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Auditory pitch discrimination in a simple melodic structure in children with autism spectrum disorder

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Introduction. It is suggested that individuals with autism spectrum disorder (ASD) exhibit specific auditory characteristics, such as superior pitch discrimination and increased responsiveness to musical melodies. *Objectives.* The aim of this research was to determine differences in auditory discrimination of high – and low-pitch melodies in children with ASD. *Methods.* Auditory pitch discrimination in a simple melodic structure was examined in a sample of thirty children with ASD, aged 7 to 18 years. This ability was tested using an instrument developed for the purposes of this study, which serves as a basis for examining auditory pitch discrimination in melodies in children with ASD. *Results.* The results of the research indicate that there are differences in the ability to discriminate pitch in a simple melodic structure, with better discrimination of melodies in higher pitch ranges compared to low-pitched melodies ($Z = –2.44$, $p = .015$). Autism severity was associated with auditory discrimination of the high-pitch melody, with response quality declining as severity increased ($U = 40.50$, $Z = -2.36$, $p = .018$). Results suggest that children with ASD who demonstrate musical talent exhibit better auditory discrimination (high-pitch: $p = .037$; low-pitch: $p = .035$). Age was not associated with the quality of melody pitch discrimination in this sample. *Conclusion.* The findings highlight the importance of strengthening theoretical knowledge and designing practical approaches that foster the special abilities and overall development of children with ASD.

Keywords: Autism spectrum disorders, auditory discrimination, pitch, musical melody

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Introduction

Autism spectrum disorders represent a group of neurodevelopmental disorders that begin in early childhood. These disorders are characterized by pathological or altered functioning in the areas of social interaction and communication, accompanied by the presence of stereotypies, repetitive patterns of behavior, and interests (Novaković & Milovančević, 2019). Atypical sensory processing within the auditory system is observed at the earliest age among individuals with autism spectrum disorder (ASD) and is one of the most prominent diagnostic criteria and predictors of autism diagnosis (Egelhoff & Lane, 2013; Ludlow et al., 2014).

The subjective experience of an acoustic stimulus arises through auditory perception. Perception is a complex process of classifying, recognizing, and discriminating signals (Plećević, 2016). Auditory discrimination, as part of the auditory perception process, represents the ability to recognize similarities and differences between two acoustic events (Jutras et al., 2020). Pitch discrimination, or the ability to distinguish between sounds of different frequencies, represents a core component of both musical and linguistic perception (Micheyl et al., 2006).

Certain auditory abnormalities are considered to be correlated with the three most well-established and clearly distinct clusters of autism symptoms. In addition, enhanced discrimination of pitch and melodies has been associated with restricted and highly focused interests and behaviors (Kujala, 2007). Enhanced pitch discrimination has been consistently reported in children with ASD, supported by electrophysiological evidence of enlarged MMN responses to pitch changes in both speech and non-speech sounds (Lepistö et al., 2005). Similarly, Järvinen et al. (2007) confirmed superior pitch discrimination in children with ASD compared to typically developing peers, in both speech and musical stimuli, thereby supporting the notion of heightened pitch awareness in this population (Järvinen-Pasley & Heaton, 2007). According to Del Rincon (2008), the strong tendency to focus on details in auditory input may explain enhanced local auditory processing in ASD, a claim further supported by studies emphasizing superior pitch perception (Kellerman et al., 2005; Ouimet et al., 2012). Importantly, enhanced discrimination is not limited to pure tones but extends to more complex auditory stimuli. Bonnel and colleagues (Bonnel et al., 2010) proposed that this ability may result from reduced interest in socially and linguistically relevant auditory information, leading to greater allocation of processing resources to non-linguistic aspects such as music. Their results suggest that superior pitch discrimination is particularly pronounced in children with ASD who present greater speech-language deficits. Further, Heaton et al. (2005) demonstrated that children with ASD are capable of distinguishing pitch variations in melodies more effectively than their typically developing peers, with discrimination being stronger in the melodic context. Enhanced melodic

pitch discrimination has also been reported in high-functioning Mandarin speakers with ASD (Jiang et al., 2015).

Taken together, previous studies have compared pitch discrimination abilities between individuals with ASD and typically developing populations, or occasionally with those diagnosed with Asperger's syndrome. However, to our knowledge, no study has examined melodic pitch discrimination exclusively in children with autism while considering factors such as age, autism severity, and musical talent. Existing findings suggest that superior pitch discrimination may be more pronounced in individuals with greater language impairments (Bonnel et al., 2010), whereas the role of age and musical talent in modulating this ability has not yet been systematically explored.

