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Psychophysical correlates of musicality in musically untrained children: evidence for musical sleepers in children

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Abstract

Background Music learning induces significant neural changes, enhancing auditory, verbal, and visuospatial skills, IQ, and speech perception. Research studies reveal structural and functional brain plasticity due to music training in adults and children. While musical abilities are linked to formal training, the existence of "musical sleepers" with heightened speech perception without formal training is noteworthy in adults. This study addresses the gap in understanding such phenomena in children, exploring psychophysical abilities in musically adept children, and aiming to impact rehabilitation models.

Materials and method A pre-experimental study involved 164 typically developing children (mean age: 9.93) without musical training. Musical abilities were evaluated using the abbreviated version of Montreal Battery for Evaluation of Musical Abilities (MBEMA) test in DMDX software, covering melody, rhythm, and memory subtests. Psychophysical tests in MATLAB assessed temporal, frequency, intensity, timbre, and binaural resolution.

Results Using a median split based on MBEMA test scores (median: 42), 84 children exhibited poor musical abilities, while 80 showed good ones. Descriptive statistics for MBEMA scores and psychophysical tests were conducted. As data did not follow normal distribution, non-parametric inferential statistics were employed.

Mann–Whitney *U* tests revealed significant differences favouring good musical abilities in all assessments: gap deduction ($p=0.01$), pitch discrimination at 500 Hz and 4 kHz ($p=0.00$), intensity discrimination at 500 Hz ($p=0.00$) and 4 kHz ($p=0.01$), profile analysis ($p=0.01$), interaural level difference ($p=0.023$), and interaural time difference ($p=0.038$). Spearman correlation showed highest correlation with pitch discrimination at 500 Hz ($r=-0.538$), 4 kHz (-0.416), intensity discrimination at 4 kHz ($r=-0.367$), and 500 Hz ($r=-0.311$), profile analysis ($r=-0.313$), interaural level difference ($r=-0.276$), and gap deduction ($r=-0.235$). All were significant ($p<0.01$), except for the interaural time difference.

Conclusion Children excelling in music surpassed those with weaker abilities in psychophysical tasks. This echoes past research, underscoring auditory discrimination's influence on musical skills in untrained children. These results potentially support the concept of musical sleepers in children. Key predictors include pitch discrimination, while interaural time difference exhibited minimal correlation. Utilising such assessments may predict musical training outcomes for children with auditory disorders, but additional robust statistical investigation is necessary.

Keywords Musical abilities, Children, Musical sleepers, Psychophysical abilities, MBEMA, Auditory discrimination

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Background

Engaging in musical activities involves intricate sensory and perceptual processes, whether listening, learning an instrument, or any musical pursuit. Melodic perception, centred on nuanced variations in musical notes, encompasses pitch, frequency structure, temporal envelope, and temporal fine structure. Similarly, harmony perception relies on discerning combinations of these variations [1]. Musical training yields significant benefits in adults, enhancing pitch processing speed, relative pitch perception, and frequency discrimination while maintaining equivalent general intelligence performance [2–4]. Musicians demonstrate superior frequency discrimination thresholds to non-musicians, highlighting the precision developed through extensive auditory tasks [5]. Adult musicians also exhibit improved speech perception in noisy environments and heightened frequency discrimination abilities, correlating with the duration of musical practice [6]. In various auditory tests, musicians consistently outperform non-musicians, emphasising the positive impact of musical training [7, 8].

In children with instrumental training, musical influence extends to both musical and speech domains, enhancing sensitivity to pitch incongruencies in melodies and sentences [9]. Another study involving school-going children with musical training showcases superior auditory processing abilities across various parameters, emphasising the role of music training in fortifying neural structures associated with temporal processing [10].

Previous musical abilities confound the benefit of musical training

While music training positively affects various skills, studies comparing musicians to non-musicians may overlook confounding factors such as cognitive abilities, demographics, and personality [11]. Musical competence in undergraduates is associated with various factors, including the duration of training, socioeconomic status, short-term memory, general cognitive ability, and openness to experience [12]. The complex relationship between music training and higher IQ scores raises questions about causation, with alternative interpretations suggesting better intellectual functioning as a driver for music enrollment [13]. Genetic factors influencing IQ and personality intertwine with music training in young children, challenging the direct link between music training and plasticity [14].

Positive associations between music aptitude and various auditory abilities further complicate the relationship. Studies reveal enhanced auditory perceptual abilities in individuals with good musical aptitude, extending to speech sounds and discriminating acoustic features [15, 16]. Measures of music aptitude, such as tonal and melodic subtests, are linked to detecting speech regularities and correlating with auditory working memory in children [17]. Moreover, like trained musicians, adults with good musical aptitude demonstrate improved frequency following response (FFR) to degraded speech sounds, suggesting an additional boost from the musical experience [11].

