Research Article

Effect of Musical Training on Temporal Resolution and Temporal Fine Structure Processing

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Highlights

- Stringed musical instruments training has no or little effect on TFS processing
- Stringed musical instruments training affects gap detection threshold considerably
- Underlying mechanisms for TFS processing and temporal gap detection are different

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ABSTRACT

Background and Aim: Many aspects and features of auditory system can be improved by musical training. This study aimed to investigate the effects of a stringed musical instrument playing course on temporal resolution and temporal fine structure (TFS) processing.

Methods: This analytical cross-sectional study was conducted on 44 normal-hearing adults aged 20–40 years divided to two groups. The first group included 22 stringed musical instruments players (13 males) with at least three years of experience, and the second group were 22 non- players (13 males). The random gap detection test (RGDT) was used to measure temporal resolution aspect of hearing. For TFS processing, latest version of temporal fine structure-adaptive frequency (TFS-AF) test was used.

Results: The TFS-AF results showed no statistically significant difference between groups in different interaural phase differences (IPDs). The RGDT results showed significant differences between groups at 500, 1000 and 2000 Hz, but not at 4000 Hz. Spearman correlation test results showed no statistically significant correlation between the results of TFS-AF and RGDT.

Conclusion: Musical training has no effect on TFS processing but considerably enhances gap detection ability. Their underlying mechanisms for TFS processing and gap detection are different.

Keywords: Temporal processing; temporal fine structures; temporal resolution; musical training; stringed musical instrument; gap detection

Introduction

Different studies on musicians have shown improvement in many different aspects of their auditory system. Enhanced auditory perception [1-6], better pitch discrimination [2-4], more sensitive temporal resolution [5] and enhanced temporal fine structure (TFS) in musicians [6] are some of these improvements. Auditory temporal processing is the ability to discover and process temporal changes in sound stimuli [7-9]. It has vital role in auditory tasks such as speech perception [1, 7, 8] and is divided into four categories: Temporal ordering, temporal integration, temporal masking, and temporal resolution. The effect of stringed musical instrument course on temporal resolution at different frequencies and on the processing of TFS is unclear. A frequent and feasible way to measure temporal resolution is the random gap detection test (RGDT) developed by Keith [10]. It is used to detect the smallest temporal gap between sound stimuli at 500, 1000, 2000 and 4000 Hz, which is reported in milliseconds (ms). The RGDT includes one screening item and four sets of tonal stimuli at four different frequencies. The screening item is used in the beginning for practice and, then, four tonal stimuli are presented at 500, 1000, 2000 and 4000 Hz. The TFS is defined as the fast subtle changes in the sound spectrum in contrast to slow changes in envelope [11-14]. Some studies suggest that TFS plays an important role in speech perception in noise [15], pitch discrimination, and lateralization [12, 16]. Latest method to measure TFS processing is the temporal fine structure-adaptive frequency (TFS-AF) test developed by Füllgrabe et al. [17]. This test measures TFS processing through ability to detect interaural phase difference (IPD) at the beginning. The test is performed binaurally. At each trial, there are two intervals which include four short sinusoidal tone bursts. One of the intervals has no IPD, while in the other one the IPD for the four tones is 0°, ϕ, 0°, and ϕ, where ϕ is the selected amount of IPD in the beginning of the test. The subjects are asked to say in which interval they felt movement of the sound in their head. A two-interval, two-alternative forced choice with feedback is used to measure IPD discrimination by applying a 2-up 1-down adaptive procedure which estimates the 71%- correct point on the psychometric function [17, 18]. Final estimate is the geometric mean of the last six reversal values which is reported in Hz. This study aimed to investigate the effect of a stringed musical instrument course on temporal resolution at different frequencies using RGDT and on TFS processing using TFS-AF test. Moreover, we examined the correlation between the results of two mentioned tests to find out more about any connection between their underlying mechanisms.

Methods

Participants

This analytical cross sectional study that was conducted on 44 normal-hearing adults aged 20–40 years. They had hearing thresholds >20 dB HL under audiometric test in both ears with normal acoustic reflex. They were divided into two groups. The first group included 22 stringed musical instrument players (13 males) with a mean age of 26.9 years and at least 3 years of experience, while the second group were 22 non-players (13 males) with a mean age of 24 years. All of them declared their informed consent to participate in the study.

