

AUDITORY ABILITIES IN INDIVIDUALS WITH AND WITHOUT FORMAL MUSICAL TRAINING

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A Study design/planning
B Data collection/entry
C Data analysis/statistics
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Abstract

Introduction: Auditory perception can be enhanced by musical training and practice. Considering the multiple brain areas involved in musical learning, good auditory perceptual skills can contribute to phonological awareness, speech recognition in the presence of noise, reading, syllable recognition, and other language skills.

Material and methods: There were 30 adults between 18 and 27 years old who participated. They were divided into two groups: 15 individuals without formal musical training (Non-Musicians) and 15 individuals with 5 years or more of formal musical training (Musicians), paired by gender and age. Procedures used for assessing their hearing skills were the Duration Pattern test, Staggered Spondaic Word test, Masking Level Difference test, and Dichotic Consonant–Vowel test.

Results: In all tests, the Musicians group showed a higher average score than the Non-Musicians. In the MLD test, the average level difference was 3 dB higher for the Musicians than for the Non-Musicians ($p = 0.001$). There were also statistically significant mean differences between the groups for the DP test, SSW test in the right ear, and DCV test (number of errors).

Conclusions: Individuals with formal musical training show better auditory attention abilities, which are important for developing good listening skills, resulting in good communication and linguistic performance compared to individuals without prior musical training.

Key words: hearing tests • music • hearing • auditory perception • acoustic stimulation

ZDOLNOŚCI SŁUCHOWE U OSÓB Z FORMALNYM WYKSZTAŁCENIEM MUZYCZNYM I BEZ TAKIEGO WYKSZTAŁCENIA

Streszczenie

Wprowadzenie: Percepcja słuchowa może zostać usprawniona przez trening muzyczny i praktykę. Biorąc pod uwagę liczne obszary mózgu zaangażowane w naukę muzyki, wysokie kompetencje w zakresie percepcji słuchowej mogą pociągać za sobą większą świadomość fonologiczną, lepsze rozpoznawanie mowy w obecności szumu, czytanie, rozpoznawanie sylab i inne kompetencje językowe.

Material i metody: W badaniu uczestniczyło 30 dorosłych w wieku od 18 do 27 lat. Zostali podzieleni na dwie grupy: 15 osób bez formalnego wykształcenia muzycznego (Niemuzycy) i 15 osób, które miały pięcioletnie lub dłuższe formalne wykształcenie muzyczne (Muzycy), dobranych parami pod względem płci i wieku. Procedury użyte w celu oceny ich kompetencji słuchowych obejmowały: test sekwencji tonów o różnej długości (Duration Pattern, DP), test Staggered Spondaic Word (SSW), test Masking Level Difference (MLD) oraz test dychotyczny typu spółgłoska-samogłoska (Dichotic Consonant–Vowel, DCV).

Wyniki: We wszystkich testach grupa Muzycy uzyskała wyższe średnie wyniki niż Niemuzycy. W teście MLD średnia różnica poziomów była o 3 dB wyższa dla Muzyków niż dla Niemuzyków ($p = 0,001$). Zarejestrowano także statystycznie istotne średnie różnice pomiędzy dwiema grupami w teście DP, teście SSW w prawym uchu i teście DCV (liczba błędów).

Wnioski: Osoby z formalnym wykształceniem muzycznym wykazują większe kompetencje w zakresie uwagi słuchowej, ważne dla rozwoju dobrych kompetencji słuchowych, skutkujących lepszą komunikacją i osiągnięciami językowymi w porównaniu do osób nieposiadających wyszkolenia muzycznego.

Słowa kluczowe: testy słuchu • muzyka • słuch • percepcja słuchowa • stymulacja akustyczna

Introduction

Central Auditory Processing (CAP) is a set of processes and mechanisms of the central nervous system that enable decoding and understanding speech, especially in unfavorable situations, such as in the presence of background noise or competing messages [1]. The adequate development of this ability depends on factors such as preserved

peripheral hearing, neurobiological maturation, environmental stimuli, and cognitive ability [2].

Assessment of central auditory processing aims at understanding auditory function and its relationship with communication, using behavioral auditory tests that aim to evaluate hearing performance in different listening tasks simulating daily life situations [3].

Central auditory abilities can be evaluated by auditory discrimination tests, binaural interaction, dichotic tasks, monaural low-redundancy, and temporal pattern tests. These abilities are involved in auditory processing and refer to the perception of auditory information by the central nervous system and the neurobiological activity underlying this perception [4].