Auditory discrimination

The ability to detect changes in the frequency of a tonal stimulus, or changes in the frequency of a pure tone, is called frequency discrimination (Litovsky, 2015). The subjective perception of changes in pitch, which depends on the extent to which the frequency must change in order for the change to be noticed, is called pitch discrimination (Lopez-Poveda, 2014; Stanutz et al., 2014). It is believed that the discrimination of acoustic stimuli in the mid-frequency range is more precise compared to those in the low and high ranges, and that the discrimination of complex tones is easier than that of pure tones (Stanutz et al., 2014. Auditory frequency discrimination is observed at the earliest age and can be tested as early as the first year of life. Research indicates that frequency discrimination matures between the third and sixth month of life. By the age of one, children reach the adult ability to discriminate frequency changes from 4000 Hz to 4008 Hz (Litovsky, 2015). Some authors suggest that pitch discrimination plays an important role in early speech acquisition. However, although it contributes to speech and language in typical cases, in children with significantly heightened pitch discrimination abilities, it may interfere with phonological development and delay early speech acquisition due to excessive focus on the perceptual quality of pitch. Authors believe that this specificity occurs in children with ASD, which hinders their early speech acquisition (Eigsti & Fein, 2013).

Specificities in auditory discrimination in ASD

Research findings suggest that individuals with autism spectrum disorders (ASD) who exhibit an increased ability to discriminate frequency may be classified into a distinct subgroup characterized by certain specificities. Authors describe these individuals as having average or even heightened intellectual abilities, but with weaker language achievements (Jones et al., 2009). Bonnel and colleagues (2010) examined differences in auditory discrimination

of simple and complex tones, varying in pitch, timbre, and loudness, among individuals with autism, Asperger's syndrome, and the typical population. The results of this study clearly indicated an enhanced ability for auditory discrimination of pitch in pure tones exclusively in individuals with autism, which distinguished this group from the other two. The authors highlight the connection between increased pitch discrimination ability and poorer speech-language development in individuals with ASD, noting that this specificity does not occur in individuals with Asperger's syndrome.

Another study confirms the heightened ability to discriminate pitch in various speech and non-speech auditory stimuli in children with ASD, compared to a typical group. What researchers discovered is that when pairs of real and meaningless words, varied in pitch, were presented, there was no difference between groups in their pitch discrimination performance concerning the type of stimulus. The authors explain that the differences between children with ASD and typical children did not depend on the speech content, but rather on the pitch at which the stimuli, whether real or meaningless words, were presented. These authors also suggest that increased perception of pitch information in speech can negatively impact speech-language development in some children. However, they emphasize the importance of joint attention and nonverbal intelligence as factors that, alongside pitch discrimination, may influence the speech and language specificities observed in children with ASD (Heaton et al., 2008).

Auditory Pitch Discrimination in Melody in ASD

An increased ability for auditory pitch discrimination in simple sound stimuli and complex tones in individuals with ASD has been established in numerous studies. While less frequent, a significant number of studies also point to the development of this ability within melodies. Heaton (2005) confirmed the hypothesis that children with ASD are better at discriminating pitch within melodies compared to typically developing children, and are particularly precise in discriminating between flat and sharp tones within melodies. However, the authors specifically highlight that in the simplest tasks, where children are required to recognize when two melodies are identical, children with autism show decreased performance. This specificity is explained by the assumption that perception in individuals with autism is heightened when small changes occur in the environment, whereas in identical melodies, no differences can be discriminated, making it difficult for these children to perceive sameness (Stanutz et al., 2014). A study examining pitch discrimination in pairs of melodies in children with Asperger's syndrome revealed that these children performed exceptionally well when discriminating the direction of pitch (higher/lower) in melodies that followed the scale contour, particularly in transposed melodies. However, they performed poorly in determining whether pairs of melodies were

the same or different when only specific notes were altered, without changes to the overall tonality (Heaton, 2005).

Other research yields similar results, where participants found it difficult to correctly discriminate the direction of pitch change in melodies when, in addition to the pitch changes, individual tones' pitch and duration were also modified (Foxton et al., 2003). In a study of a small group of individuals with ASD, the authors gained significant insights into their ability to distinguish small changes in melodies. They found that individuals with ASD were better at identifying and marking tones and had superior tonal memory compared to the typical population. The study concluded that children with ASD were more capable of distinguishing tones based on frequency than children with typical development, and their discrimination ability was stronger in the context of melodies (Allgood & Heaton, 2015).