Musical sleepers in adults

Individuals with music training tend to exhibit higher musical abilities. At the same time, musical abilities are associated with music training [12, 18, 19]. While the benefits of music training have been debated for decades, a volume of research flashed light on musical sleepers, individuals with good musical abilities without formal music training. Musical sleepers tend to have heightened speech perception [11]. Also, Musical abilities were associated with better auditory perceptual abilities. An association between the individuals' music competence and ability to process non-native speech sounds, predicted by the temporal, pitch and spectral discrimination ability, was established by Kempe et al. [16].

The study is motivated by the recognised association between musical abilities and the perception of intricate acoustic features within an auditory scene, a process contingent on diverse psychophysical abilities. While "musical sleepers" have been established in adults, showcasing their heightened auditory and speech perception capabilities, exploring this phenomenon in children remains uncharted territory. The potential implications of such exploration are significant, particularly in reshaping existing rehabilitation models.

Despite evidence of musical sleepers in adults and the acknowledged impact of previous musical experiences, examining whether specific auditory abilities can forecast elevated musical proficiency in children devoid of prior musical training is lacking. This study seeks to address this gap by investigating the predictive relationship between certain auditory capabilities and heightened musical abilities in musically untrained children. The objective is to establish evidence supporting the existence of musical sleepers among children.

Moreover, the study extends its importance beyond theoretical insights by paving the way for the development of innovative music-based treatment models. By systematically comparing various psychophysical abilities in musically untrained children, the research aims to contribute valuable information to the understanding and potential intervention of individuals with auditory, linguistic, and cognitive disorders.

Aim

The study investigates and compares various psychophysical abilities among typically developing children with a wide range of musical abilities.

Primary objectives

To assess and compare psychophysical abilities, including temporal resolution, frequency resolution, intensity resolution, timbre resolution and binaural resolution, in typically developing children with good and poor musical abilities.

Secondary objective

To identify the key psychophysical ability that correlates best with musical abilities in typically developing children.

Method

Participants

A pre-experimental static group comparison involved 164 typically developing children aged 9 to 11 years (mean: 9.93; SD: 0.77; see Table 1) who had not undergone musical training. Screening for auditory processing disorder was carried out using the Screening Checklist for Auditory Processing, SCAP [20], while assessment for autistic features was carried out using the Modified Checklist for Autism in Toddlers-Revised, MCHAT-R [21]. All the participants were Kannada speakers native to the Mysore region of the Indian state, Karnataka. The demographic details were collected from the participants' parents through Google Forms, a web-based survey administrator module developed by Google Inc. (USA). Demographic details about exposure to music, the habit of listening to music, musicians in the family, and formal music training were included in the proforma of questions. The summary of responses collected from the participants through the proforma related to the music background of the participants is represented in Fig. 1.

Table 1 Demographic details of the participants

Variables	Group 1 (participants with poor musical abilities)		Group 2 (participants with good musical abilities)	
	Mean	SD	Mean	SD
Age ($N=184$)	9.89	0.76	9.98	0.78
SCAP score ($N=184$)	1.06	0.05	1.1	0.06
MCHAT-R score ($N=184$)	0.60	0.01	0.40	0.02

Materials and procedures

Test for assessing musical abilities

The abbreviated version of the Montreal Battery for Evaluation of Music Abilities, MBEMA [22] , evaluated the participants' musical abilities. The test comprises three subtests for melody, rhythm and memory. Each subtest has 20 pairs of musical melodies. In melody subtests, ten melodies will not vary; four melodies have scale variations, three pairs have contour variations, and the other three pairs have interval variations. In rhythm subtests, the rhythm of the melodic pairs is altered by changing the duration of two adjacent tones while retaining the number of notes and original meter. The participant is involved in a discrimination task by responding to whether the melodic pairs are the same or different for both melody and rhythm subtests. The memory subtest will have ten melodies used in previous subtests and ten new melodies. The test was conducted using DMDX software [23], a computer-based module used to conduct behavioural experiments. The participant had to indicate whether the presented melodies were familiar or not. All the stimuli were presented at 60 dB SPL. Scores for the number of correct responses were recorded for each subtest, and a total score was calculated.

Test for temporal resolution

The gap deduction test in MATLAB Psychoacoustic toolbox [24] assessed temporal resolution abilities. It involved three blocks of 750 ms white noise stimuli with a varying gap duration in the varying block. The participant had to identify the block with a gap. The overall stimuli were ramped at the start and end with raised cosine ramps of 0.5 ms. The test adopted in the current study will be similar to that reported by [25]. The test terminated after ten reversals, and the last four reversals were averaged to determine the converged gap deduction threshold (GDT).

