Research Article

The Perception of Pitch Contours in Typically Developing Children with and without Musical Training

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Highlights

- Musical training enhances the perception of pitch cues in children
- Pitch contours mimic musical stimulus and can be used to assess musical ability

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ABSTRACT

Background and Aim: Musical training causes neuroplasticity changes which are transferred to other modalities like- audition, cognition. All the musical tests use musical stimuli, which can be challenging for children without musical training due to the unfamiliarity of the stimuli. Dynamic stimuli like pitch contours, mimic musical stimuli. Hence the present study aimed to investigate the perception of pitch contour for different tonal stimuli in typically developing children with and without musical training.

Methods: Children aged 9–13 years were categorized into two groups: Group I (with formal musical training) and Group II (without musical training). Musical abilities were assessed using the Montreal Battery for Evaluation of Music Abilities (MBEMA) test, with melody, rhythm, and memory subtests. The melody and rhythm subtests had discrimination of musical tones, while the memory subtest had identification of familiar melodies from previous subtests. Pitch contours for tonal stimulus were generated using PRAAT software. These contours consisted of tone sweeps representing nine patterns (rising, rising-flat, rising-falling, flat, flat-rising, flat-falling, falling, falling-flat, and falling-rising) for 500 Hz, 1, and 2 kHz tones. Children were familiarized with these contours and tested using closed-set identification task using DMDX software.

Results: Group I outperformed Group II in both musical ability and pitch contour identification tests. MANOVA revealed significant differences in MBEMA and pitch contour identification between the groups.

Conclusion: The contour perception of the different pitch shows evident differences induced by musical training. It is proposed to assess the musical ability of the individual with the tonal pitch contours.

Keywords: Perception; pitch contours; musical training

Introduction

Sounds that are of utmost interest for research are speech and music, as they contain acoustical parameters that are very rich and are continuously changing with time. Both music and speech consists of quasi-periodic segments with rich harmonic complexity (syllables and notes), which are parted by bursts of noise, silence, and or transients that are systematized with timing. These perceptual origins are distinct in terms of spectral envelope, fundamental frequency, and duration [1]. Perception of these dynamic cues is important to understand speech and enjoy music. Pitch is one of the important cue for both speech and music perception. Pitch information helps to segregate competing sound sources, identify speakers, and understand the meaning of the sentences in speech. In adverse conditions also pitch cues serve as major cue in separating competing speech streams in the presence of noise. The variation in the natural speech helps in better speech recognition of speech in noisy environments [2]. Whereas in music pitch cues are used to segregate multiple instruments and perceive melody [3]. Music and speech stimuli are dynamic sounds varying continuously along the time of presentation [4].

Musical training is said to make neuroplasticity changes and the skills acquired from the music training are transferred to other modalities like cognition, audition [5, 6] and have helped in the betterment of the quality of life. Children with musical training are expected to show a good prognosis after the training. Hence knowing whether the child has musical ability or not would determine the prognosis of the child. However, there are only limited tests to assess musical ability in children and all of them use musical stimuli as their stimulus. Therefore, children who have been trained in music obtain better scores, whereas other children without training would not perform well, even though they have abilities, because of the unfamiliarity with the instrumental tune. Therefore, it is important to assess the musical abilities of children using much simpler stimuli that can mimic the basics of the musical stimulus.

In real listening environments, we encounter signals with rapidly changing spectral components like speech and music. Correct identification of phonemes in speech depends upon the sensitivity of the auditory system to respond to rapid changes of formant transitions which is critical for distinguishing consonants. Dynamic frequency like tonal sweeps or contours of varying frequencies could form a simplified representation of speech and musical formant transitions [7]. The pitch contours play a crucial role in the perception of the intonation, structure of the signal, and emotional meaning of the music. Perception of tonal sweeps in terms of pitch change detection and direction has been studied in children and adults, which has shown significant improvement with maturation [8, 9]. Poor coding of tonal sweeps in children is attributed to poor performance in adverse listening than adults has been reported [7]. Studies have reported the advantage of musical experience or laboratory training on pitch contour perception [10] and coding of pitch direction [6] in adults. Similarly, few studies have demonstrated improved frequency discrimination and coding of pitch in children who receive musical training [3, 6, 11]. The perception of pitch contour of stimuli is salient for listeners of all age groups. The pitch processing information has been reported to be difficult in stimuli with changing spectral envelopes [12]. Hence the present study aimed at studying the effect of musical training on the perception of pitch contour for different tonal stimuli like rising, rising-flat, rising-falling, flat, flat-rising, flat-falling, falling, falling-flat, and falling-rising in typically developing children.

