Musicians Outperform Nonmusicians in Speech Imitation

Barbara Pastuszek-Lipińska

Adam Mickiewicz University, School of English, al. Niepodległości 4,
61-874 Poznań, Poland
energin@wp.pl

Abstract. Recently can be observed a growing interest in the effects of music on humans. Music has been called a food or a multi-sensory fitness of the brain. Many studies have already confirmed that practice and active involvement in music improve spatio-temporal functions, verbal memory, visuo-spatial abilities, reading, self-esteem, and generally cognitive processes. In the present paper, a general overview of research on the influence of music on humans has been provided. Moreover, it has been presented data on a research project, which was conducted with the aim to examine whether music education may be viewed as one of the factors, that improve second language acquisition.

Keywords: musicianship, musical abilities, foreign language acquisition, speech perception, auditory functions, cognition.

1 General Characteristics of Music Education

The faculty of music is, in a sense, unique to humans. Humans are the only creatures who have developed notation, who compose music, and who are able to learn to play and sing music as well as play instruments in a group. All activities in the music faculty – e.g. music performance, playing an instrument, singing, composing, etc. – are very demanding, requiring sophisticated abilities and skills whose attainment demands conscious and goal-directed practice.

Music education and training engages all human senses and involves all cognitive processes (sensory, perceptual and cognitive learning, memory, emotion, etc.), but it also requires motor activation (utilized while playing an instrument) and appropriate articulation (utilized while singing or playing).

1.1 Influence of Music on Humans – Musicians Versus Nonmusicians

While it is well documented that the human brain is a dynamic rather than a stable system, there are still relatively few data answering the question of whether the plasticity of neural circuits is accompanied by changes in behaviour [19].

Several factors may influence neural circuits and one of those factors seems to be music education and training, which alters the organization of the auditory and somatosensory cortices in people active in music domain. Research that conceives of music

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as an important medium for understanding the human cognitive processes and development, as well as the human brain, is relatively new.

The topic gained more attention after the study done by Bever and Chiarello in 1974 [3], in which they examined the patterns of cerebral dominance among musicians and nonmusicians and found that intensive musical training resulted in the modification of hemispheric lateralization during music processing. After the study, the traditional view of a hemispheric dichotomy in which music was processed in the right hemisphere and language in the left could not be maintained, as there was evidence that professional musicians processed music in the left hemisphere and nonmusicians processed it in the right hemisphere.

Most of the work in this field has been done in the last ten years. According to many investigators, the human brain is both functionally and structurally adaptable to environmental stimuli, as well as to different kinds of requirements and even injury-related impairments. One of the most vital topics is the question of how musicians' brains differ from the brains of nonmusicians. Several studies have reported that there is generally a high degree of plasticity in the brains of trained musicians. Several of the most recent studies reveal that the brains of musicians and nonmusicians differ in terms of function and structure/anatomy.

Some functional differences have been observed by Ohnishi and co-workers, who found that there is "a distinct cerebral activity pattern in the auditory association areas and prefrontal cortex of trained musicians" [17].

In a detailed discussion of the structural and functional brain differences between musicians and nonmusicians, Schlaug enumerated several anatomical adaptations. He reported differences in the corpus callosum that had been observed by himself and his co-workers in a study, which revealed that the anterior half of the corpus callosum was significantly larger in musicians. This difference was particularly noticeable when contrasting musicians who started training early (<7 years old) with musicians who started music lessons late (>7 years); however, the difference between the brain structures of musicians and nonmusicians was still more significant.

Schlaug also mentioned that there was greater symmetry in the intrasulcal length of the posterior bank of the precentral gyrus in musicians [25], and thus there were differences in the motor cortices of musicians and nonmusicians. Schlaug also cited studies whose results suggested "microstructural adaptations in the human cerebellum in response to early commencement and continual practice of complicated bimanual finger sequences" [25].