Test for frequency and intensity resolution

Differential limen for frequency (DLF) and differential limen for intensity (DLI) tasks, implemented in the Psychoacoustic toolbox of MATLAB, assessed frequency and intensity resolution. DLF and DLI involve a pitch and loudness discrimination task using 500 Hz and 4000 Hz pure tones of 250 ms duration. The pitch perception abilities improve as the fundamental frequency increases. Also, intensity discrimination is frequency dependent on lower sensation levels [26]. Hence, the DLF and DLI tasks were carried out in two different frequencies, 500 Hz and 4000 Hz, to assess the children's pitch and loudness

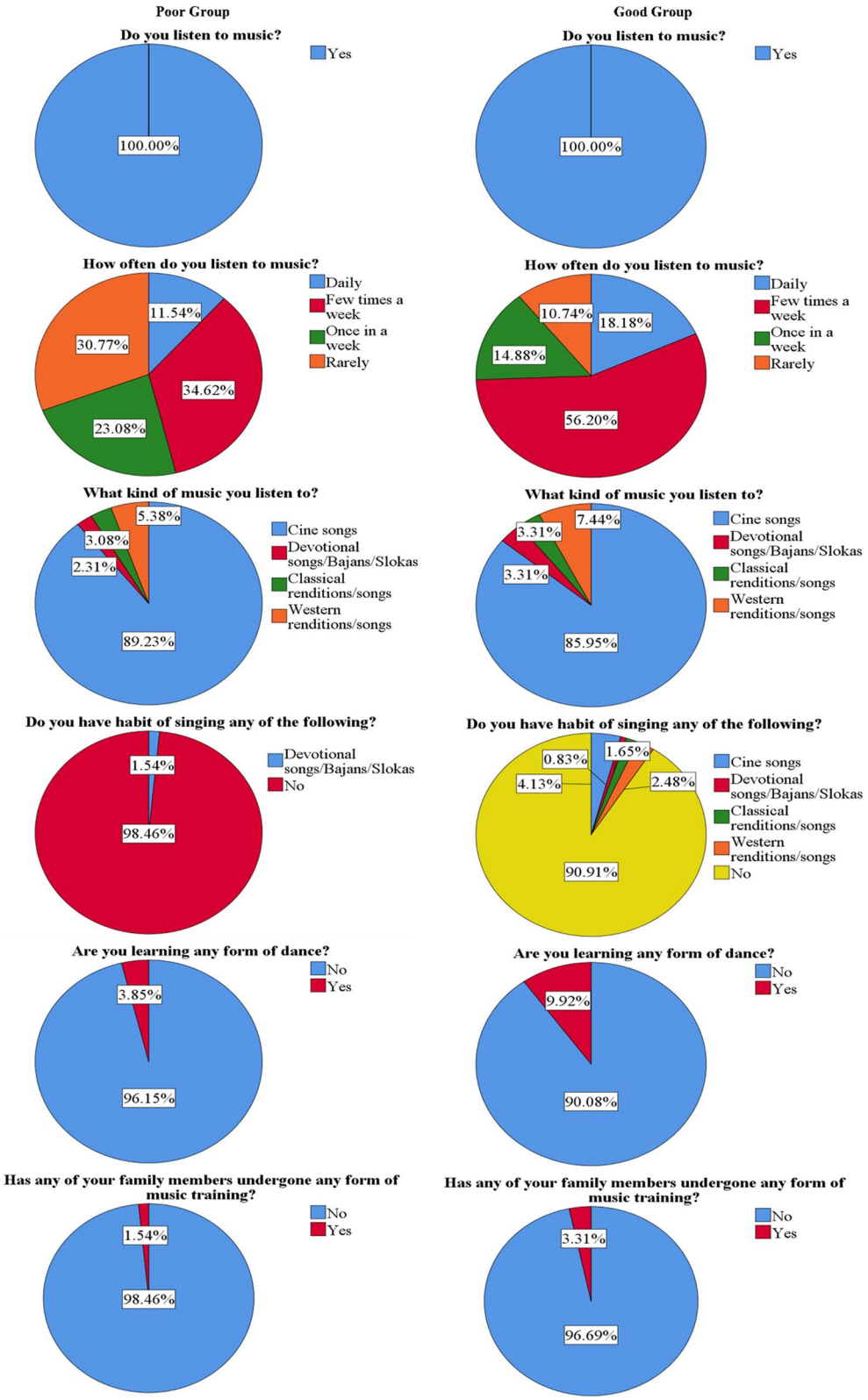

Fig. 1 Summary of responses (percentage) collected from the participants regarding music background

discrimination abilities for low and high frequencies. In the DLF task, the frequency of the variable block varies according to the subject's response. In DLI, the intensity of the variable block varies according to the subject's response. The participant had to identify the variable block with a higher pitch in the DLF task and a louder tone in the DLI task. The overall stimuli were ramped at the start and end with raised cosine ramps of 10 ms. The test terminated after ten reversals, and the last four reversals were averaged to get the converged DLF and DLI threshold at 500 Hz and 4000 Hz.