Failure to perceive auditory information, or in the underlying neurophysiological processes, may affect the communication and cognitive performance of individuals with central auditory processing disorder (CAPD). As a consequence, it can also result in learning disorders and socio-emotional issues. Therefore, one must use several tests to characterize central auditory function involving as many auditory abilities as possible.

Currently, music has been studied as to its brain modulation capacity and resulting functional changes, which can improve some cognitive aspects. Musical learning correlates with brain adaptations that can differentiate the performance of individuals with and without musical experience [5].

The first years of brain maturation are essential and formal musical training, initiated early in life, can result in structural adaptation, probably involving plastic reorganization (that is, changes in the synaptic connections and/or in the growth of neuronal extensions) [6]. The time dedicated to music exposure is also important, as significant changes in brain connectivity and functionality may occur [7].

Research conducted with the objective of relating musical to psychoacoustic abilities (in addition to those that address the relationship between music, language, cognition, and auditory processing), have given important data regarding the effect of music on an individual's cognitive development, especially in terms of memory and attention skills [8–11].

Learning a musical language involves using several brain areas simultaneously. These are perception, from the auditory pathways to processing in the upper regions of the brain; cognition, memory, attention, and executive functions; motor and auditory skills, as well as the ability to adapt to novel emerging stimuli, characterized by brain plasticity [12].

Musical practice develops with the auditory perception of melodies, harmonies, and rhythms via perceptual training of musical parameters. Considering the many brain activities involved in learning music, auditory perceptual skills can contribute to phonological awareness, speech recognition tasks in the presence of noise, reading, syllable recognition, and other language skills [13–16].

Thus, musical practice is an activity that can also improve speech recognition skills in noisy environments. Speech perception in noisy environment provides information on auditory function under limited conditions, since it requires integrating cognitive, linguistic, and sensory processing systems in response to sound input [17–20].

Based on the above, this study aims to characterize the auditory abilities of figure–ground and temporal ordering in adults with and without formal musical training.

Methods

This project was submitted to the Research Ethics Committee with approval number 2,317,345. All participants received information on each of the procedures performed in the research and signed an informed consent form. Adults between 18 and 27 years old, with auditory thresholds within the normal range of 0.25 and 8 kHz (equal to or less than 25 dB HL) and type A tympanograms, participated in the study. Subjects were matched in terms of age and school level. There were 12 subjects who had college degrees and 18 were college students.

The sample consisted of two groups, divided according to musical experience and matched by gender and age: the first group consisted of 15 adults without musical experience and without complaints regarding language, while the second group consisted of 15 adults with at least 5 years of formal musical training who played any musical instrument except percussion. Both groups were recruited by in-person invitation from one of the project researchers who had contact with musicians from studios and music schools. The participants' formal musical training time ranged from 5 to 14 years, with an average of 8.7 years.

The Masking Level Difference test (MLD), Staggered Spondaic Word test (SSW), Dichotic Consonant–Vowel test – free recall (DCV), and Duration Pattern test (DP) were used to evaluate auditory processing. The tests were undertaken in 1-hour sessions with the participant inside an acoustic booth and using earphones.

MLD is a test that involves auditory binaural interaction. It determines the threshold to a 500 Hz pure pulsed tone in the presence of white noise under two conditions: noise and a pure tone in phase in both ears (homophasic) and in the other, a pure tone in phase in both ears and inverted phase noise in one of the ears (antiphasic) [21]. Participants were instructed to answer “yes” when they heard the tone (pulsed tone) and the noise, even if at low intensity and “no” when they heard only the noise [22]. To determine MLD, we subtracted the threshold obtained in the antiphasic condition from the threshold in the homophasic condition. Thresholds greater than 10 dB were considered within the standard criterion [23].

SSW is a dichotic test involving the auditory figure–ground ability for words and temporal ordering and the physiological mechanisms of selective attention and temporal processing. Each participant had to repeat the four words presented, maintaining their order of presentation [24]. First, the results underwent a quantitative analysis, considering the correct answers in the competitive conditions, regardless of ear. For adults or children over 9 years of age, the answers to the conditions Competitive Right and Competitive Left are expected to be greater than or equal to 90% of correct answers [25].

The DCV test evaluates the auditory figure–ground ability for syllables and the physiological mechanism of verbal sound recognition in a dichotic task. The study used only the free recall condition, in which the participant listened to a list with 24 pairs of syllables and was instructed to randomly choose one syllable to repeat. Norms for adults

are to reach at least 19 correct responses with right ear advantage and 5 errors at maximum. For those who are left-handed, the number of correct answers in the left ear may be higher than in the right [26].

