Pitch, Intensity, Duration and Spectrum - Psychoacoustic Thresholds of Musicians Compared to Non-Musicians

N. Amir[a], E. Globerson[b] and L. Kishon-Rabin[a]
[a]Tel Aviv University, Ramat Aviv, 52621 Tel Aviv, Israel
[b]Jerusalem Academy of Music, Givat Ram, 52621 Jerusalem, Israel
noama@post.tau.ac.il

Auditory performance of musicians is of interest because their exceptional listening abilities may serve as a reference for the limits of the human auditory system. Superior auditory performance of musicians has been reported primarily on tests that reflect specific facets of music, which may be the result of many years musical training. Only a few studies, however, attempted to compare the auditory abilities of musicians and non-musicians on basic psychoacoustic tasks. So far comparison between the two groups focused primarily on pitch discrimination abilities. The purpose of the present study was to compare the capabilities of musicians and non-musicians on different psychoacoustic abilities. Twelve musicians and 15 non-musicians, all with normal hearing, participated in this study. Each participant performed four psychoacoustic tests, obtaining thresholds for pitch, duration, intensity and spectral discrimination. For each test, five thresholds were obtained. Both groups improved thresholds on the pitch and intensity tasks only. On average musicians performed significantly better) on all but the intensity task. Their continued improvement within the study suggests that that the limits of the auditory system were not reached. Our findings that musicians performed better than non-musicians on tasks that they did not specifically train on may indicate the influence of top-down processing driven by music exposure and learning

1 Introduction

It is generally accepted that musicians have exceptional listening skills [15]. Interestingly, this inference has been made despite the fact that little is actually known about the relative acuteness of hearing of highly trained musicians, in comparison with those of the general adult population [15, 16].

Superior auditory performance of musicians has been reported primarily on tests that reflect specific facets of music, such as timbre and rhythm [17], mistuned harmonics [18,19] and the identification (labeling) of musical intervals (frequency ratio) [19,20,21]. Only a few studies however, have attempted to compare the auditory abilities of musicians and non-musicians in simple basic psychoacoustic tasks [6,7,14,15,16,22]. Most of these tests investigated frequency discrimination abilities based on the rationale that musicians are required to detect minute changes for correct tuning of musical instruments and for detecting mistuned melodies [6,7,15]. Results of the frequency discrimination studies revealed that when no training was provided, thresholds of the musicians were on average two to six times smaller compared to non-musicians [6,7,15]. After training this difference was reduced to four times smaller [7]. In single study published on duration discrimination, musicians were found to have duration discrimination thresholds that are, on average 10% better than non-musicians [22].

The purpose of the present study was to compare the auditory discrimination abilities of musicians and non-musicians on four psychoacoustic tasks, each focusing on a different physical dimension: frequency, intensity, duration and spectrum. Results of such tests in professional musicians who had a lifelong experience with musical training may serve as a reference for the limits of the human auditory system.

2 Methods

2.1 Participants

Twenty seven subjects participated in the study, divided into two groups. The first (**M**) group (n=12) was composed of musicians. All were students or graduates of a higher education program in music Six were men and six women, aged 22 to 35 years, with musical experience of 9 to 20 years. The second (**NM**) group (n=15) was composed of non-musicians. All members of this group had less than a year of experience on a musical instrument. Six were men and nine women, aged 23 to 34 years.

All participants were tested for normal hearing (ANSI, 2009).

2.2 Procedure

Four psychoacoustic threshold tasks were administered to each participant in two different orderings The tasks were:

- FD –**frequency** discrimination
- IDD –**interval** duration discrimination
- ID – threshold of **intensity** discrimination
- SD– threshold of **spectrum (timbre)** discrimination

Five thresholds were estimated for each task.

Stimuli for each task were as follows:

- FD: 300 msec pure tones between 1000 and 1200 Hz.
- IDD: Two recorded drumbeats separated by a time interval ranging from 0.375 sec. to 0.75 sec. This range corresponded to tempos of 160 bpm to 80 bpm.
- ID: 300 msec pure tones at 1000 Hz, spanning a range of 20dB in intensity.
- SD: complex tones composed of 11 harmonics spaced 200Hz apart from 200Hz to 2000Hz. The spectral envelope of these harmonics was a straight line ranging in slope from 0 to -20 dB/octave.

Thresholds were obtained using three-interval two-alternative forced-choice procedure. That is, participants heard three stimuli and had to indicate whether the second or third stimulus was different from the first. An adaptive 2-down 1-up threshold seeking procedure was used, stopping after 8 reversals at minimum stepsize or after 200 repetitions. For each task, the minimum stepsize was 1/200 of the range. To facilitate comparison between the different tasks, all results are reported in units of "steps," corresponding to this minimum stepsize of each task. Note that in the results below, lower thresholds correspond to better psychoacoustic abilities.