The research by Järvinen-Pasley and Heaton (2007), as well as prior studies, confirmed heightened pitch discrimination in children with ASD compared to their typical peers in musical auditory stimuli, supporting the hypothesis of superior pitch awareness in these children. According to the authors, this increased ability to discriminate pitch in children with autism may be explained by a reduced interest in specific social and speech auditory stimuli. In contrast, there is an increased focus on non-speech auditory stimuli, leading to greater activation of the mechanism for processing pitch toward non-linguistic aspects, such as musical tones. This ability is more pronounced in individuals with more significant speech-language deficits, which is why it is less prominent in individuals with Asperger's syndrome, as they typically exhibit fewer speech-language impairments compared to those with more pronounced deficits (Bonnel et al., 2010).

The Present Study

The general aim of the research is to determine whether there is a difference in auditory pitch discrimination in a simple melodic structure within a group of children with ASD. In order to achieve this general research goal, specific research hypotheses have been defined: a) to determine whether age affects auditory pitch discrimination in a simple melodic structure in children with ASD; b) to determine whether the severity of autistic disorder affects auditory pitch discrimination in a simple melodic structure in children with ASD; c) to determine whether musical talent affects auditory pitch discrimination in a simple melodic structure in children with ASD.

Materials and methods

Participants and Procedure

The sample consists of 30 students of primary and secondary school age, attending the "School and Dormitory for students with impaired hearing, Kragujevac." The participants include both male and female students, aged between 7 and 18 years. The sample was divided into three age groups: 11 students in the 7–10 years group, 7 students in the 10–14 years group, and 12 students in the 15–18 years group. Participants were selected based on a clear inclusion criterion: only children with a documented diagnosis of autism spectrum disorder in their school records were included, whereas those with other developmental disorders or without a formal diagnosis were excluded from the study. According to the severity of autism spectrum disorder, as assessed by the Childhood Autism Rating Scale (CARS), the participants were classified into three categories: 4 students (mild), 12 students (moderate), and 14 students (severe). This represents a convenience sample, given that the participants were intentionally selected based on their diagnosis of ASD and their accessibility to the researcher due to the nature of their work setting. Following the selection of participants in collaboration with the school's professional service and obtaining consent from the parents/guardians, the study was conducted at the "School with a Dormitory for Hearing-Impaired Students, Kragujevac." Initially, parents completed questionnaires containing general and specific information about the child. In the first phase of the study, the CARS scale was completed for each participant. Subsequently, auditory pitch discrimination was tested individually for each child. The testing was conducted in quiet rooms, free from any distracting factors. Each participant's testing took approximately 15 minutes. After data collection, analysis was performed using appropriate statistical software. The study was conducted in 2023.

Instrument

Several instruments were used for the purposes of this stydy.

A questionnaire, completed by the children's parents and designed specifically for this study, collected general and specific information about each child. It included yes/no and open-ended questions regarding the child's sex, age, history of ear-related illnesses, the presence of musical talent, and its possible hereditary nature and treatment onset. For example, parents were asked questions such as: *"Does your child demonstrate a noticeable musical talent?".* Only the relevant sections were analyzed, focusing on parents' perception of their child's musical talent, while other sections (hereditary nature of talent, treatment onset, history of ear-related illnesses) were not included in the present study. Participants had been previously selected by the school's professional service based on school records containing diagnostic information related to ASD. Written consent was obtained from all parents/guardians. The information obtained through this questionnaire was used to define and operationalize variables

for subsequent statistical analyses. For instance, the research question *"Are there differences in auditory pitch discrimination between children with ASD whose parents report musical talent and those whose parents do not?"* was formulated based on these parental reports.

The Childhood Autism Rating Scale (CARS) is a standardized behavioral rating scale used to determine the severity of autism symptoms through quantifiable ratings based on direct observation of the child's behavior (Schopler et al., 1980; Schopler et al., 1988). It consists of 15 subscales focusing on developmental characteristics, including: Relationship to people, Verbal and motor imitation, Emotions, Body awareness, Relationship with objects, Adaptation to change, Visual perception, Listening perception, Receptor responsiveness to proximity, Anxiety reactions, Verbal communication, Non-verbal communication, Activity level, Intellectual functioning, and General impressions. Each subscale is rated on a scale from 1 (behavior appropriate for the child's age) to 4 (severely abnormal behavior), with Intermediate scores indicating behavior between two values. Scores from all 15 items are summed to produce a total score ranging from 15 to 60, with higher scores indicating greater symptom severity. Based on the total score, participants were categorized into three groups: mild (15–30), moderate (30–37), and severe autism (37–60) (Schopler et al., 2010; Schopler et al., 1980; Tamaš, 2010). CARS has demonstrated strong psychometric properties. The original study (Schopler et al., 1980) reported high internal consistency ($\alpha = .94$) and good inter-rater reliability, as research has further confirmed its reliability and validity across diverse populations (Schopler et al., 1980, 1988). In the present study, Cronbach's alpha was not recalculated for the CARS, as it is a well-established diagnostic instrument with robust reliability and validity reported in previous studies.