Methods

Participants

The study included typically developing children in the age range of 9–13 years (mean age: 11 years, SD 1.58). All the children had pure tone threshold of ≤15 dB HL for octave frequencies from 250–8000 Hz and normal; middle ear functioning ascertained by ‘A’ type tympanogram with reflexes present. Further children were screened for Central Auditory Processing Disorders (CAPD) using Screening Checklist for Auditory Processing (SCAP) [13]. SCAP is a checklist designed to be administered on the class teacher or the parent of the child. The checklist consists of 12 questions related to symptoms and deficits of auditory processing namely auditory perceptual processing, auditory memory, and other miscellaneous symptoms. This checklist is a two-point rating scale with a response of "yes or no". Each question with a "yes" response was scored 1 point and "no" was scored 0. Children with a score of more than 50% (i. e. a score of 6 out of 12 or more) were considered "at risk" for auditory processing deficits and children with less than 50 % score were considered as having no auditory processing deficits. Children with less than 50% scores were included in the study. These typically developing children were divided into two groups, children undergoing any form of musical training (vocal or instrumental, Indian or Western music) for at least one year were considered in the musical training group i.e. Group I (15 participants), and children without any formal training in music were included in non-musical training group i.e. Group II (35 participants). Written consent was obtained from the parents of all the participants.

Test to assess musical abilities

All the children were assessed for their musical ability using an abbreviated version of the Montreal Battery for Evaluation of Music Abilities (MBEMA) [14] which comprised three subsections– melody, rhythm, and memory. Each subtest had 20 pairs of musical melodies. In melody subtests, ten pairs of melodies, four pairs had scale variations, three pairs had contour variations, and the other three pairs had interval variations. In rhythm subtests, the rhythm of the melodic pairs was altered by changing the duration of two adjacent tones while retaining the number of notes and the original meter. The memory subtest had ten melodies used in previous subtests and ten new melodies. The test was conducted in DMDX software [15], which is a program software that is designed to precisely time the presentation of audio, video, and graphical materials. This software also enables to precisely measure the reaction time of the responses from the subject which is given in an output file. DMDX is a hybrid name where DM indicates its lineage as part of the DMASTR system and DX refers to DirectX which is a set of Dynamic Link Library routines (DLLs). The participant was involved in a discrimination task by responding to whether the melodic pairs were the same or different for both melody and rhythm subtests. For the memory test, participants had to indicate whether the presented melodies were familiar or not from the previous subsections (melody and rhythm). All the stimuli were presented at 60 dB HL (test is recommended to be carried out at a comfortable level). The stimulus for each experiment was calibrated using a Bruel & Kjaer 2270 sound level meter (HBK Company, Denmark) connected to a GRAS manikin (GRAS Sound and Vibration). Each subtest had two practice trials and 20 test trials which were presented in random order. The responses are recorded and scores for the number of correct responses were calculated for each subtest.

To assess pitch contour perception

The pitch contour stimuli for the present study that was generated consisted of 500 ms tonal sweeps of 500 Hz, 1000 Hz, and 2000 Hz, representing changes in the pitch. A total of nine pitch contours were generated using PRAAT software [16] which included the following patterns- rising, rising-flat, rising-falling, flat, flat-rising, flat-falling, falling, falling-flat, and falling-rising for each of the test frequencies (500, 1000 and 2000 Hz). With the PRAAT software, a flat tone was generated at a sampling frequency of 44.1 kHz with 500 ms. Later these flat tones were manipulated using the pitch tier option to obtain different contour patterns. The spectrum of the stimuli can be seen in Figure 1.

Initially, children were familiarised to identify the nine contours and to match with their corresponding line drawings. Later, with the use of DMDX software, the actual testing was done. The test was carried out using a personal laptop with stimulus presented with high-fidelity circumaural headphones (Sennheiser HD 569). The test employed a closed set identification task, where each trail was presented with 3 blocks of line drawings representing the different contours and 1 audio stimulus of the contour. Children were asked to listen to the contour and identify it by matching it with the corresponding line drawing by pressing 1 or 2 or 3 keys on the keyboard. The test screen of the DMDX software can be seen in Figure 2. Each pattern in pitch contour was presented three times, resulting in 27 patterns in 10 random trials resulting in a total of 270 patterns for each frequency contours. The responses were recorded in the DMDX software, a score of 1 was given for each correct response, and the total number of correct responses was calculated.