3 Results

The average results for the M and NM groups for each of the five threshold estimates are shown in figures 1-4 for the four tasks, respectively. It can be seen that, in general, the musicians performed better than the non-musicians for

all tasks. This difference, however, appears to be task dependent and for some tasks more pronounced in the first threshold estimates compared to the last one.

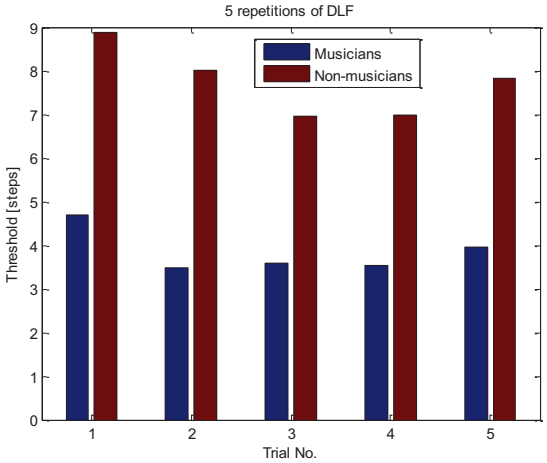

Figure 1: Mean group FD thresholds for each of the five threshold estimates.

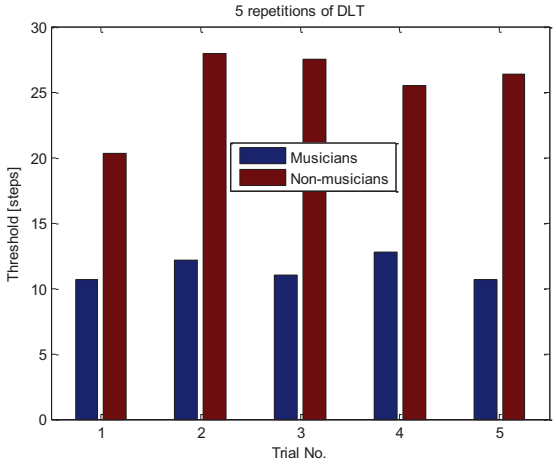

Figure 2: Mean group IDD thresholds for each of the five thresholds estimates.

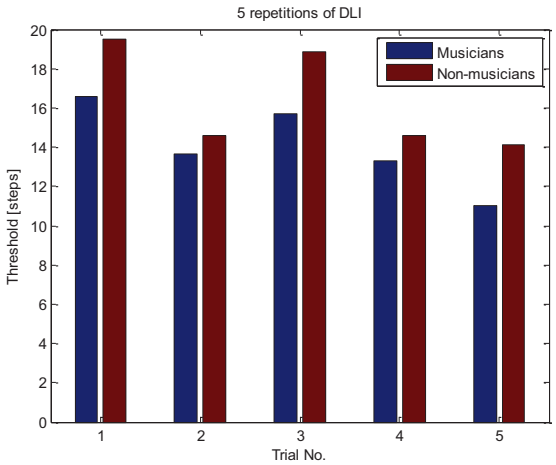

Figure 3: Group mean ID thresholds for each of the five thresholds estimates.

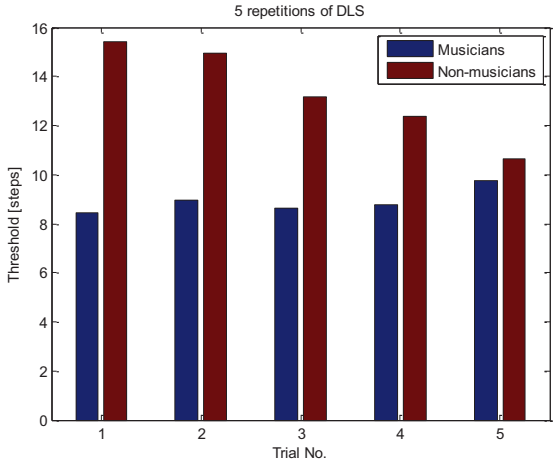

Figure 4: Group mean SD thresholds for each of the five thresholds estimates.

Specifically, in the first threshold estimate musicians performed better than non-musicians in the FD, IDD and SD tasks. This was confirmed in t-test analyses comparing the results of the two groups at the first threshold estimate for FD [$t(25)=4.220$, $p<0.001$], IDD [$t(25)=2.197$, $p=0.037$] and for SD [$t(25)=3.750$, $p=0.001$] . By the fifth threshold estimate, the superior performance of the musicians was still apparent but only for FD and IDD [$t(25)=2.294$, $p=0.03$, $t(25)=3.784$, $p=0.001$, respectively]. For the SD task, the difference between the groups was practically diminished [$t(25)=0.589$, $p>0.05$] . This reduction appears to be attributed primarily to improvement over time seen only in the NM group but not in the M group.

