

## RESEARCH ARTICLE

# Effects of learning to play stringed instruments in adulthood on frequency discrimination by pitch pattern sequence test

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### Abstract

**Background and Aim:** Frequency discrimination is an important skill in central auditory processing which plays a critical role in proper reading, writing, and speech perception. Music training is among the ways that improve this skill. Most of the reviewed literature is based on the impact of learning music on the early stages of childhood. Therefore, if the tests used in the assessment of central auditory system are proved to be effective in music training in adulthood, they could be recommended as an appropriate option for adult central auditory processing disorder rehabilitation. This study aimed to investigate the effects of learning to play stringed instruments in adulthood on frequency discrimination by pitch pattern sequence test.

**Methods:** This cross-sectional and non-interventional study was performed on 46 normal hearing subjects aged 20-45 years, 28 non-musicians and 18 musicians who were trained to play music as an adult. They were compared by PPST. The results were analyzed by 2-way analysis of variance.

**Results:** There was a significant difference between the average scores of the two groups, the non-musicians and the musicians, for both ears

( $p < 0.001$ ). On the other hand, there was no significant difference between the two test results in both groups gender wise ( $p > 0.05$ ).

**Conclusion:** More correct answers of musicians indicated their better frequency discrimination compared to non-musicians, which could be a reason for improvement in the performance of the central auditory system caused by music training even in the verge of adulthood.

**Keywords:** Central auditory processing; music training; frequency discrimination; pitch pattern sequence test; frequency pattern test

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### Introduction

The ability of the central auditory system to use auditory information is called central auditory processing [1]. Central auditory processing disorder (CAPD) is a deficit in auditory information processing which is not secondary to linguistic, cognitive or other higher-order involvements [2]. This disorder can lead to difficulties in different auditory behaviors such as temporal perception, speech pitch processing, lateralization and localization problems, as well as speech perception difficulty in noise [3]. Based on extensive studies, CAPD is a quite prevalent disorder among all ages and can lead to gradual

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depression, stress, and isolation in children and adults [1]. Recent studies show that adults may suffer from CAPD in spite of normal or near normal peripheral hearing sensitivity [4,5].

Currently, there are several rehabilitation methods that each targets a specific central deficit in CAPD [6]. One of the approaches for improving auditory skills and decreasing CAPD adverse effects is music training [7]. Recent studies suggest that continuous music training can improve brain capability for acoustic judgment and its ability for auditory information perception [6]. For example, Slater et al. study on elementary school children showed that their speech in noise perception improved significantly after music training [8].

Music training effects on neural processing are related to two factors: the starting age of music training and the duration of music training [7]. In some studies, the different critical periods have been suggested for music training to be effective on the central auditory system [9-11]. Watanabe et al. studied two similar groups of musicians. They only were different in starting age of musical training (before or after 7 years old). They showed that earlier age of training has more effects on neural integrity and timing [10]. Tierney et al. studied 14 years old children in Chicago and showed that music-related changes start two years after start of the music training. Therefore starting music training even at the final years of high school can result in neural changes [12]. Kraus and Strait suggested that one to three years of music training (two years on average) is effective for improving speech perception in noise in both children and adults [13]. In most research studies, subjects who have three conditions are called musicians: receiving music training sessions for at least twice a week, each session lasts for at least 20 minutes, and their trainings start since childhood. However, subjects with even less music training might probably show auditory processing improvements [14].

As it was mentioned, central auditory processing includes different skills that help recognition and perception of vowels, consonants, syllables, phrases, supra-segmental characteristics

of speech and melodies [6,15-17]. One of these skills is pitch perception that is essential for identification and perception of speakers' message and emotional content of speech [18]. Patients with the pitch perception problem have difficulty in speech prosody perception and often have trouble in discriminating questions (rising pitch) from declarative sentences (falling pitch) and this can lead to reading, spelling and speech understanding difficulties [19]. It seems that music training can improve pitch perception [7,20]. Wong et al. studied musicians and showed that musicians with at least 6 years of constant music training before 12 years old had better pitch perception function in auditory brainstem response [21]. In a study conducted by Meyer et al. on 7.5-12 years old children (one group with violin training and the other without any musical experience), children with music training had shorter MMN (mismatch negativity) latency than children without any musical experience [22]. For evaluating pitch processing, several tests are available which one of them is pitch pattern sequence test (PPST) [23].

As most of the studies are focused on music training in childhood and evaluating its effects in adulthood, there is little information on the of music training in adults for improving central auditory processing skills. If central auditory processing tests show positive effects, then music training can be an option for CAPD rehabilitation in adults. The present study aimed at determining the effects of learning to play stringed instruments on frequency discrimination in adults by PPST.