Test for timbre resolution

The spectral profile analysis test, adapted from [27], assessed timbre resolution. The test involved the identification of timbre differences in a set of complex tones. The timbre difference was induced by varying the amplitude of 3rd component in a five-harmonics complex tone with a fundamental frequency (f0) of 330 Hz. The complex harmonic tones were presented at 60 dB SPL, and the participant had to identify the variable block with a different timbre. The test terminated after ten reversals, and the last four reversals were averaged to determine the converged threshold for timbre resolution (TRT).

Test for binaural resolution

Tests for interaural time difference (ITD) and interaural intensity difference (ILD) assessed binaural resolution. Both the tests involved presenting a white noise of 250 ms binaurally, with the standard blocks being presented centrally without any time or intensity differences between the ears, whereas the variable block had a white noise of 250 ms with a delay to the right ear stimulus for ITD and an increased intensity in the right ear stimulus for ILD. The variable block's time delay and intensity change varied by 3 ms and 0 dB for ITD and ILD respectively. The time delay and the intensity change resulted in the lateralisation of the stimulus to the right ear. The participant's task was to identify the block lateralised to the right ear. All the stimuli were presented at 60 dB SPL and ramped at the start and end with raised cosine ramps of 10 ms. Both tests terminated after ten reversals, and the last four reversals were averaged to obtain the converged ITD and ILD thresholds.

All psychophysical tests were conducted using a three-down, one-up adaptive staircase procedure with three alternate forced choices (3AFC) implemented in the Psychoacoustic toolbox of MATLAB R2021b.

Statistical analysis

Descriptive statistics were applied to the total scores obtained from the abbreviated version of the Montreal Battery for Evaluation of Musical Abilities (MBEMA). A median split was conducted to categorise participants into two groups based on their musical abilities [11]. Participants scoring above the median (42 in this study) were classified as having good musical abilities, while those scoring at or below the median were categorised as having poor musical abilities. This process resulted in 84 children identified with poor musical abilities and 80 with good musical abilities (see Fig. 2).

The Shapiro-Wilk test was performed to assess the data distribution within each group. The results indicated that the data did not conform to a normal distribution. Consequently, non-parametric inferential statistics were employed for subsequent analyses.

The Mann-Whitney *U* test was utilised to compare the thresholds of psychophysical abilities between children with good and poor musical abilities. This non-parametric test is particularly suited for comparing two independent groups when the assumption of normal distribution is unmet.

Furthermore, a Spearman correlational analysis explored the relationship between the total MBEMA scores and the thresholds obtained from all psychophysical ability tests. Spearman correlation is a robust method suitable for assessing associations between variables when the assumption of linearity or normal distribution is unmet.

These statistical procedures were crucial in uncovering potential differences in psychophysical abilities between children with varying musical abilities. The non-parametric approach ensures the validity of the analyses given the non-normally distributed nature of the data. The correlational analysis, on the other hand, provided insights into the potential associations between overall musical abilities and specific psychophysical skills, shedding light on the intricate interplay between musical and auditory perceptual domains in the examined cohort.

Results

The SCAP, with a cutoff score of 6, has a sensitivity of 71% and specificity of 68% in identifying school-going children at risk for auditory processing disorder [28]. Hence, children scoring 6 or above will be considered at risk for auditory processing disorder. All the children in the current study have scores below 6 on the checklist answered by the parents (see Table 1). Hence, the risk of auditory processing disorder was ruled out in the participants.

Similarly, MCHAT-R is a screening checklist for autistic behaviours in children. Children who score 0–2 will have a low risk (less than 47.5%) of autism spectrum disorders (ASD) [29]. In the current study, all the participants scored less than 2; hence, they were not at risk of ASD (see Table 1). The history of musical training and musical habits of the participants and their family