The instrument for testing auditory pitch discrimination in melody in children with ASD, designed specifically for this study, is a questionnaire that serves as the basis for assessment. The questionnaire consists of 13 items describing the type of auditory responses, patterns of auditory responses, and a section for recording the timing of response occurrences to melodies with different pitch levels. The first three items—direct localization, indirect localization, and response without localization—refer to the type of initial reaction to melodies, with only one of the three listed reactions recorded for each participant. Direct localization refers to directly localizing and maintaining the gaze focus toward the sound source during the melodic stimulus. Indirect localization refers to turning toward the sound source without direct and precise localization and can be described as an attempt to locate the sound source. A response without localization refers to a behavioral pattern change in response to the propagated stimulus, but without attempting to locate the sound source. If none of the three reactions appear in a participant, the absence of a response is recorded (no response). The following ten items refer to qualitative patterns of auditory responses, i.e., forms of auditory behavior, with all response patterns being recorded. The last two items refer to the absence of responses to melodies and habituation to the sound. Each melody is played multiple times to record after which play the habituation

occurs. High- and low-pitch melodies are individually observed, and the results are then compared. The obtained data were analyzed based on the type and quality of auditory responses. Direct localization of the sound represented the highest-quality response, followed by indirect localization, reaction without localization, and absence of response as the lowest-quality response. Subsequently, patterns of auditory behavior were observed, with a greater number of distinct response patterns indicating better auditory discrimination and a consistent tendency to respond to one of the pitch levels.

Stimulus – Melodies

The stimuli used to elicit auditory reactions and auditory behavior were melodies created by the author for the purposes of the study. The melody is a reconstruction of the children's song "Old McDonald," recorded in two octaves: low pitch C2 and high pitch C8, each lasting 15 seconds. Auditory stimuli were presented through the built-in speakers of a Samsung Galaxy A51 smartphone at a controlled intensity of 50 dB, measured using the Sound Meter 3.6.9 application. Volume levels were kept constant across all participants. Testing was conducted in quiet rooms approximately 50m², free from distracting factors such as background noise or the presence of other children. The rooms were not acoustically treated but had typical classroom furnishings (e.g., carpeted floor, curtains) that reduced reverberation and echo. Children were given time to adapt to the environment and select an object or activity of their choice. Once engaged, the examiner presented the auditory stimuli from a distance of 50 cm behind the participant. The child's reactions, behavioral responses, and reaction times were recorded. Pairs of high- and low-pitch melodies were alternately presented four times to assess auditory discrimination.

Data Analysis

The obtained data were processed using the SPSS 23 statistical package (SPSS – Statistical Package for the Social Sciences, V.23; SPSS Inc., Chicago, Illinois, USA). The data analysis included simple frequency distributions with percentages, as well as descriptive statistics encompassing measures of central tendency mean (M), and measures of variability- standard deviation (SD), minimum reaction time (Min), and maximum reaction time (Max). To examine the study hypotheses, the normality of the data distribution was assessed using the Shapiro–Wilk test. The results indicated that the data significantly deviated from a normal distribution. Additionally, given the relatively small sample size (N = 30), the assumptions required for parametric tests (e.g., paired-samples t-test, one-way ANOVA) could not be confidently met. Therefore, nonparametric statistical tests were employed for all analyses, including the Wilcoxon signed-rank test, Kruskal–Wallis H test, and Mann–Whitney U test, to ensure the validity of the results.

Results

I Results of differences in auditory pitch discrimination abilities in children with ASD

Table 1 presents the distribution of participants based on the types of auditory reactions to the "Old McDonald" melody in both high and low pitch. The results indicate that for the high-pitch melody, direct localization and reaction without localization are equally represented, occurring in 36.7% of participants. Indirect localization is observed in 23.3% of participants, and only one participant did not exhibit any reaction to this high-pitch melody. Regarding the low-pitch melody, the most frequent reaction is without localization, which occurs in 50% of participants. The frequency of indirect localization is slightly lower, at 30%, while direct localization is observed in only 13.3% of participants. Additionally, 6.7% of participants show no response to the low-pitch melody. Comparing the data, it can be noted that children with ASD in the tested sample exhibit a higher frequency of auditory reactions to the high-pitch melody, characterized by qualitatively better reactions (direct localization) (36.7%), compared to the low-pitch melody (13.3%). This suggests better auditory discrimination for the high-pitch melody.