The DP test assesses auditory temporal ordering and the physiological mechanism of temporal processing. In this procedure, the participants listened to three-tone sequences based on long (L, 500 ms) and short (S, 250 ms) tones in six combinations – LLS, LSL, LSS, SLL, SLS, and SSL – and were then asked to name the sequence heard. For adults or children over 12 years of age, the standard criterion for this type of response is at least 83% correct answers [27].

Statistical analysis used Student’s t-test or the Equality Test of two means – when it is assumed that population variance is known, independent, and normal – to compare the groups regarding age and performance in the tests. The qualitative analysis of the SSW test employed a Chi-squared test, which verifies whether two variables have a statistical dependence (association) or not. Pearson’s correlation was used to measure how much one variable was related to the other; it was used to correlate the time of formal musical training and the test results.

We used statistical confidence intervals of 95% and considered a significance level of 0.05%.

Results

Table 1 shows the quantitative results of the MLD test for both groups. Here, there is a statistically significant difference between the groups, with the mean in decibels being nearly 3 dB higher for the Musicians than for the Non-musicians.

Table 2 shows descriptive measures of group performance for the DP, SSW, and DCV tests, in percentage of correct answers. There was a statistically significant mean difference between the groups for the DPT, SSW-RE, and DCV-Errors tests. We observed that in all tests the Musicians presented a higher average of correct answers compared to the Non-musicians (except of course for the variable DCV-Errors, which is an inverse measure – that is, less mistakes made by the musicians).

Table 3 shows the data of the qualitative analysis of the procedures applied in each group. There is a statistical significance between the groups for the distribution in the results of the MLD, SSW, and DCV tests. In these three procedures there was a higher percentage of “normal results” for the musicians than for non-musicians.

Table 4 shows the correlations between the extent of formal musical training and the results of the tests evaluating auditory processing. Here there is no statistically significant correlation.

Discussion

For the Masking Level Difference (MLD) test (Table 1), we observed that the Musicians group had a higher average than the Non-musicians group. The test involves auditory binaural integration and, as described in the literature, studies with MLD in children have shown that the peripheral and brainstem auditory processes responsible for MLD are completely formed by the sixth month of life [28,29].

The Musicians group had a mean MLD response of 10.3 dB, which shows that they had good binaural integration, significantly better than the Non-musicians, which had a mean

Table 1. Descriptive measures of group performance in terms of Masking Level Difference (MLD in dB)

Groups	Mean	Median	Standard deviation	CV	Min	Max	N	CI	p-value
MLD	Musicians	10.27	10	1.67	16%	6	12	15	0.84
	Non-musicians	7.33	6	2.69	37%	4	12	15	1.36

Key: CV – Coefficient of Variation; CI – Confidence Interval

Table 2. Descriptive measures of group performance in the DP, SSW, and DCV tests (percentage of correct answers)

Groups	Mean	Median	Standard deviation	CV	Min	Max	N	CI	p-value
DP	Musicians	98.9%	100%	2.0%	2%	93%	100%	15	1.0%
	Non-musicians	93.4%	93%	5.6%	6%	80%	100%	15	2.8%
SSW-RE	Musicians	98.3%	100%	2.2%	2%	93%	100%	15	1.1%
	Non-musicians	94.8%	95%	4.2%	4%	88%	100%	15	2.1%
SSW-LE	Musicians	96.3%	98%	3.5%	4%	90%	100%	15	1.8%
	Non-musicians	94.0%	93%	4.7%	5%	88%	100%	15	2.4%
DCV-RE	Musicians	50.0%	54%	13.3%	27%	25%	67%	15	6.7%
	Non-musicians	46.6%	46%	8.2%	18%	33%	63%	15	4.2%
DCV-LE	Musicians	35.3%	33%	8.9%	25%	25%	50%	15	4.5%
	Non-musicians	29.7%	25%	10.3%	35%	17%	50%	15	5.2%
DCV-Errors	Musicians	14.7%	17%	6.1%	41%	8%	29%	15	3.1%
	Non-musicians	23.6%	25%	6.4%	27%	13%	33%	15	3.3%

Key: CV – Coefficient of Variation; CI – Confidence Interval; DP – Duration Pattern test; SSW – Staggered Spondaic Word test; DCV – Dichotic Consonant-Vowel test; RE – right ear, LE – left ear

Table 3. Results of tests according to group (musicians vs non-musicians)