Measures

Pure-tone audiometry was first performed using a calibrated clinical audiometer (MADSEN Astera Otometrics). RGDT was then conducted using sound stimuli prepared from AudiTec Ltd., presented through TDH 39 circumaural headphone connected to a PC. All measurements were performed in a soundproof room. For RGDT, the screening item was played in the beginning for familiarization. Then, four sets of tonal stimuli were presented at 500, 1000, 2000 and 4000 Hz. All stimuli were presented binaurally at 55 dB SL. Gaps included in this test were 0, 2, 5, 10, 15, 20, 25, 30 and 40 ms. The screening item utilized gaps in an ascending order while the order of gaps in the tonal stimuli were random. For each tonal stimulus, the gap presentation time was 15 ms and the time interval between gaps were 4.5 ms. Subjects were asked to answer with gestures whether hearing one or two tones while there was a gap between tones. The smallest time gap detected by subject was reported in ms at each frequency (Table 1). The TFS processing was examined by TFS-AF test in a notebook (ASUS G56JK), with a built-in 24-bitsound card and a headphone (HAVIT HV-H2150D). The test was performed binaurally at 30 dB SL and IPDs were 90° and 180°. Variable in this test was frequency, which increased after 2 consecutive correct answers and decreased after one wrong answer. Subjects were trained properly before the start of test. They were asked to pay attention to two sets of stimuli being played and answer with gestures when they felt the movement of sound in their head. Result of the test was the geometric mean of the final six reversals in which the subject was able to detect IPD in the presented stimuli. For more information about this test, see Reference [17] (Table 2).

Statistical analysis

For statistical analysis, Kolmogorov-Smirnov test was first used to examine the normality of data distribution. In order to analyze the results of RGDT, a two-way repeated measures analysis of variance (ANOVA) was used where musical training was a between-subject factor and frequency of stimulus as a within-subject factor. For TFS-AF results, a two-way repeated measures ANOVA was also used where musical training was a between-subject factor and IPD values as a within-subject factor. Independent sample t-test was used to compare the results between the study groups. Correlation of TFS-AF and RGDT results was examined using Spearman correlation test.

Results

Regarding the TFS-AF test score, ANOVA results showed no significant effect of IPD ($F1,42 = 0.03$, $p = 0.86$), but revealed the significant effect of group ($F1,42 = 5.42$, $p \leq 0.05$). The interaction effect of IPD and group was not significant ($F1, 42 = 0.24$, $p = 0.625$). Regarding the RGDT score, ANOVA results showed the significant effect of frequency ($F3, 42 = 7.75$, $p \leq 0.05$) and group ($F1,42 = 8.39$, $p \leq 0.05$). The interaction effect of frequency and group was also significant ($F3, 42 = 2.71$, $p \leq 0.05$). Independent samples t-test results revealed a significant difference at 500 Hz ($p \leq 0.05$), 1000 Hz ($p \leq 0.05$) and 2000 Hz ($p \leq 0.05$) between the two groups but the difference was not significant at 4000 Hz ($p = 0.790$). Moreover, Spearman correlation test results showed a significant negative correlation between TFS-AF score with IPD at 90° and RGDT score at 500-Hz frequency ($p \leq 0.05$) in non-players (Table 3).

Discussion

The purpose of this study was to evaluate the effect of a stringed musical instrument course on TSF processing

Table 1. Mean and standard deviation of random gap detection test in each frequency in musicians and non-musicians

	Mean (SD) random gap detection test (ms)			
Group	500 Hz	1000 Hz	2000 Hz	4000 Hz
Non-musicians	7.50 (4.405)	8.14 (4.764)	8.86 (3.060)	8.73 (5.016)
Musician	3.55 (2.923)	4.68 (3.301)	6.64 (4.042)	8.36 (3.898)

Table 2. Mean and standard deviation of temporal fine structure-adaptive frequency in musicians and non-musicians

	Mean (SD) TFS	
Group	IPD 180	IPD 90
Non-musicians	1310.836 (170.1941)	1330.400 (186.5725)
Musician	1456.845 (320.3123)	1415.832 (328.9622)