The statistics generally support the initial observations. Initially, the M group was better at all tasks except the ID task. By the fifth repetition, the NM group was as good as the M group on the SD task, no change occurred on the ID task, and the M group remained better on the IDD and FD tasks.

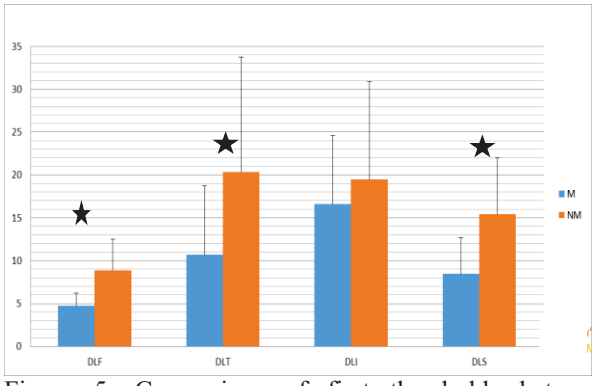

Figure 5: Comparison of first thresholds between groups, for the four tasks (order is FD, IDD, ID and SD). Stars denote a significant difference between groups.

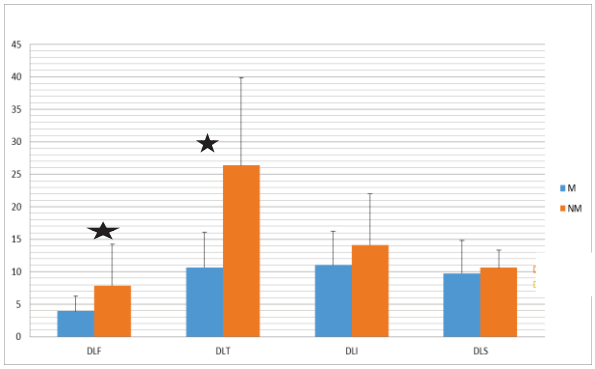

Figure 6: Comparison of fifth thresholds between groups, for the four tasks (order is FD, IDD, ID and SD). Stars denote a significant difference between groups.

4 Discussion

The current study examined thresholds in a group of musicians, and a control group of non-musicians in four psychoacoustic tasks (FD, IDD, ID and SD) which were repeated each 5 times. The main outcome of this study was that musicians showed better performance on three of the tasks (FDD, IDD and ID) but not on SD.

The superior performance of the musicians compared to the non-musicians may be attributed to years of musical training that resulted in improved perceptual skills that allowed discriminating between miniscule differences of different physical dimensions. For example, it is known that musicians must develop sensitivity to timbre, aiming to produce an optimal tone quality in their musical instrument. This may result in improvement of auditory perceptual abilities dedicated to the perception of spectral attributes of sound. The results of the current study, demonstrating better thresholds for musicians in detecting spectral changes support this conjecture. Similarly to timbre discrimination, excellent frequency discrimination is required in daily practice of musicians when tuning their instruments. The results of the current study replicate prior results indicating superior frequency discrimination for musicians [6, 7].

Interestingly, no difference was found between the musician and non-musician groups in intensity discrimination thresholds. In Western classical music playing, intensity is a major factor supporting musical expression [9]. Therefore, if exposure to nuances in pitch, tempo, and timbre enhances psychoacoustic abilities in musicians, exposure to miniscule loudness changes should have had a similar effect. The reason for the lack of findings in the current experiment could be attributed to the fact that the participants involved were not classical musicians, but, rather pop/rock musicians. This could mean that since they are used to playing and singing in high sound volume, miniscule volume differences are not as important for them as they are for classical music performers. Future studies, involving classical and non-classical musicians could examine whether classical musicians are superior in their intensity discrimination thresholds.

The findings of the present study continue to support the general notion of superior perceptual skills of musicians compared to non-musicians. A positive effect of musical training was found for higher cognitive abilities, such as language perception [1,5,8,13], and lower auditory perceptual thresholds [6]. These effects were also manifested in brain electrical activity. EEG and MEG signals measured in individuals with musical training showed enhanced brain activation in responses to a variety of auditory perceptual tasks, such as pitch discrimination [14] and timbre [10], as well as higher musical structures, such as melodic contour [4]. Music performance involves miniscule tempo changes which are, in some cases, below average thresholds [11,12]. Musicians have also been found to be better in tapping to a beat [3] and synchronizing to a changing beat [2].