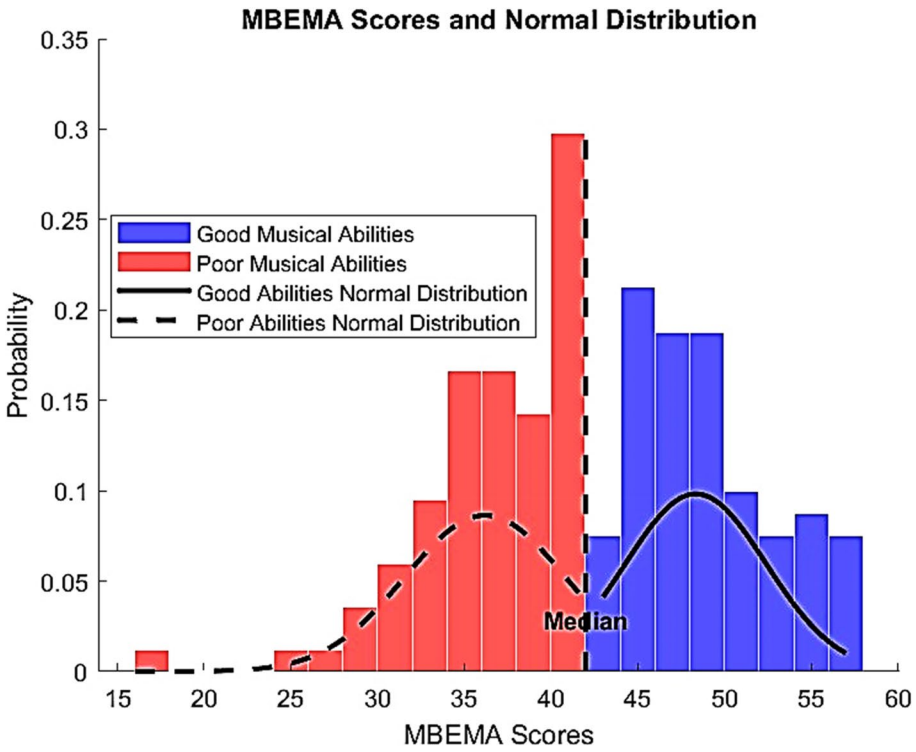

Fig. 2 Distribution of total MBEMA scores with a normal probability curve for each group divided by median (dashed vertical line)

members were verified using customised questions, and it was made sure that neither the participants nor their family members had undergone any formal musical training. Also, the musical habits of the participants were similar. One hundred per cent of the participants habitually listened to some form of music, either cine songs or

Table 2 Demographics of musical habits and history of musical training in participants

Questions	Responses	Frequency
1. Do you listen to music?	Yes	100%
	No	Nil
2. How often do you listen to music?	Daily	50%
	A few times a week	21%
	Once in a week	20%
	Rarely	9%
3. What kind of music do you listen to?	Cine songs	92%
	Devotional songs/Bhajans/Slokas	Nil
	Classical renditions/songs	Nil
	Western renditions/songs	8%
4. Do you have a habit of singing any of the following?	Yes	Nil
	No	100%
5. Are you learning any form of dance?	Yes	Nil
	No	100%
6. Has any of your family members undergone music training?	Yes	Nil
	No	100%
7. Are you undergoing any form of music training?	Yes	Nil
	No	100%

Western albums. The frequency of such habits varied from daily to rarely (once in a few weeks) (see Table 2).

Figure 3 indicates the median thresholds of all the psychophysical abilities, including the GDT, DLF at 500 Hz and 4 kHz, DLI at 500 Hz and 4 kHz, TDT, ILD, and ITD. Children demonstrating good musical abilities exhibited significantly superior performance across all conducted tests compared to their counterparts with poor musical abilities

The Mann–Whitney U test results revealed significant differences in the GDT ($U=2579.00$, $p=0.01$), DLF at 500 Hz ($U=1336.00$, $p=0.00$) and 4 kHz ($U=2012.50$, $p=0.00$), DLI at 500 Hz ($U=2477.00$, $p=0.00$) and 4 kHz ($U=2066.00$, $p=0.01$), TDT ($U=2085.00$, $p=0.01$), ILD ($U=2667.00$, $p=0.023$) and ITD ($U=2729.00$, $p=0.038$).

A Spearman correlational analysis explored the relationships between the total MBEMA score and various psychophysical abilities to address the study's secondary objective. Figure 4 is a scatter plot between the MBEMA scores and thresholds of psychophysical abilities, with a trend line. The results demonstrated the strongest correlation between the MBEMA score and DLF at 500 Hz ($r=-0.538$), followed by DLF at 4 kHz ($r=-0.416$), DLI at 4 kHz ($r=-0.367$), and 500 Hz ($r=-0.311$). Additionally, TDT ($r=-0.313$) and ILD ($r=-0.276$) showed a moderate negative correlation. The GDT negatively correlated with the MBEMA score ($r=-0.235$). Notably, all these correlations were statistically significant at $p<0.01$. However, the ITD did not correlate significantly with the MBEMA score.