## Methods

This study was a cross-sectional and non-interventional study conducted on 46 subjects with normal hearing, at least with high school diploma, right-handed (based on Edinburgh questionnaire), monolingual (Persian speaking), without any otologic and neurologic disorders, and under no psychological and psychoactive medication. They were divided non-randomly into two groups: musicians and non-musicians. They were selected from general population and

**Table 1. The musical background of the musician group**

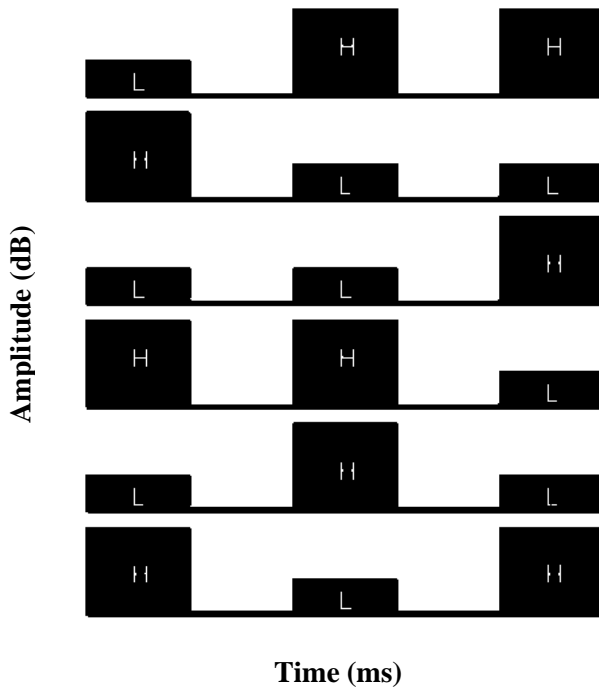
|                                | Female       |         | Male          |         |
|--------------------------------|--------------|---------|---------------|---------|
|                                | Mean (SD)    | Min-Max | Mean (SD)     | Min-Max |
| Age of starting to play (year) | 21.88 (6.49) | 15-35   | 20 (4.94)     | 15-28   |
| Duration of training (year)    | 5.25 (2.18)  | 2-7     | 10.50 (5.52)  | 5-19    |
| Weekly practice (hour)         | 7.38 (4.40)  | 2-15    | 11.90 (7.37)) | 3-25    |

music training institutes. Non-musicians consisted of 28 participants (14 females, 14 males), aged 22-36 years, without music training. Musician group comprised 18 subjects (8 females, 10 males), aged 21-44 years, with at least 2 years ( $5.03 \pm 8.15$  years) of music training with stringed instruments. They had music training for at least twice a week and each session lasted 30 minutes (2-25 hours per week). Their starting age of training was 15 years or higher ( $20.53 \pm 5.58$  years old) and they were under music training at the time of the study (Table 1). Based on Tierney et al. who considered subjects with the mean age of 14.7 years old as adults [12], in the present study, music training in subjects aged  $\geq 15$  years was considered as adulthood training. After obtaining informed consent and collecting preliminary information by a questionnaire, otoscopy, tympanometry, and audiometry exams were performed for all cases. Inclusion criteria were as follows: normal otoscopy, type An tympanogram ( $SC=0.28-1.8$ ; middle ear pressure=  $\pm 50$  daPa) [24] with the presence of ipsilateral and contralateral auditory reflex within frequencies of 500-2000 Hz at 80-100 dBHL [25], auditory thresholds  $\leq 15$  dBHL at octave frequencies of 250-8000 Hz [26] and speech recognition score of  $\geq 92\%$  [27]. PPST (Auditec Inc. version) was performed in the sound treating room by using Astera two-channel audiometer (GN Otometrics, Denmark) with TDH-39 headphone. This test was performed monaural at 50 dBSL (re: 1000 Hz threshold). This test is applicable for the subjects older than 8 years [23] and has six patterns, each consisted of three-tone combination including low tones (L) of 880 Hz and high

tones (H) of 1122 Hz [28]. In Auditec version, the high tone is 1430 Hz, so it differs from original Musiek version [29]. Combination of these two tones makes up six different patterns, including LLH, LHL, LHH, HLH, HLL, and HHL (Fig. 1) [23]. The duration of tones is 150 ms with rise/fall time of 10 ms. the time interval between tones and patterns are 200 ms and 7 second, respectively [23]. Responding task was taught to the subjects by visual and verbal instructions and they were asked to repeat back each item in the correct order. If they repeat an item in the pattern incorrectly or repeat it in the reverse manner, it is considered wrong recognition [28]. If the examinee could recognize the first 30 items correctly, the test would be stopped. However, if the subject had even one incorrect or reverse response in the first 30 items, the remaining 30 items were presented as well. Test score was calculated from correct recognition responses for each ear (number of correct responses  $\times 1.66$ ). During the test, adequate resting times were provided to avoid subjects' fatigue. Tests lasted for about one hour for each subject. All subjects were volunteers and an informed consent was obtained from them. To evaluate the main effect and interaction among variables, 2-way ANOVA was used. Type I error was set at  $\alpha=0.05$ . The obtained data were analyzed by SPSS 24.