Table 1

Types of auditory reactions to high- and low-pitch melodies ("Old McDonald")

	High-Pitch		Low-Pitch		Total	
	N	%	N	%	N	%
Direct localization	11	36.7	4	13.3	15	25
Indirect localization	7	23.3	9	30	16	26.7
Reaction without localization	11	36.7	15	50	26	43.3
No response	1	3.3	2	6.7	3	5

Note. N – number of participants.

Table 2 presents the average response time for auditory reactions during the presentation of the "Old McDonald" high- and low-pitch melodies. The average response time for children to the high-pitch melody is 2.6 seconds (for direct and indirect localization), with a slightly slower average for reactions without localization, which is 2.5 seconds. The average response time to the low-pitch melody is higher, with 3 seconds for direct localization, 5.78 seconds for indirect localization, and 5.4 seconds for reactions without localization. When analyzing the maximum response time, or the slowest reaction time, it is observed that as the quality of the reaction decreases, the response time increases. Thus, the slowest response time to the high-pitch melody is 8 seconds, while it is 12 seconds for the low-pitch. It is evident that the response to the high-pitch melody is faster, indicating better auditory discrimination.

Table 2

Average response times to high- and low-pitch melodies ("Old McDonald")

	High-Pitch					Low-Pitch				
	N	Min	Max	M	SD	N	Min	Max	M	SD
Direct localization	11	1	4	2.6	1	4	1	5	3	1.8
Indirect localization	9	1	5	2.6	1.5	9	2	12	5.78	3.2
Reaction without localization	9	1	8	2.5	2.1	15	1	12	5.4	3.3

Note. Values are expressed in seconds. N – Number of participants; Min – Minimum reaction time in seconds; Max – Maximum reaction time in seconds; M – mean in seconds; SD – Standard deviation

The application of the Wilcoxon signed-rank test yielded the results of the statistical significance of differences in auditory discrimination of high- and low-pitch melodies of "Old McDonald," as presented in Table 3. The results indicate that there is a statistically significant difference in auditory discrimination between the high- and low-pitch melodies of "Old McDonald" ($Z = –2.44$, $p = .015$). Based on the obtained results, it can be concluded that auditory discrimination is better for the high-pitch melody than for the low-pitch melody of "Old McDonald".

Table 3

Wilcoxon signed-rank test for auditory discrimination of high- and low-pitch melodies ("Old McDonald")

	N	Mnd	IQR	Z	P
High-Pitch Melody – "Old McDonald"	30	2.00	1.00		
Low-Pitch Melody – "Old McDonald"	30	3.00	1.00	-2.44	**.015**

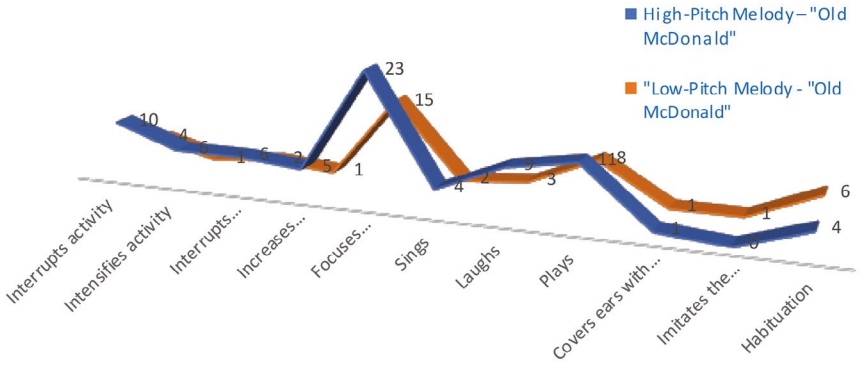
Note. Mdn = median; IQR = interquartile range; $p < .05$

By analyzing the results of the qualitative patterns of auditory reactions, the frequencies of reaction patterns occurring during the auditory discrimination of high- and low-pitch melodies of "Old McDonald" were obtained, as shown in Figure 1. It can be observed that the most frequent behavior pattern in the tested sample is the focusing of auditory attention. This behavior is more frequently displayed during the auditory discrimination of the high-pitch melody of "Old McDonald," as observed in 23 participants. The next most frequent reaction patterns include activity interruption, laughing, and playing along with the melody. These reactions are more pronounced and appear in a larger number of participants during the discrimination of the high-pitch melody compared to the low-pitch melody. A more detailed analysis of the obtained data reveals an increased frequency of various reaction patterns to high-pitch melodies compared to low-pitch melodies. Based on this, it can be concluded that auditory

discrimination of high-pitch melodies in children with ASD in the tested sample is better than the auditory discrimination of low-pitch melodies.