Discussion

Children diagnosed with auditory processing disorder (APD) exhibited diminished musical abilities, including challenges such as musical pitch discrimination, rhythm reproduction, and singing [30]. Conversely, children diagnosed with autism spectrum disorder (ASD) tend to demonstrate heightened pitch perception and enhanced musical memory [31]. To mitigate potential confounding factors in the present study, participants underwent screening for both APD and ASD, ensuring that only those who passed were included. This meticulous screening process aimed to eliminate the influence of these conditions on the observed musical abilities.

Recognising the potential impact of age and gender as additional confounding factors, a preliminary pilot study was conducted for male and female children aged 7 to 13 years. The findings from this pilot study revealed that musical abilities remained stable within the age range of 9 to 11 years. Consequently, participants within this specific age bracket were exclusively included in the current study. Furthermore, an examination of gender effects indicated that the musical ability scores of participating children did not exhibit any gender-related variations.

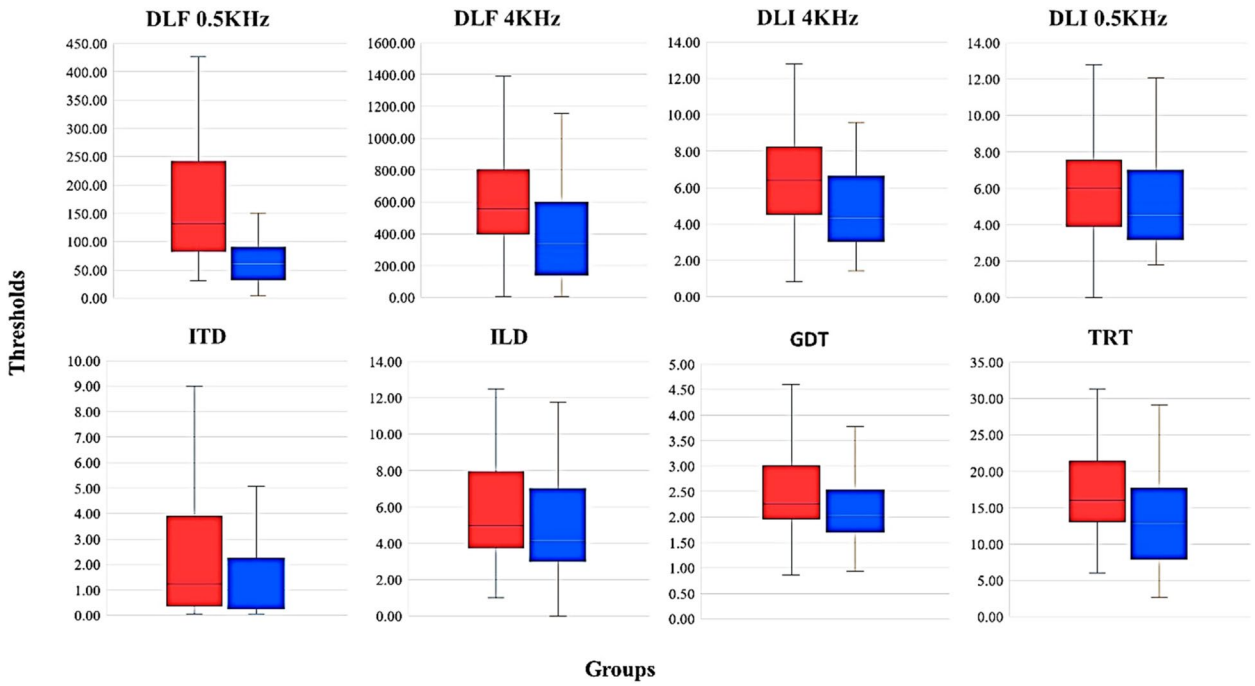

Fig. 3 Box plot with median (centre line) and minimum and maximum thresholds for psychophysical abilities (DLF at 500 Hz and 4 kHz, DLI at 500 Hz and 4 kHz, ITD, ILD, GDT, and TRT) in a group with poorer musical abilities (red coloured) and a group with good musical abilities (blue coloured)