		Musicians		Non-musicians		Total		p-value
		N	%	N	%	N	%	
MLD	Altered	2	13.3%	11	73.3%	13	43.3%	0.001
	Normal	13	86.7%	4	26.7%	17	56.7%	
SSW	Altered	0	0.0%	5	33.3%	5	16.7%	0.014
	Normal	15	100.0%	10	66.7%	25	83.3%	
DCV	Altered	3	20.0%	10	66.7%	13	43.3%	0.010
	Normal	12	80.0%	5	33.3%	17	56.7%	
DP	Altered	0	0.0%	2	13.3%	2	6.7%	0.143
	Normal	15	100.0%	13	86.7%	28	93.3%	

Key: MLD – Masking Level Difference test; DP – Duration Pattern test; SSW – Staggered Spondaic Word test; DCV – Dichotic Consonant–Vowel test

Table 4. Correlations between years of formal musical training and test results

	Corr (r)	p-value
MLD	–3.7%	0.896
DP	22.8%	0.415
SSW-RE	–32.0%	0.245
SSW-LE	10.7%	0.705
DCV-RE	–15.8%	0.574
DCV-LE	22.6%	0.418
DCV-errors	1.9%	0.948

Key: Corr – correlation; MLD – Masking Level Difference test; DP – Duration Pattern test; SSW – Staggered Spondaic Word test; DCV – Dichotic Consonant–Vowel test, RE – right ear, LE – left ear

MLD of 7.3 dB. Binaural integration helps in identifying a sound source and gives better temporal auditory perception. The brainstem is responsible for detecting time and intensity differences between the ears, which contributes to improve speech recognition in the presence of competing noise [17,30–32].

Table 2 shows that the Musicians group had a higher average of correct answers compared to the Non-musicians in the DP test; SSW test, and DCV test; of course, with the DCV-Errors variable the number was lower.

Musicians had better performance for the figure–ground and temporal ordering skills, revealing better capacity for selective attention and temporal processing in this group [18]. In the literature, some studies have already shown the better performance of musicians in these abilities [5,7–9,18]. Musicians have better frequency discrimination and ordering than non-musicians, and other authors have concluded that musical training promotes speech processing plasticity, resulting in better ability to understand speech in noise, which relates to selective attention capacity. Musicians also have better auditory temporal ordering, suggesting that their training and musical experience improves this performance.

Table 2 shows an advantage for the right ear in both groups in the DCV test. Such an advantage is related to

the neurophysiological model of dichotic listening, in which information received by the right ear is processed in the left hemisphere and is often more quickly analyzed and organized than information received by the left ear. This is because the left hemisphere contains most of the structures involved in perceiving speech acoustic cues (frequency, intensity, and duration) [6,11,32].

Musicians had a lower amount of errors in the DCV test than the non-musicians (Table 2), indicating better phonemic discrimination of similar sounds by musicians, since the test stimuli involves pairs of syllables that differ only by the sound of the consonant [8,9,11].

The Musicians group had a higher percentage of responses within the normal range for the MLD, SSW, and DCV tests than the Non-musicians (Table 3). Thus, as mentioned earlier, this indicates that formal musical training cultivates a better performance in figure–ground, binaural integration, and temporal ordering skills.

Other studies have described the better performance of musicians in temporal processing. However, our results found no statistically significant difference between the groups, as both had good results in the DP test, reflecting an adequate performance and temporal ordering capacity. With a bigger sample, perhaps this result might be different.

Regarding the correlation of time of formal musical training with the test results described in Table 4, there was no correlation between the variables, showing that regardless of the length of musical training each participant had been through, the results did not differ. In our sample, the time of formal musical training ranged from 5 to 14 years, that is, the selected group had already devoted considerable time to learning music. Perhaps, therefore, their nervous systems had already been considerably shaped by this training, which may explain the lack of correlation. According to the literature, the time dedicated to music is an important factor in determining the plastic reorganization and neurological structural adaptations generated by musical learning [12,14–16]. As already described, musical learning provides great advantages to auditory and cognitive performance, leading to a better result when compared to people without musical training.

Our study has shown that musical training provides better figure-ground with competing noise, binaural interaction, and temporal processing skills, which brings benefits not only for auditory performance, but also for linguistic skills. We infer that people with developed musical skills could potentially be better listeners, speakers, and communicators.

More studies involving larger samples and considering different variables such as type of instrument and method of music learning are encouraged.

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Conclusions

After analyzing the results of this study, we conclude that individuals with formal musical training show better auditory attention skills, such as better ability to understand speech in a noisy environment, binaural interaction, and temporal processing. Thus, musical learning and practice contribute to developing good auditory skills, resulting in better communication and linguistic performance compared to individuals without previous musical learning.