The findings of the present study give rise to several future research questions. One such question relates to the association between psychoacoustic abilities and the instrument mastered by musicians. For example, violin playing involves miniscule differences in intonation. It is therefore possible that violinists exhibit better pitch discrimination abilities than pianists, who do not need to tune their instruments or adjust their intonation. Percussion instrumentalists are trained to master extremely complicated rhythmic patterns. Hence, it may be possible that their sensitivity to sound duration would be higher than musicians specializing in melodic instruments. Future studies could also examine the effect of auditory perceptual training of the tasks presented in the current study. The results of the current study demonstrate that the group differences in the SD task were reduced after 5 repetitions of the task. A similar effect may or may not be exhibited in the other tasks after a longer period of training, thus differentiating between "real" and task-related group differences in auditory perceptual abilities.

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References

[1] Anvari, S. H., Trainor, L. J., Woodside, J., & Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children *J. Experimental Child Psychology 83* 111–130.

[2] Aschersleben, G., Stenneken, P., Cole, J., & Prinz, W. (2002). Timing mechanisms in sensorimotor synchronization. In W. Prinz & B. Hommel (Eds.), *Common mechanisms in perception and action: Attention and performance* (pp. 227-244). Oxford Oxford University Press.

[3] Franek, M., Mates, J., Radil, T., Beck, K., & Poppel, E. (1991). Finger tapping in musicians and nonmusicians. *Int J Psychophysiol, 11*(3), 277-279.

[4] Fujioka, T., Trainor, L. J., Ross, B., Kakigi, R., & Pantev, C. (2004). Musical training enhances automatic encoding of melodic contour and interval structure. *J Cogn Neurosci, 16*(6), 1010-1021.

[5] Ho, Y. C., Cheung, M. C., & Chan, A. S. (2003). Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children. *Neuropsychology, 17*(3), 439-450.

[6] Kishon-Rabin, L., Amir, O., Vexler, Y., & Zaltz, Y. (2001). Pitch discrimination: Are professional musicians better than nonmusicians? *Journal of Basic and Clinical Physiology and Pharmacology, 12*, 125–143.

[7] Micheyl, C., Delhommeau, K., Perrot, X., & Oxenham, A. J. (2006). Influence of musical and psychoacoustical training on pitch discrimination. *Hear Res, 219*(1-2), 36-47.

[8] Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S. L., & Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: more evidence for brain plasticity. *Cereb Cortex, 19*(3), 712-723.

[9] Palmer, C. (1997). Music performance. *Annu Rev Psychol, 48*, 115-138.

[10] Pantev, C., Roberts, L. E., Schulz, M., Engelien, A., & Ross, B. (2001). Timbre-specific enhancement of auditory cortical representations in musicians. *Neuroreport, 12*(1), 169-174.

[11] Repp, B. H. (1990). Patterns of expressive timing in performances of a Beethoven minuet by nineteen famous pianists. *J Acoust Soc Am, 88*(2), 622-641.

[12] Repp, B. H. (1992). Diversity and commonality in music performance: an analysis of timing microstructure in Schumann's "Traumerei". *J Acoust Soc Am, 92*(5), 2546-2568.

[13] Schon, D., Magne, C., & Besson, M. (2004). The music of speech: music training facilitates pitch processing in both music and language. *Psychophysiology, 41*(3), 341-349.

[14] Tervaniemi, M., Just, V., Koelsch, S., Widmann, A., & Schroger, E. (2005). Pitch discrimination accuracy in musicians vs nonmusicians: an event-related potential and behavioral study. *Exp Brain Res, 161*(1), 1-10.

[15] Spiegel, M. F., Watson, C. S. (1984). Performance on frequency discrimination tasks by musicians and non-musicians. *J Acoust Soc Am, 76,* 1690-1696.

[16] Moore, B. C. J., Peters, R. W. (1992). Pitch discrimination and phase sensitivity in young and elderly subjects and its relationship to frequency selectivity. *J Acoust Soc Am, 91*, 2881-2893.

[17] Prior, M., Troup, G. A. (1988). Processing of timbre and rhythm in musicians and non-musicians. *Cortex 24*, 451-456.

[18] Koelsch, S., Schroger, E., Tervaniemi, M. (1999). Superior pre-attentive auditory processing in musicians. *Neuroreport , 10*, 1309-1313.

[19] Burns, E. M., Houtsma, A. J. M. (1999). The influence of musical training on the perception of sequentially presented mistuned harmonics. *J Acoust Soc Am, 106*, 3564-3570.

[20] Ward, W. D. (1963). Absolute Pitch, Part II. *Sound, 2*, 33-39.

[21] Burns, E. M., Ward, D. W. (1978). Categorical perception – Phenomenon or epiphenomenona: Evidence from experiments in the perception of melodic musical intervals. *J Acoust Soc Am, 63,* 456-468.

[22] Guclu, B., Sevinc, E., Canbeyli, R. (2011). Duration discrimination by musicians and non-musicians. *Psychological Reports*, *108(3)*, 675-687.