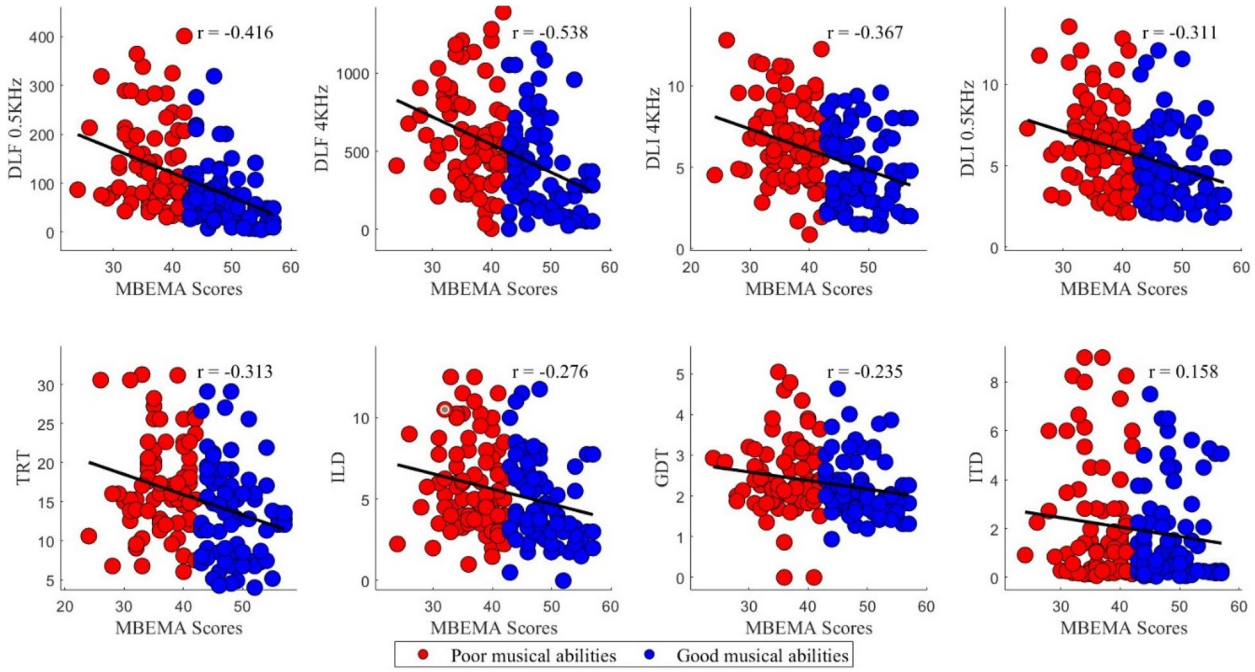

Fig. 4 Scatter plot depicting the correlation between total MBEMA scores and thresholds of various psychophysical abilities (DLF at 500 Hz and 4 kHz, DLI at 500 Hz and 4 kHz, ITD, ILD, GDT, and TRT) with a linear trend line fitting each correlation's data and *R* values

This comprehensive approach effectively controlled for potential confounding effects of age and gender in the current study.

Individuals with a background in musical training exhibit remarkable musical proficiency and demonstrate enhanced auditory perceptual abilities. A substantial body of literature has extensively supported this correlation between superior auditory perceptual skills and musical abilities. Numerous studies, including those by [11, 15–17, 32], consistently highlight the heightened auditory capabilities of individuals with musical training.

Furthermore, the link between musical training and auditory perceptual prowess extends to child development [33] and found that children who received musical training surpassed their untrained counterparts in tasks related to differential limen frequency (DLF), differential limen intensity (DLI), and gap detection threshold (GDT). This evidence strongly suggests that proficient musical abilities are associated with superior auditory perceptual skills, even in the early stages of development.

The outcomes of the current study further reinforce the implications of these findings. Here, children with robust musical abilities consistently outperformed their peers with comparatively weaker musical skills across all assessed psychophysical abilities. This noteworthy discovery underscores the direct impact of auditory discrimination abilities on musical proficiency in typically developing children who have not undergone formal musical training.

The significance of these results extends beyond the immediate context of the study, hinting at the potential identification of "musical sleepers" in children. The term "musical sleepers" suggests individuals who exhibit heightened musical abilities despite lacking formal musical training. This tantalising prospect opens avenues for further exploration and emphasises the intricate relationship between auditory discrimination and musical prowess, particularly in the developmental stages of childhood.

The correlational analysis conducted in our study establishes a significant link between frequency discrimination ability and the musical abilities of typically developing children, echoing the findings reported by Kempe et al. [16]. This underscores the pivotal role that pitch discrimination plays in musical proficiency.

Pitch discrimination, denoting the ability to differentiate between various pitches or frequencies, constitutes a fundamental aspect of auditory perception. This skill is paramount in identifying deviations from established scales within a musical context. Individuals with heightened pitch discrimination skills demonstrate superior acuity in perceiving subtle pitch differences between notes. This heightened sensitivity enables them to detect deviations from the expected pitches

defined by a particular scale, contributing to a more nuanced musical perception.

Furthermore, the correlation between pitch discrimination skills and variations in pitch contours supports the notion that individuals with robust pitch discrimination abilities are better equipped to discern a melody's overall shape or contour. Melodic contour, encompassing the rising, falling, or consistent pitch sequences in a melody, is integral to understanding musical structure. Pitch discrimination plays a vital role in detecting changes in melodic contour, including upward or downward intervals, leaps, or repeated pitches.