Statistical analysis

The data were analyzed using the IBM Statistical Package for Social Sciences version 20.0 (SPSS)

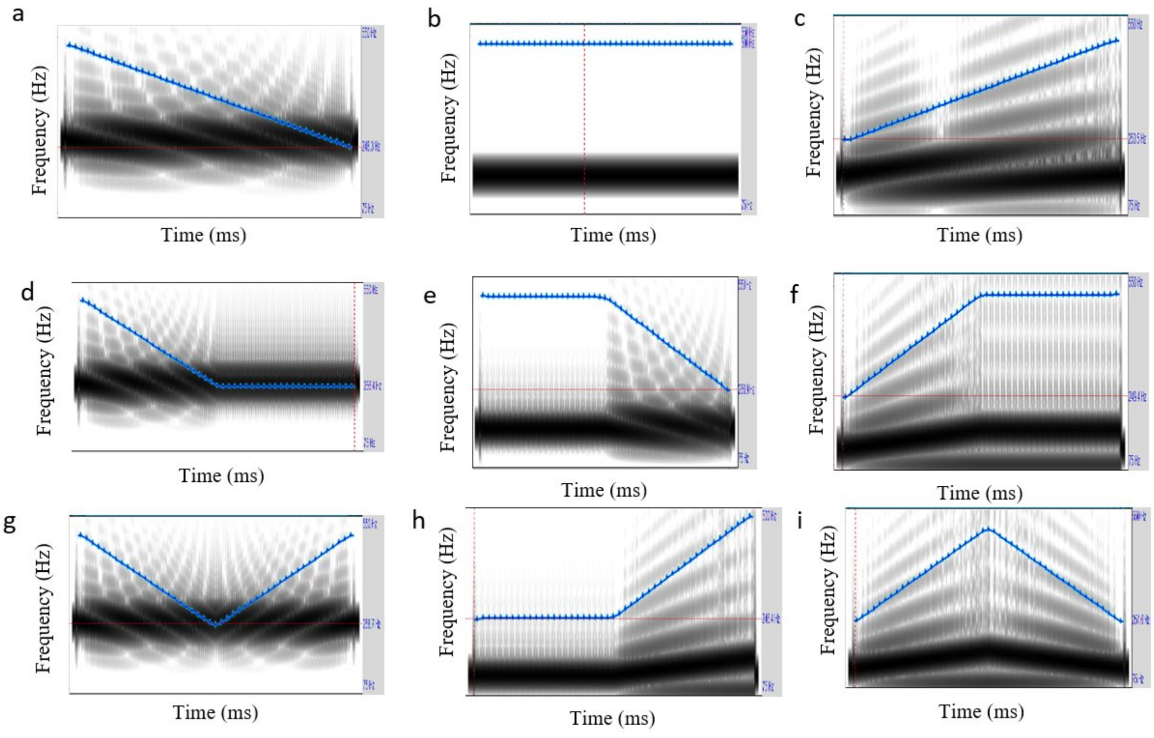

Figure 1. Illustration of spectrum of pitch contours for 500 Hz tone of 500 ms duration representing a) falling, b) flat, c) rising d) falling-flat, e) flat-falling, f) rising-flat, g) falling-rising, h) flat-rising and, i) rising-falling

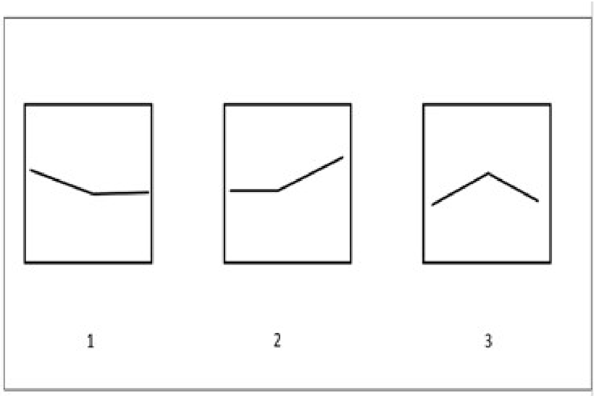

Figure 2. The test screen of closed set identification test of pitch contours using DMDX software

software. Descriptive statistics was done for each group to obtain the mean and standard deviation (SD) of the test parameters. The Shapiro-Wilk's test of normality showed normal distribution of data for overall pitch contour identification. Hence Multivariate Analysis of Variance (MANOVA) was carried out to compare the test scores of musical abilities and pitch contour identification. However, the pitch contour identification scores across the contour were non-normally distributed. Hence Mann-Whitney U test was used to compare contour identification scores for each contour between the children with and without musical training. Further, Friedman's test was used to compare contour perception across frequencies within the group.