Figure 1

Auditory reaction patterns to high- and low-pitch melodies ("Old McDonald")



II The results of auditory pitch discrimination abilities in children with ASD in relation to age

Table 4

Kruskal–Wallis H tests for auditory discrimination of high-pitch melodies by age ("Old McDonald")

Type of Melodies	Age Groups	N	Mean Rank	Sum of Ranks	H(2)	P
High-Pitch	7–10	11	18,82	207.00		
	10-14	7	17.00	119.00	4.61	.100
	14-18	12	11.58	139.00		
Low-Pitch	7–10	11	17.68	194.50		
	10-14	7	12.57	88.00	1.71	.424
	14-18	12	15.21	182.50		

Note. Lower ranks indicate better (more precise) reactions. N = number of participants; *H(2)* and *p* values refer to the overall group comparison (Kruskal–Wallis test).

To determine whether the differences between the groups of participants according to age are statistically significant, Kruskal–Wallis H tests were applied. The results, as shown in Table 4, revealed no significant differences in auditory responses to the high-pitch melody across age groups ($H(2) = 4.61$, $p = .100$). Similarly, responses to the low-pitch melody did not differ significantly by age group ($H(2) = 1.71$, $p = .424$). Although mean ranks suggest that older children (14–18 years) showed somewhat better reactions to the high-pitch melody, and

middle-aged children (10–14 years) showed slightly better reactions to the low-pitch melody, these differences were not statistically significant. Overall, age was not associated with the quality of melody pitch discrimination in this sample.

III The results of auditory pitch discrimination abilities in children with ASD in relation to the severity of the autistic disorder

To examine whether auditory discrimination abilities differed by ASD severity, a Kruskal–Wallis H test was conducted. The results showed a significant difference for the high-pitch "Old McDonald" melody across severity groups (*H(2)*= 6.06, *p* = .048). Post hoc analysis using the Mann–Whitney U test indicated that children with moderate ASD exhibited significantly better and more precise responses than children with severe ASD (*U* = 40.50, *Z* = -2.36, *p* = .018). Children with mild ASD responded similarly to the severe group, although the small sample size (*N* = 4) limits interpretation. For the low-pitch 'Old McDonald' melody, children with severe autism showed somewhat weaker responses compared to the mild and moderate groups; however, these differences were not statistically significant (*H(2)*= 2.51, *p* = .286). Overall, autism severity was associated with the quality of auditory discrimination responses for the high-pitch melody, but not for the low-pitch melody.

Table 5

Auditory discrimination of high -pitch melody by ASD Severity ("Old McDonald")

ASD Severity	N	Mean Rank	Sum of Ranks	H(2)	P
Mild (up to 30)	4	18.00	72.00		
Moderate (up to 37)	12	10.92	131.00	6.06	**.048**
Severe (up to 60)	14	18.71	262.00		

Note. Lower ranks indicate better (more precise) auditory localization responses. ASD Severity -autism spectrum disorder severity; N = number of participants; *H(2)* and *p* values refer to the overall group comparison (Kruskal–Wallis test); Post hoc Mann–Whitney U tests indicated that children with moderate ASD performed significantly better than those with severe ASD (*U* = 40.50, *Z* = –2.36, *p* = .018). Differences between mild vs. moderate and mild vs. severe groups were not significant.

IV The results of auditory pitch discrimination abilities in children with ASD in relation to musical talent

As shown in Table 6, out of a total sample of 30 participants, 19 were identified as musically talented, as reported by parents, reflecting an interest in music, attempts to reproduce melodies, and enjoyment of singing. Mann–Whitney U tests revealed significant differences in auditory discrimination between children with and without musical talent for both high-pitched (*U* = 60.00, *Z* = -2.02, *p* = .043) and low-pitched melodies (*U* = 54.50, *Z* = -2.33, *p* =

.020). Children with musical talent exhibited lower mean ranks, indicating more precise responses to musical stimuli. Crosstab analyses confirmed that talented children most frequently demonstrated direct or indirect localization, whereas non-talented children predominantly showed weaker responses (no localization or no reaction). Pearson's Chi-square test indicated that group differences were not statistically significant for the high-pitched melody ($\chi^2(3) = 4.77$, $p = .19$) but approached significance for the low-pitched melody ($\chi^2(3) = 7.82$, $p = .050$). Linear-by-linear association tests further supported a significant association in both cases (high-pitch: $p = .037$; low-pitch: $p = .035$), suggesting that musical talent is associated with more precise and frequent localization responses across both stimulus types. These results indicate that musical talent affects auditory discrimination abilities in children with ASD.