These results were posited to suggest that there might be differences between musicians and nonmusicians that were indeed the result of microstructural changes caused by long-term motor activity and motor skill acquisition. Schlaug also provided evidence of regional differences in gray matter volume between musicians and nonmusicians. More specifically, "professional musicians showed higher gray matter concentrations compared to nonmusicians in the perirolandic region, the premotor region, the posterior superior parietal region, the posterior mesial perisylvian region bilaterally, and the cerebellum" [25].[1]

[1] "The superior parietal cortex does play an important role in music performance, since it may serve to integrate of visual and auditory information with motor planning activities" [25].

Several empirical studies have also provided other evidence of functional brain differences between musicians and nonmusicians, specifically in the area of auditory processing. The main observation, that was reported by the studies and discussed by Schlaug, concerns the processing of music and the processing of several musical tasks, which seemed to be different in musicians as compared to nonmusicians; musicians apparently "process music in a different way" [25]. The results showed that music is processed by the brains of musicians by both the right and left hemispheres. It appears from the studies cited by Schlaug that the group of musicians, especially musicians with absolute pitch, demonstrated "an increased leftsided asymmetry of the planum temporale" [25].

Other structural brain changes that have resulted from musical training have been reported in a study by Gaser and Schlaug [6]. Specifically, they found that "areas with a significant positive correlation between musician status and increase in gray matter volume were found in perirolandic regions including primary motor and somatosensory areas, premotor areas, anterior superior parietal areas, and in the inferior temporal gyrus bilaterally" [6]. Also these findings suggest that intensive musical training may generate changes in the human brain.

Similarly, other studies have reported that cortical plasticity and reorganization of cortical representations have occurred due to musical training. The results of those studies revealed that increased auditory cortical representation has been observed in musicians.

Pantev and his co-workers performed a comparison of musicians who were proficient with string instrument and nonmusicians. This comparison found that cerebral representation of the cortical sources responsible for the fingers of the left hand, which are intensively used in string instruments, was increased among the musicians as compared with the controls. Therefore, Pantev and his colleagues proved that "music education and training is reflected in the organization of auditory and somatosensory representational cortex in musicians" [19]. The reported cortical response for stimulation was dependent on the age at which the musicians had started their musical training.

Similar results were observed in a study that provided auditory stimuli. On the basis of these findings, Pantev and his colleagues suggested that "intensive training can trigger a functional adaptation of the cortical organization" and induce plastic changes of the human brain [19].

It should be noted that neuroplastic adaptations in the auditory cortex and changes in auditory evoqued responses have been to date observed both in children [5] and in adults [26].

1.2 Nature or Nurture

Although the number and range of studies confirming the impact of musical training on humans is growing quickly, there is still doubt as to whether these changes are due to experience, or whether they are innate.

To answer that question, Lahav and his colleagues, among others, conducted experiments that revealed the existence of a functional linkage between actions and sounds. They taught musically naïve subjects to play a melody on the piano by ear.

The subjects were then divided into three groups – the piano-listening group[2], the "nature-listening"[3] group, and the practicing group – and over the course of one week they participated in three additional 20-minute listening/practicing sessions. After this period, the subjects' ability to play the previously learned melody was tested. The results revealed that the practicing group performed better than other groups, which is not surprising. However, the piano-listening group performed significantly better than the nature-listening group. The authors found that even passive listening to music influenced the motor performance of musically naïve subjects (the piano-listening group), and concluded that the findings may suggest that "during passive listening, neural mechanisms linking sounds and actions may implicitly facilitate musical motor performance" [12].

All of the presented studies reveal that musical practice may generate changes in both the motor and auditory areas of the brain, and that sounds and actions may interact implicitly.

The number of experiments and studies in which differences between musicians and nonmusicians were demonstrated in the results is more significant than cited above. The purpose of introducing this small sample was to provide data on the neurological evidence showing how musical training may change humans' brains. The evidence has attracted the interest of several researchers (including the present author) and has prompted the question of whether the training may also result in behavioral changes and/or affect other human abilities and disciplines, including those that use similar patterns (in this case, sounds).

According to Pantev and his collaborators "to induce plastic alterations" active practice is needed. The authors also highlighted that it was best to begin training early in life [19]. They also suggested that it is possible to adapt cortical organization even in adulthood, but added that "adults have to work harder" [19].