Results

Musical ability test

The scores of the musical ability test were compared between Group I and Group II. Figure 3 shows the mean and SD of the groups. It can be noticed that the children with musical training obtained higher scores than the children without any formal training.

Pitch contour identification

The scores of pitch contour identification showed children with musical training (Group I) obtained higher scores than children without musical training (Group II) for tonal sweeps of 500, 1000, and 2000 Hz. The mean and SD for pitch contours identification is represented in Figure 4. The detailed mean and SD of the identification scores for different pitch contour falling, flat, rising

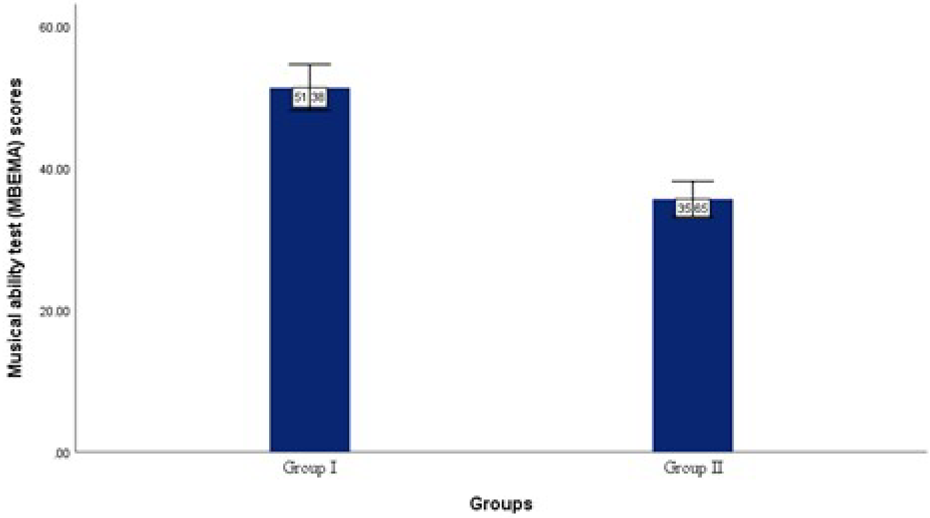

Figure 3. Mean and standard deviation of the musical ability test scores obtained by children with musical training (Group I) and without musical training (Group II). MBEMA; Montreal battery for evaluation of music abilities