Table 6

Auditory discrimination of high- and low-pitch melodies by musical talent ("Old McDonald")

	High-Pitch					Low-Pitch				
MT	N	Mean Rank	Sum of Ranks	U	**p**	N	Mean Rank	Sum of Ranks	U	p
yes	19	13.16	250.00	60.00	**.04**	19	12.87	244.50	54.50	**.02**
no	11	19.55	215.00			11	20.50	220.50		

Note. Lower ranks indicate better (more precise) reactions; *MT* – musical talent; *N* – number of participants; *U*- Mann–Whitney U statistic; *p* – statistical significance of the U-test; $p < .05$*

Discussion

The results indicate a difference in auditory pitch discrimination in a simple melodic structure within a group of children with autism spectrum disorder. The difference is reflected in better auditory discrimination of high-pitched melodies, which manifests through more frequent and faster auditory responses to high-pitched melodies. The analysis revealed an increased number of different patterns of auditory reactions to high-pitched melodies, with the most characteristic pattern being the focusing of auditory attention. These findings are consistent with the results of research by Heaton and colleagues (Allgood & Heaton, 2015; Heaton, 2005), who report an enhanced ability for auditory discrimination of high-pitched tones in children with ASD. Given that the ability was observed in the context of melodies, the results confirm previous research conclusions about preserved auditory discrimination of melodies and superior auditory discrimination of pitch within a melody (Allgood & Heaton, 2015; Bonnel et al., 2010; Jamey et al., 2019). It seems that the heightened auditory discrimination of high-pitched tones, confirmed in this study as well as in numerous previous studies, is a specific characteristic of auditory perception

in individuals with ASD. Since the focusing of auditory attention emerges as the most prominent response combined with better discrimination of high-pitched melodies, and considering that individuals with ASD have difficulties in attention shifting, there is a need to design approaches that will utilize the findings of this research to improve attention, as well as verbal and non-verbal communication.

Statistically significant differences in auditory discrimination related to age were not found, although there is slight evidence of more complex reactions in the oldest group, who demonstrate better quality responses to melodies. The research of Jamey et al. (2019) reports the influence of age on auditory pitch discrimination, with this ability improving with age. The current results did not reveal statistically significant age effects, suggesting that other individual characteristics, such as autism severity and musical talent, may play a more prominent role.

The research results indicate a statistically significant difference in auditory discrimination abilities for the high-pitch melody across autism severity. It is observed that with a decrease in ASD severity, the quality and frequency of auditory reactions increase. These results contrast with the findings of Jamey et al. (2019), who suggest that the ability for auditory pitch discrimination does not depend on the severity of autism. On the other hand, they are partially consistent with the results of other studies, which indicate the existence of a phenotype of high-functioning children with ASD, where auditory pitch discrimination increases with higher intellectual abilities but decreases with lower speech and language skills (Kargas, 2014). In contrast to the findings of the present study, Eigsti and Fein (2013) reported that better auditory pitch discrimination was associated with greater severity of autism symptoms, as well as with more pronounced delays in speech and language development. This discrepancy may be attributed to differences in sample characteristics, assessment methods, or the type of auditory stimuli used, highlighting the need for caution when generalizing across studies. Previous research has primarily focused on the influence of speech–language abilities on auditory discrimination in children with autism, rather than on overall autism severity. This highlights the importance of considering multiple aspects that determine autism severity, while treating speech and language abilities as a distinct factor.

The sample predominantly consists of participants with expressed musical talent, but it should be emphasized that the data regarding the degree of musical talent were obtained from parents and were generally described as "more of an interest in music rather than talent." Such parental reports were also found in the study by Bhatara et al. (2013), which discusses the increased interest and enjoyment of music in children with ASD, as well as their attempts to reproduce melodies and sing, a finding also observed in this research. Eigsti and Fein (2013) also reported that enhanced pitch discrimination may be linked to a fascination with music, suggesting that children with autism who show interest in music

tend to exhibit better pitch discrimination. To date, no studies have specifically examined the influence of musical ability on auditory pitch discrimination within melodies. Evidence indicates that some children with autism can perceive absolute pitch, a rare ability in the general population (Bonnel et al., 2010; Kellerman et al., 2005). These findings underscore the importance of considering musical ability as a potential factor contributing to auditory pitch discrimination in melodies.