Research on music perception has established that "the cognition of music is underpinned by the human ability to extract, store and manipulate a range of abstract structural representations from a complex multi-dimensional stimulus stream" [14]. Moreover, musical training fosters other abilities, such as attention, motivation, concentration, and general discipline.

Thus, from the cited studies it is clear that music education may generate changes in structure and function of humans' brains. However, the question of the behavioural effects of sensory experience still requires more attention and examination [23]. Interdisciplinary approaches are needed to examine whether the observed plastic alterations are important only in music or perhaps affect also other human activities. Currently can be observed an ongoing debate on the possibility of transfer between the music and other cognitive domains. In the paper most attention is given to the influence of musical training on foreign language (speech) acquisition.

1.3 Is the Transfer Music-Language Possible?

A number of studies revealed that a range of factors affects language acquisition and various processes take place during the acquisition. Although the first component of

[2] The participants listened to the same melody that was played by practicing group.
[3] The participant listened to the sounds of nature.

language development, which is appropriate brain and the whole nervous system organization, seems to be crucial, however, several other factors such as e.g. environmental, emotional and motivational ones cannot be omitted.

It has been well documented that transfer effects are possible and tend to occur between the specific area of training and other areas that present similar contexts [32]. In the case of music education researchers have also found correlations between dissimilar contexts and domains. Several previous studies provided evidence of positive associations between music education and general intelligence as well as mathematical skills. Other abilities were positively associated with music education as well, such as spatio-temporal reasoning, verbal memory, visuo-spatial abilities, reading, self-esteem, and others.

Only a limited number of studies examined a possible impact of music education on language acquisition (e.g. [9], [13], [31], [32]). Moreover, there is a still ongoing discussion on the level of relationship. Namely, it is examined whether music education, music exposure or musicality improve human potential in language acquisition [24].

Jackendoff [8] mentioned the possible transfer indirectly. He claimed that "there must be levels of mental representation at which information conveyed by language is compatible with information from other peripheral systems such as vision, nonverbal audition, smell, kinaesthesia, and so forth. If there were no such levels, it would be impossible to use language to report sensory input" [8].

When looking for the possible transfer between musical training and language several approaches have been proposed. The approaches have been mainly based on the fact that training in music requires engagement and refinement of processes involved in the analysis of pitch patterns over time and then the processes may be activated during interpretation of emotions conveyed by spoken utterances. Indeed, some recent studies have provided evidence confirming the relationship (cf. [9], [31], [32]).

Some of the processes are shared by both language and music (e.g. discrimination of emotional meaning, acoustical cues), several of them are domain-specific. To date the issue has been noticed in several studies (e.g. [31], [32]). For instance, in two of their experiments Thompson, Schellenberg and Husain [31] examined the hypothesis that music lessons generate positive transfer effects that influence speech perception. The authors provided evidence that musically trained participants outperformed untrained examinees in extracting prosodic information from speech and they suggested the existence of cognitive transfer between music and speech. They have also claimed that music lessons improve the ability to extract prosodic cues as well as the ability to interpret speech prosody.

Recently, also other researchers have reported interrelations between music training and prosody processing. For instance, Palmer and Hutchins [18] highlighted the rising neurological evidence suggesting a direct connection between musical and linguistic prosody. Specifically, subjects who have impairment in musical discrimination and perception very often encounter similar impairments in the discrimination and perception of linguistic prosody [22].

Music education and training seem to stimulate mechanisms of straightening brain circuits that are involved in the performance of different tasks. Schön, Magne, and Besson compared how musicians and nonmusicians detect pitch contour violations in music and in language [27]. They found that subjects with extensive musical training were able to detect very small frequency manipulations in both music and speech, while subjects without such training could not do so.

Moreno and Besson have also conducted a set of event-related brain potential studies that examined the influence of musical training on pitch processing in children. Specifically, they provided children with eight weeks of musical training, and found that after this short period of time, changes in pitch processing in language could be noted [14].