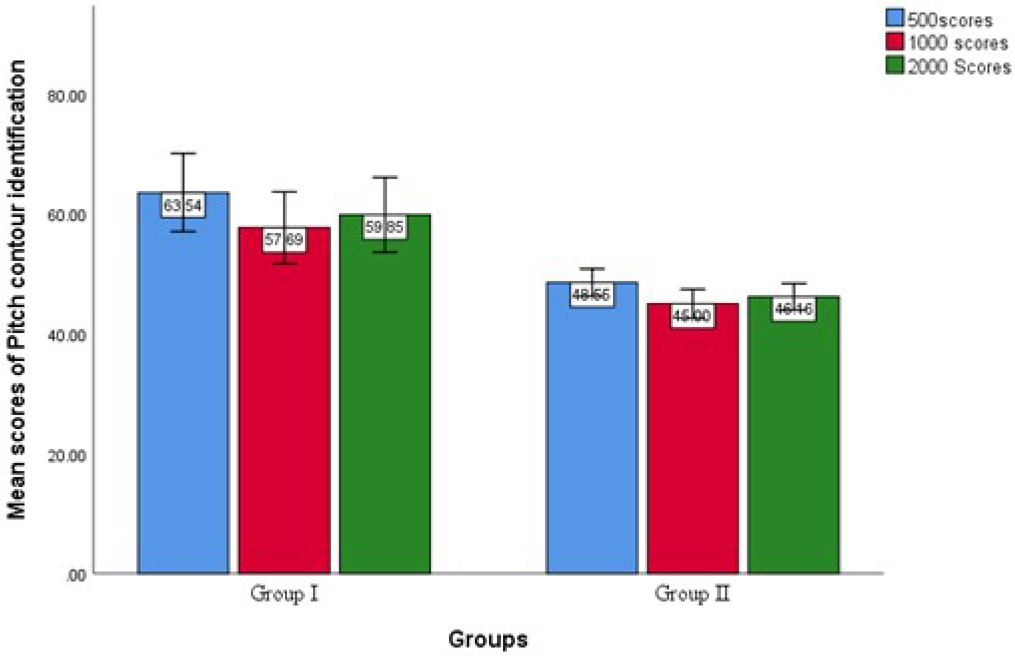

Figure 4. Mean and standard deviation of the pitch contour identification scores obtained by children with musical training (Group I) and without musical training (Group II) for tonal sweeps 500 Hz, 1000 Hz, and 2000 Hz

falling-flat, flat-falling, rising-flat, falling-rising, flat-rising, and rising-falling across groups for tonal sweeps 500, 1000, and 2000 Hz are depicted in Figure 5.

Musical training and pitch contour perception

The overall pitch contour identification scores were normally distributed and parametric test was carried out. The results showed a significant difference between Group I and Group II for the musical ability test: $F_{(1,42)}=54.7$ $p<0.001$; and the overall pitch contour identification scores for 500 Hz $F_{(1,42)}=33.99$ $p<0.001$, 1000 Hz $F_{(1,42)}=25.04$ $p<0.001$ and 2000 Hz $F_{(1,42)}=30.27$, $p<0.001$.

Further, test showed non-normal distribution of pitch contours identification scores, and hence non-parametric statistical tests were used to compare contour

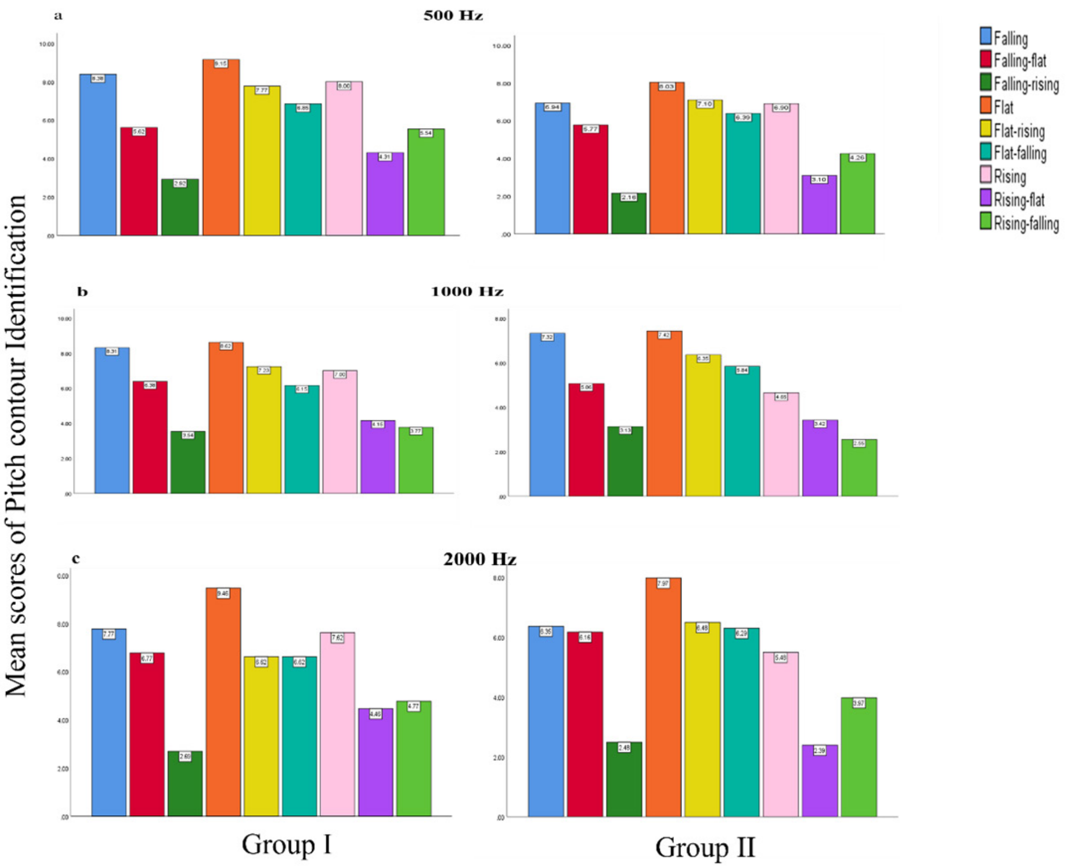

Figure 5. Mean and standard deviation of the identification scores for different pitch contour falling, flat, rising falling-flat, flat-falling, rising-flat, falling-rising, flat-rising, and rising-falling across groups for tonal sweeps a) 500 Hz, b) 1000 Hz, and c) 2000 Hz