## Results

This study was conducted on 28 non-musicians and 18 musicians with normal hearing. The sample size was calculated based on a pilot study on 5 subjects. The sample size for non-musicians was higher than musicians, as the



**Fig.1. The six frequency (pitch) patterns with low tone (L) of 880 Hz and high tone (H) of 1122 Hz [29].**

standard deviation was higher in them in the pilot study. Table 2 shows the results of PPST in musicians (case) and non-musicians (control) and for both sexes and ears. There was a significant PPST score difference between two groups in both ears ( $p < 0.001$ ). Although the mean score of males was higher than females, there was not any statistically significant difference between the percentages of correct responses between two sexes ( $p > 0.05$ ).

## Discussion

This study aimed at evaluating music training effects with stringed instruments in adulthood on frequency discrimination by PPST. As it was mentioned earlier, pitch perception is one of the central auditory abilities that help recognition and perception of music melody, supra-segmental characteristics of speech and speech perception [6]. Therefore it is a vital skill for language processing and perception in sub-cortical level, and the pitch is one the most important linguistic components that carries information [30].

In the present study, non-musicians were compared with musicians (starting age of training at 15 years old and higher with a mean age of 20 years old) to study the effects of late music training on frequency discrimination in adulthood. The results showed that PPST score in both ears had a significant difference between two groups ( $p < 0.001$ ). The performance of musicians was significantly better than non-musicians. This is indicative of positive effects of music training on frequency discrimination. Musicians had an average of 8 years music training. Other studies have shown that this training has positive effects on children and adults [12,13]. They have shown that regardless of onset of music training, 8 sessions of 30-minute music training can improve pitch perception [31]. On the other hand, during development, synaptic density increases at early childhood and starts to decrease at adolescence. Different mechanisms can affect this developmental

**Table 2. Mean standard deviation correct response of pitch pattern test in musician and non-musician groups**

| Group        | Ear   | Mean (SD) correct response | Mean (SD) correct response |               |
|--------------|-------|----------------------------|----------------------------|---------------|
|              |       |                            | Female                     | Male          |
| Musician     | Right | 97.72 (3.57)               | 96.38 (4.65)               | 98.80 (2.09)  |
|              | Left  | 97.33 (3.91)               | 95.75 (5.03)               | 98.60 (2.27)  |
| Non-Musician | Right | 77.43 (14.17)              | 76.57 (12.16)              | 77.07 (12.76) |
|              | Left  | 78.50 (15.03)              | 78.29 (16.36)              | 79.93 (17.37) |

trend [12]. Music training can increase grey matter volume in the brain and synaptic density in the auditory system and leads to better learning and auditory performance, especially pitch [12,32]. Therefore the relation between two groups seems logical. Based on the present study there is a possibility that music training can change synaptic density [33].

Music training and its effects on auditory processing have been the focus of many studies in recent years. The present study results are in agreement with other studies in different age groups. Chen et al. showed that auditory performance of children with the cochlear implant after music training got significantly higher than cochlear implanted children without music training [34]. In studies of Onada et al. and Nascimento et al., the subjects with music training had better results in PPST than subjects without music training [35,36]. PPST norm in the study conducted by Musiek was 75% [37] and 76% [38]. Although Musiek method was different from the present study, the mean scores were similar to non-musicians (77.43% in the right ear and 78.5% in the left ear) in the present study and were significantly different from musicians (97.72% in the right ear and 97.33% in the left ear).

In similar studies, other methods were used for evaluating pitch perception in musicians and these studies have shown that music training can make a significant difference between two groups [39-41]. It is worth mentioning that in previous studies the starting age of music training was before 15 years.

In the present study, females score was lower than males but in neither of the groups, there was a significant PPST score difference between two sexes which is in agreement with Musiek, Onada et al. and Majak et al. studies [23,35,42]. The reason for the difference in musicians can be attributed to the different starting age of music training. There are some studies that support this result [38,43]. Chen et al. suggested that there is no significant sex difference in PPST between two sexes but males have a higher score [34]. In their study, it was assumed that the reason for this difference

might be females' need for longer inter-stimulus interval for pattern recognition [43]. In another study, it was suggested that males have more dominant right hemisphere than females so they have better pattern recognition. High level of testosterone in males can stimulate right hemisphere development and lag left hemisphere development [44]. The results of the present study are in agreement with Brazilian studies in regards to non-musicians' score, music training effects, and sex [38].

In the present study, there was a limited access to musicians. Professional musicians and music teachers, most of the time had started their training from childhood and many others who started training at adulthood, had left the training because of their busy lives. In addition, some participants left the study because of time-consuming tests and fatigue.

### Conclusion

The results of the present study showed that pitch perception is better in musicians than non-musicians even in subjects who started their training in adulthood. This indicates that music training for improving the auditory processing, even in adulthood, can improve frequency discrimination. Therefore it seems plausible that we use music training in rehabilitation of adults with central auditory processing disorder (CAPD) and dyslexia. In addition, music training is linked to expression of feeling and can be a motivation for patients to attend the rehabilitation program.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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