Similar results were also reported in another study by Magne, Schön, and Besson [13], who reported in an ERP study that 3 to 4 years of extended musical training enabled children to outperform others who had not had such training in the detection of pitch violation in both music and speech. Thus, they have also provided evidence of positive transfer effects between music and language, and of a common pitch-processing mechanism in language and music perception [13].

Dodane has found some other interactions between musical and linguistic education, having focused on early second language acquisition. More specifically, Dodane conducted several experiments examining the second-language acquisition abilities of musically trained children versus those of children who had not had music lessons. She analyzed the analogies between musical and verbal forms and conducted her analyses at two levels: the global (prosody) and the local (segmental). The treatment at the global level involved pitch contour tracking, while the local treatment involved a detailed analysis of intervals in music and of the phonemic contrasts (relations between formant frequencies and phonemes) in language. Dodane compared the performance of the musically trained children with that of the non-musically trained children and found that at an early stage, music education plays an important role in learning second language, as a musically trained ear is better prepared to perceive both the intonation and the melody of a foreign language, as well as the phonetic contrasts [4].

The present author conducted a study that involved shadowing speech (i.e. stimuli repeated just after listening). She asked a pool of 106 musicians and nonmusicians (Poles) to repeat – among others – the question "May I help you?" after they had heard it three times; then she recorded their attempts. These productions were randomly presented to 7 native speakers of English, who gave their scores on them. The data revealed that musicians received better scores and were rated as being closer to native speaker production. Pastuszek-Lipińska interpreted the finding as preliminary evidence that musicians are better at perceiving and producing foreign language sounds than are nonmusicians [21]. Moreover, the finding revealed that musicians better that nonmusicians deal with foreign speech material.

Another interesting proof of the influences exerted by music education on foreign language acquisition was substantiated by Jakobson and her coworkers, who provided evidence that musical training improved auditory temporal processing skills. As a consequence, enhanced verbal memory performance was observed in musicians, and these improved skills enabled them to learn foreign languages more easily [9].

A study by Alexander, Wong, and Bradlow [2] provided evidence that musical background can influence lexical tone perception. They conducted two experiments in order to examine whether speech and music are indeed separate mental processes, as was suggested by several earlier studies. In the course of the study, they found another proof that certain aspects of music and speech may be shared between the two domains. More specifically, they provided evidence of overlapping in the processing of fundamental frequencies in both music and speech, and showed that this overlap is more visible in musicians than in nonmusicians. In a set of two perception experiments, American-English-speaking musicians proved to be more successful in identifying and discriminating lexical tones than their nonmusician counterparts. This suggests that experience with music pitch processing may facilitate the processing of lexical pitches as well.

More recently, Norton and her collaborators supported the suggestions that music and language processing may be linked, based on observed similarities in auditory and visual pattern recognition. They also suggested that language and music processing may share the neural substrates, due to innate abilities or implicit learning during early development [16].

Slevc and Miyake [28] examined whether there is a link between musical ability and second language proficiency in adults. They have demonstrated that such a relationship exists and that people "who are good at analyzing, discriminating, and remembering simple musical stimuli are better at accurately perceiving and producing L2 sounds" [28].

Moreover, a number of studies have substantiated the assertion that auditory abilities may be improved through auditory training, and that such training may be either linguistic or musical, as this kind of training affects auditory perception in general (cf. [15], [11]).

Thus, the presented data reveal that musical training may in fact exert an influence on language acquisition, and that this is possible even after a short period of training. Still, it seems that the range of existing evidence requires new approaches and analyses, and the issue of an interdomain relationship has not been sufficiently examined.

2 Research Design

A research study has been developed with the aim to investigate relationship between music education and second language acquisition. The focus was given to sounds and construct perception and production. The main goal of the study was to examine whether active involvement in music has influenced second language acquisition.

2.1 The Corpus

82 word sequences in 6 languages: American English (15), British English (14), Belgian Dutch (11), French (10), Italian (10), European Spanish European (6), South American Spanish (4), and Japanese (10) have been synthesized for the corpus. The ScanSoft® RealSpeak™ application was used for the purpose.

Languages were chosen according to the typological classification. Stimuli involved both stress-timed, syllable-timed and moraes-timed languages. Amongst the sentences were questions, statements, and orders. The corpus also contained some phonological words, names and/or other short word sequences.