Limitations and Future Recommendations: A key limitation of this study is the relatively small sample size. Future studies with larger samples are recommended to determine whether the present findings reflect general characteristics of the ASD population or are specific to this particular sample. Future research should further investigate in greater depth the influence of age on auditory pitch discrimination. It would be valuable to explore how pitch discrimination abilities are connected with speech and language development, in order to better understand the functional significance of these auditory processes in children with ASD. Another limitation concerns the uneven distribution of participants across autism severity. Specifically, the group with mild ASD severity was the least represented, which may explain why the quality of melodic responses was not clearly evident in this subgroup. To ensure greater accuracy and reliability of results, future studies should include a larger sample with balanced representation across severity levels. Moreover, it is recommended that future research examine the specific influence of distinct symptom profiles associated with ASD severity on auditory pitch discrimination. Another limitation relates to the assessment of musical talent. In this study, musical talent was identified based solely on parental reports, which may have introduced subjectivity and inconsistency. Future research should utilize standardized tools specifically designed to assess musical ability in children with ASD, ensuring greater objectivity and comparability across participants

As ASD cases are becoming increasingly common in the child population, it is crucial to explore different domains of their functioning, with a particular focus on strengths and specific abilities, among which superior auditory discrimination stands out. The results of this, as well as future studies, should be used to overcome limitations and enhance knowledge of the superior auditory abilities of children with ASD. The insights gained into the specifics of auditory pitch discrimination should be applied when designing treatments and planning activities, taking into account the individual characteristics of each child with ASD, with the aim of fostering overall development and special abilities.

Conclusions

The present study demonstrates that children with ASD in the tested sample exhibit superior auditory discrimination for high-pitch melodies compared to low-pitch melodies. High-pitch stimuli elicited qualitatively better responses, including a higher frequency of direct localization and faster

reaction times, indicating enhanced pitch discrimination. Severity of autism significantly influenced performance, with children with moderate ASD showing more precise responses than those with severe ASD for the high-pitch melody. Additionally, musical talent emerged as a significant factor: children with musical talent demonstrated more accurate and consistent auditory responses than their non-talented peers. Age, however, did not significantly affect auditory discrimination in this sample. These findings suggest that both stimulus characteristics (pitch) and individual factors (autism severity, musical talent) contribute to auditory discrimination abilities in children with ASD. Given that music is a common focus of repetitive and stereotypical interests in these children, understanding these pitch discrimination specificities may inform the development of targeted interventions and educational strategies to support nonverbal communication and cognitive skills.

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Auditivna diskriminacija visine tonaliteta u melodiji jednostavne melodijske strukture kod dece sa poremećajem iz spektra autizma

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Uvod: Pretpostavlja se da osobe sa poremećajem iz autističnog spektra (PSA) pokazuju specifične slušne karakteristike, kao što su superiorna diskriminacija visine tona i povećana osetljivost na muzičke melodije. *Cilj*: Cilj ovog istraživanja je da utvrđivanje razlike u slušnoj diskriminaciji melodija visokog i niskog tonaliteta kod dece sa poremećajem iz autističnog spektra (PSA). *Metode*: Auditivna diskriminacija visine tona ispitivana je na uzorku od tridesetoro dece sa PSA, uzrasta od sedam do 18 godina. Ta sposobnost testirana je pomoću instrumenta razvijenog posebno za potrebe ovog istraživanja, koji predstavlja osnovu za procenu diskriminacije visine tona u melodijama kod dece sa poremećajem iz spektra autizma. *Rezultati:* Rezultati istraživanja ukazuju na postojanje razlika u sposobnosti razlikovanja visine tona u jednostavnoj melodijskoj strukturi, pri čemu je zabeležena bolja diskriminacija melodija višeg tonaliteta u odnosu na melodije niskog tonaliteta ($Z = –2.44$, $p = .015$). Težina autizma bila je povezana sa auditivnom diskriminacijom melodije visokog tonaliteta, pri čemu je kvalitet odgovora opadao sa povećanjem težine autizma ($U = 40{,}50$, $Z = -2{,}36$, $p = .018$). Rezultati sugerišu da deca sa PSA koja pokazuju muzički talenat imaju bolju auditivnu diskriminaciju (visoki ton: $p = .037$; niski ton: $p = .035$). Uzrast nije bio povezan sa kvalitetom diskriminacije melodijskih tonova u ovoj populaciji. *Zaključak:* Dobijeni nalazi mogu doprineti produbljivanju teorijskih saznanja i rešavanju praktičnih problema, u cilju podsticanja specifičnih sposobnosti i sveukupnog razvoja dece sa PSA.

Ključne reči: poremećaji iz spektra autizma, auditivna diskriminacija, visina tona, muzička melodija

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