based Interventions. *Journal of Neuroscience, 42*(45), 8498-8507. https://doi: 10.1523/JNEUROSCI.1135-22.2022
Gold, C., Wigram, T., & Elefant, C. (2006). Music therapy for autistic spectrum disorder. *The Cochrane Database of Systematic Reviews*, (2), CD004381. https://doi.org/10.1002/14651858.CD004381.pub2
Grandgeorge, M. & Masataka, N. (2016). Atypical Color Preference in Children with Autism Spectrum Disorder. *Frontiers in Psychology*, *7*, 1976. https://doi.org/10.3389/fpsyg.2016.01976
Hagtvedt, H. & Brasel, S. A. (2016). When the color of a product influences taste: The role of color in the food industry. *Journal of Retailing*, *92*(3), 345-355.
Kanner, L. (1968). Autistic disturbances of affective contact. *Acta Paedopsychiatrica*. *35*, 100-136.
Koch, C. & Koch, E.C. (2003). Preconceptions of taste based on color. *Journal of Psychology*, *137*(3), 233–242.
Koelsch S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience, 15*(3), 170-80. https://doi: 10.1038/nrn3666.
Lopez-Espejo, M.A., Nuñez, A.C., Moscoso, O.C., & Escobar, R.G. (2021). Brief Report: Health-Related Quality of Life in Preschoolers with Autism Spectrum Disorder is Related to Diagnostic Age and Autistic Symptom Severity. *Journal of Autism and Developmental Disorders*, *51*(12), 4704–4710. https://doi.org/10.1007/s10803-021-04909-w
Manippa, V. & Tommasi L. (2023). The shape of you: do individuals associate particular geometric shapes with identity? *Current Psychology*, 42, 10042-10052. https://doi.org/10.1007/s12144-021-02297-z
Pellicano E. & Burr D. (2012). When the world becomes 'too real': a Bayesian explanation of autistic perception. *Trends in Cognitive Sciences, 16*(10), 504-510. https://doi: 10.1016/j.tics.2012.08.009.
Quintin, E.M., Bhatara, A., Poissant, H., Fombonne, E., & Levitin, D.J. (2012). Processing of musical structure by high-functioning adolescents with autism spectrum disorders. *Child Neuropsychology*, *19*(3), 250–275. https://doi.org/10.1080/09297049.2011.653540
Reynoso, C., Rangel, M. J., & Melgar, V. (2017). El trastorno del espectro autista: aspectos etiológicos, diagnósticos y terapéuticos [Autism spectrum disorder: Etiological, diagnostic and therapeutic aspects]. *Revista Médica del Instituto Mexicano del Seguro Social*, *55*(2), 214–222.
Robertson, C. E. & Baron-Cohen S. (2027). Sensory perception in autism. *Nature Review Neurosciences, 18*(11), 671-684. https://doi.org/10.1038/nrn.2017.112
Ruiz-Lázaro, P. M., Posada de la Paz, M., & Hijano-Bandera, F. (2009). Trastornos del espectro autista. Detección precoz, herramientas de cribado. *Revista de Pediatría y Atención Primaria, 11*(Supl 17): 381-397.
Shattuck, P.T., Roux, A.M., Hudson, L.E., Taylor, J.L., Maenner, M.J., & Trani, J.F. (2012). Services for adults with an autism spectrum disorder. *Canadian Journal of Psychiatry. Revue Canadienne de Psychiatrie*, *57*(5), 284–291. https://doi.org/10.1177/070674371205700503
Spence, C. (2015). The influence of color on taste perception: What we can learn from the "food-coloring" phenomenon. *Frontiers in Psychology*, *6*, 237.
Spence, C. & Ngo, M.K. (2012). Assessing the shape symbolism of the taste, flavour, and texture of foods and beverages. *Flavour*, *1*, 1-12.
Velasco, C., Michel, C., Youssef, J., Gamez, X., Cheok, A.D., & Spence, C. (2016). Color–taste correspondences: Designing food experiences to meet expectations or to surprise. *International Journal of Food Design, 1*(2), 83–102.
Wan, X., Spence, C., & Wang, Q. (2018). On tasty colours and colourful tastes? Assessing, explaining, and utilizing crossmodal correspondences between colours and basic tastes. *Flavour*, *7*(1), 8. https://doi.org/10.1186/s13411-018-0127-2
Wigram, T. & Gold, C. (2006). Music therapy in the assessment and treatment of autistic spectrum disorder: clinical application and research evidence. *Child: Care, Health and Development*, *32*(5), 535–542. https://doi.org/10.1111/j.1365-2214.2006.00615.x
Wing L. (2004). The spectrum of autistic disorders. *Hospital Medicine (London, England: 1998)*, *65*(9), 542–545. https://doi.org/10.12968/hosp.2004.65.9.15984