The study also underscores the association between pitch discrimination and interval variations, as strong pitch discrimination skills empower individuals to identify specific intervals, such as thirds, fifths, or octaves. Recognising the pitch gap between two notes is crucial for accurately perceiving interval variations within a melody, contributing to a nuanced understanding of musical relationships.

In contrast, our findings indicate that the least correlation exists between interaural time difference (ITD) and musical abilities, suggesting a lack of a spatial component in the musical ability test employed. Notably, our study material involves the detection of scale, contour, interval, and rhythm deviations, aligning with the comprehensive approach that Peretz et al. [22] suggested. The robust correlation between musical abilities and pitch discrimination thresholds underscores the significance of pitch-related skills in predicting overall musical proficiency. The lesser correlation with ITD emphasises the potential importance of incorporating a spatial component into musical ability tests to assess the multifaceted nature of musical perception and performance comprehensively.

The secondary objective of the study was to identify the key psychophysical ability that correlates best with musical abilities in typically developing children. The correlational analysis has revealed that the key psychophysical ability that correlates best with musical abilities is pitch discrimination, especially at low frequencies. This reflects the importance of low-frequency pitch discrimination for musical abilities, particularly in melody recognition, harmony discrimination, rhythm and beat perception, etc. Hence, the psychophysical abilities that are crucial for musical abilities are found to be pitch discrimination. The heightened musical abilities of musical sleepers could be because of their intricate pitch discrimination skills. Hence, when targeting across-domain transfer of benefits through musical intervention, pitch discrimination should be given higher priority.

Conclusion

Children categorised according to their musical abilities exhibited significant differences in psychophysical capacities. Those with elevated musical abilities demonstrated markedly superior performance across a comprehensive psychophysical test battery. This discernible trend hints at a phenomenon akin to musical sleepers in children. However, to substantiate this hypothesis, a more thorough comparative analysis with adults is imperative, providing a stronger and more comprehensive foundation for understanding the persistence of this phenomenon across different age groups. The psychophysical abilities of typically developing children, devoid of any musical training, emerge as a pivotal predictive factor for their musical abilities. This discovery holds promising implications for implementing predictive models to anticipate musical training outcomes, particularly for children grappling with various auditory disorders. Integrating psychophysical assessments into such models could significantly enhance their precision in foretelling the musical development of children facing auditory challenges. Nevertheless, it is crucial to acknowledge the imperative need for further investigation, incorporating more robust statistical analyses to establish the observed predictive phenomenon. Strengthening the evidence through meticulous statistical scrutiny will contribute to the resilience and credibility of the conclusions drawn, providing invaluable insights into the intricate relationship between psychophysical abilities and musical development in children. Another significant finding in the current study was that musical abilities correlated most strongly with pitch discrimination and least strongly with ITD (interaural time difference). This highlights the critical role of pitch in music perception and the absence of spatial components in the materials used to assess musical abilities. Since spatial processing is a vital skill for musicians involved in live music production, the lack of assessment tools for its contribution to musical abilities needs to be addressed.

Limitations and future directions

The current study addresses the question of musical sleepers in children and their psychophysical abilities, there are certain limitations which has to be addressed in future. The psychophysical abilities are compared in children with good and poor musical abilities, who are musically untrained, yet further comparison with a third group of participants who are trained in music would provide more virtue about how musical sleepers are comparable to musically trained individuals. Also, the socioeconomic status of the participants was not assessed and controlled in the current study, which would probably confound the outcome of the results because musical

abilities were found to be associated with socio-economic status, so this could be a limitation of the current study.

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Authors' contributions
SS conceptualised and designed the study, conducted the data collection and analysis, and drafted the initial manuscript. DN guided throughout the research process, offering critical feedback on study design, data interpretation, and manuscript revisions. Both authors have read and approved the final manuscript, contributing significantly to this paper's intellectual content and research development.

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Availability of data and materials
The data and materials supporting the findings of this study are available upon reasonable request. Researchers interested in accessing the dataset or related materials may contact the corresponding author for further information.

Declarations

Ethics approval and consent to participate
This study received ethical approval from the All India Institute of Speech and Hearing, Mysore Institute Ethics Committee to ensure compliance with ethical standards in research involving human participants. Informed consent was obtained from the parents of all participants, and confidentiality and privacy were maintained throughout the study. All procedures in this study complied with the ethical guidelines of bio-behavioural research involving human subjects [34].

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests concerning the research, including financial, personal, or professional affiliations, that could influence the interpretation or presentation of the study's results.

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