Thus, the stimuli differed phonemically and phonostylistically and contained a variety of lexical items; the length of the sequences was diversified as well. All word sequences were recorded on CD, and were repeated three times each, with short gaps left between the repetitions of each sequence and a longer pause after each sequence that provided speakers with time needed to repeat the sentence. In this way, a recorded corpus was developed, which served for further data collection.

2.2 Participants

A group of 106 subjects was examined: all of the participants were native speakers of Polish, but the participants had varying levels of language competence, and some had had musical education and training while others had not. All subjects were recruited in the Lodz and Kutno areas and participated in the study they had given verbal consent on a voluntary basis. They were not paid for their participation in the study. All subjects were aged from 15 to 69 years, with a mean age of 32 (median 28). All subjects reported that they had normal hearing, although some of them filled out in questionnaires that they had some hearing-related illnesses in the past (e.g. otitis, other temporal impairments). As well, some of the subjects who were advanced in age could have had age-related hearing changes.

While planning the research, it was intended that there would be two groups, the first composed of nonmusicians and the second composed of professional musicians (who had studied music through secondary school, in Poland it is usually after 10-12 years of education).

2.3 Questionnaire

For the purpose of the study, a special questionnaire was developed. The questionnaire was designed to elicit information on each participant's sex, age, education (including the start date of their musical education and training, as well as their contact with foreign languages), music exposure, occupation, job, interests, and health (subjects were asked to give information on previous hearing problems and all illnesses that could have a negative impact on their hearing).

Although prospective participants were informed prior to the study that the main criterion of participation in the procedure was musicianship, several inconsistencies and instances of contradictory data were noticed during data analysis. After the pretest had been completed and background information had been gathered from participants in the main procedure, it was noticed that both the first classification (of musical competence) and the second one (of language competence) did not sufficiently describe the subjects, and that the earlier expectations could not be fully reached. For instance, some professional musicians who had had 10-12 years of musical education were currently not active in music, and some subjects who claimed to be nonmusicians had some musical experience in childhood. There was also a small group of subjects – nonmusicians - who, even without any formal training, had performed as non-professional amateur musicians. Some subjects could not be classified according to the current division.

The aspect of language experience was ignored, as it was almost impossible to find subjects who had no background in any language other than their native one. Instead, data on the language experience previous to the study have been collected.

2.4 Research Procedure

The current study, which was aimed at investigating the issues discussed in the previous sections, included several steps. The first step investigated participants' musical skills and memory for music sequences. The second step examined how musicians and nonmusicians tackled foreign language word sequences.

It should be noted that the successful realisation of the task, which consisted of shadowing repetitions (repeated just after listen to), has been recognised as a good indicator of phonological short-term memory. This, in turn, has been recognised as a predictor of language learning success [7]. The digitized productions of the participants were analysed and examined, using several different tests and experiments so as to obtain a view of how musicians' and nonmusicians' productions differ; some data that may be relevant in answering this question are posited in the current paper.

The procedure also aimed to evaluate which language components caused the greatest challenges to examinees; thus, the speakers' productions were analyzed both at the segmental (local) and the suprasegmental (global) levels.

2.5 Test of Musical Abilities

In order to gather data on the musical skills of the participants, a special test designed to examine their musical abilities was developed. The test was not a standardized test, but it was developed so as to examine general musical skills and memory for music stimuli in a short time. Thus, subjects without any musical background participated in a test of musical competence and abilities [20].

The test was prepared with the following tasks: participants were asked to repeat 5 tones, sing 4 words according to the model presented on a CD. They were also asked to respond to 4 sets of tones and chords: a tone, a chord of three musical tones with the middle tone to repeat, two tones with the lower tone to repeat and finally a chord of three tones with the highest tone to repeat. Participants were then asked to compare of two melodies that were slightly different in rhythm and in pitch, to compare a short melody when produced in a major key and then in a minor key, and then to reproduce 4 rhythms by clapping hands. Results of the test are provided in Figure 1.