TFS; temporal fine structure, IPD; interaural phase difference

Table 3. Spearman correlation coefficients between temporal fins structures in two phases and random gap detection test results in musicians and non-musicians

Group		RGDT 500		RGDT 1000		RGDT 2000		RGDT 4000	
		ρ	p	ρ	p	ρ	p	ρ	p
Non-musicians (n=22)	TFS 180°	–0.272	0.221	–0165	0.464	–0.154	0.494	–0.94	0.677
	TFS 90°	–0445	0.038	–0.069	0.761	0.228	0.0307	0.015	0.946
Musicians (n=22)	TFS 180°	0.004	0.986	–0.312	0.157	0.028	0.0903	0.080	0.724
	TFS 90°	–0.072	0.751	–0.291	0.189	–0.141	0.531	–0.176	0.434

RGDT; random gap detection test, TFS: temporal fine structure and temporal resolution using TFS-AF test and RGDT. We also attempted to evaluate the correlation between the scores of these two tests in order to find out more about any connection between their underlying mechanisms. Using the TFS-AF test, the statistical results showed no significant difference between instrument players and non-players at both IPDs. This is inconsistent with the findings of other studies [5, 6]. This discrepancy may be due to the use of researcher-made stimuli by mathematical functions or the use of older versions of TFS-AF test [5, 6]. This finding suggest that the TFS-AF test is not sensitive to enhanced TFS processing. A possible reason for this finding is that this test uses IPD to assess TFS processing; IPD and interaural time difference (ITD) may be intertwined with each other [8]. A popular and well known model to process ITD is the Jeffress model [19]. Due to link between IPD and ITD, it can be said that IPD is also processed by the Jeffress model. This suggests that the Jeffress model of ITD processing is unaffected or slightly affected by musical training.

The results of RGDT in our study were consistent with the findings of others studies [5, 20]. We found that, as the frequency of stimuli increased, the gap detection threshold decreased. At 500, 1000 and 2000 Hz, there were significant differences between the two groups, but no significant difference was observed at 4000 Hz. Other studies have also reported enhanced gap detection thresholds due to musical training [2, 5]. Anand et al. studied the gap detection threshold on amateur musicians aged 10–16 years using extended version of RGDT and showed better gap detection thresholds at lower frequency compared to higher ones [21]. One possible explanation to why gap detection thresholds is worsened with the increase of frequency is as Moore explains; the neurons are not able to keep up with the firing rate required to process high frequencies in RGDT because there are two brief tones with a short time gap therefore there is a limitation and this very limitation results in deterioration of RGDT in high frequencies required for processing high frequencies results in deterioration of temporal resolution [22]. Another reason may be the frequency spectrum of the musical instrument which can result in different effects on players [22, 23].

The negative significant correlation of TFS-AF test and RGDT only at 90° IPD and at 500-Hz frequency in non-players, highly suggests that even though the two tests seems to be related to temporal resolution aspect of central auditory nervous system, their underlying mechanisms are different. There is a need for more studies in this regard. It should be noted all instrument players participated in this study had experience with playing stringed musical instruments; hence, it is unclear whether the same results are obtained if TFS-AF and RGDT are performed on different instruments players. Further studies should be conducted on different kinds of instruments players.

Conclusion

Musical training, specifically on stringed musical instruments, has no effect on the temporal fine structure-adaptive frequency (TFS-AF) score. Random gap detection test (RGDT) scores are significantly different at 500, 1000 and 2000 Hz between instrument players and non-players. There is no significant correlation between the results of TFS-AF and RGDT indicating that their underlying mechanisms for TFS processing and gap detection are different.

Ethical Considerations

Compliance with ethical guidelines

Current study has been approved by the Shahid Beheshti Medical Sciences Ethics Committee (IR.SBMU.RETECH.REC.1398.718).

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Authors' contributions

YP: Study design, data collection, interpretation and writing the manuscript; AN: Study design and writing the manuscript; LJK: Data collection and supervising data collection; AAB: Analysis of the data; AM: Data collection.

Conflict of interest

No conflict of interest was disclosed.

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