identification scores for each contour between the children with and without musical training across test frequencies. The results showed a significant difference for tonal contours of 500 Hz for flat (Z=88, p=0.03) and falling pattern (Z=126.5, p=0.46); 1000 Hz for rising (Z=104.5, p=0.11) and falling-flat (Z=121.5, p=0.037); 2000 Hz for falling (Z=125, p=0.045), flat (Z=103, p=0.08) and rising patterns (Z=108, p=0.015).

Contour perception across frequencies in children with musical training was compared. It was observed that there was a significant difference across the frequencies in flat-rising pattern (Z=9.05, p=0.01) and rising-flat pattern (Z=5.41, p=0.05). In children without musical training, significant differences were observed in falling-flat (Z=8.82, p=0.01), flat (Z=5.86, p=0.05), flat-rise (Z=8.27, p=0.01), flat-falling (Z=9.06, p=0.01), rising (Z=15.3, p<0.001) and rising-flat patterns (Z=9.264, p=0.01).

And also among the musical training group children with instrumental training (flute, piano, guitar) scored more accurately than other forms of training like vocals. Among the non-musical training group children with interest or habit of listening to music performed better than children with no interest in music.

Discussion

The children with musical training obtained better scores in the MBEMA test than the children without training, this could be attributed to their knowledge and a better understanding of the musical melody and rhythm of the musical tunes. Similarly, the better performance in the identification of pitch contour by the children who had undergone musical training could be attributed to the precision in the acoustic processing of the pitch changes related to the melody and prosodic aspect of the stimuli. The plasticity induced by musical training for the processing of the pitch and the pitch direction in musically trained children enables them to be sensitive for the perception of the smaller changes in the pitch and time differences in perceiving the pitch contour. The significant difference between the musically trained and non-trained groups observed in the study can be attributed to the enhancement of neural coding of pitch traces obtained from the musical training [6]. Previous studies on musicians have found that musical training had shaped cochlear processing and had increased the resolution of peripheral auditory filters thus better performance was seen by musicians in the behavioral studies [17]. The effect of the advantage of musical training has been reported to strengthen the categorical perception of the stimuli and greater sensitivity to temporal and spectral information of the auditory representation [18]. However, in the present study, the perception of the different pitch contours was heterogeneous, as it has been reported that difficulty could be attributed to their cognitive load, exacerbating the difficulty in identifying the direction of the pitch change [19].

The comparison of contour identification scores between the groups showed a significant difference between Group I and Group II for contour patterns like flat, rising, and falling contours than other patterns. This could be attributed to the salient and simplicity of the single contour making the trained group identify significantly better than the other group by using their musical knowledge. Whereas the other combination patterns like – rising-falling, and falling-flat were not more salient and did not show the effect of training. However, studies have shown better performance with fixed contour than mixed contour [20] and poor performance for any change in contour with speech stimuli [21]. The discrepancies could be due to the use of tonal stimuli in the present study. Since the pitch contour are representation of the pitch variations across different speech and non-speech stimuli, and has a better correlation with the musical training, the tonal identification task can be used as an assessment procedure to understand the musical ability component of children.

Conclusion

Pitch contours can mimic variations like music stimuli; hence it can be used as test material for assessing the perception of musical abilities in children. The present study showed that musically trained children performed significantly better using pitch cues. In other sense training for these pitch cues directly by using the test material can aid better understanding of musical pitch too. Music induced plasticity will help children with a better understanding of changes in pitch sweeps or tonal contour stimuli and also can improve the performance in other skills like cognitive, auditory skills, and speech-language skills. However, furthermore investigation according to the type of musical training can provide insights into the effect on speech perception and music perception.

Ethical Considerations

Compliance with ethical guidelines

The study conformed to the institutional ethical guidelines (DOR.9.1/Ph.D/RE/911/2020-21 dated 06-12-2022) for bio-behavioral research involving human subjects [22].

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Authors' contributions

RE: Literature review, data collecting, data analysis, and writing; DN: Design, analysis, and interpretation of the data.

Conflict of interest

The authors declare that there is no conflict of interest to be reported.

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