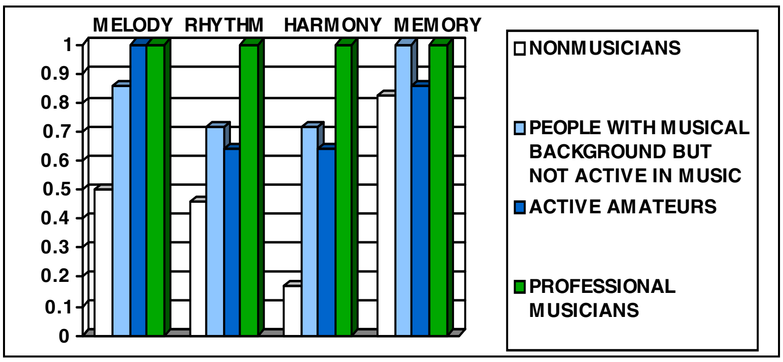

Fig. 1. Results of the test of musical abilities

All the tasks were recorded with Sharp MD-MT200 portable recorder and UNITRA-Tonsil Microphone MCU-53 with a linear characteristic, and then the author developed a CD with the tasks and recorded instructions. The task lasted around 5 minutes. The test of musical skills was based on the standard entrance tests to music schools in Poland; it contained similar tasks to those that are included in that standardized tests of musical skills, but the number of questions was limited. On the basis of the pre-test results, it was assumed that all musicians were able to pass the tasks without any problems. The assumption was also based on real-life cases – namely, it is not possible to start and then continue one's musical education without successful completion of the described test.

Nonmusicians' responses to musical stimuli were not recorded. The present author rated their productions auditorily[4]; she used a three-grade scale to evaluate four abilities – pitch tracking, rhythmic skills, harmonic hearing, and memory for music stimuli. Results were noted in questionnaires that had been earlier prepared separately for each participant. It can be seen that nonmusicians' performances differed significantly.

2.6 Main Procedure

Subjects' ability to imitate foreign language phrases was tested. The task was meant to examine an ability to integrate different components of linguistic information such as: phonology, syntax, and intonation. The task was meant to examine the participants' ability to integrate different components of linguistic information, such as phonology, syntax, and intonation. The task was not a pure measure of the enumerated components, but was instead aimed at finding a key to success or failure in the acquisition of language sounds and structures (perception and production).

Table 1. Example sentences used in the study

Language	Material
American English	Sorry to keep you waiting.
Belgian Dutch	Een fantastisch spektakel.
British English	Is it yours?
French	Tout le monde!
Italian	La storia si ripete.
Japanese	Konnichiwa.
Spanish	Más vale tarde que nunca.

Subjects were asked to repeat as accurately as they could some synthetic foreign language word sequences played on a CD player (Grundig) placed in a quiet area. No other information was given to the subjects. Examinees were not informed that they heard synthetic stimuli. Subjects' productions were recorded with Sharp MD-MT200 portable recorder and UNITRA-Tonsil Microphone MCU-53 with a linear characteristic. Example sentences are provided in the Table 1.

[4] As the present author is a professional musician and has graduated from the Academy of Music, she was able to evaluate the productions of subjects.

The data were collected in different areas, not in a laboratory, which was not available to the author. Thus, the prepared technical equipment enabled the author to move about easily and reach the subjects in different places, even at their homes.

All recordings were carefully listened to and analyzed. The main goal was to determine whether subjects with different musical expertise perform at the same, similar or different level. It was assumed that there might be differences among subjects (and statistically among groups). It was also assumed that subjects' performances might differ between languages, due to their typological differences.

2.7 Data Analysis

The study did not aim to ascertain solely whether musicians repeated word sequences better than nonmusicians, also aimed to determine which aspects or components of language caused both groups the greatest difficulties. Another aim was to observe whether accuracy at the global level accompanied with accuracy at the local level. In order to discover the exact differences in the mispronunciations, all the word sequences were analyzed.

The author rated the speech samples by auditory analysis. Recordings were examined in a randomized order and after a period of more than one year from data collection so that to ensure unbiased evaluation of all performances.

In the first round of data analysis the scoring procedure was based mainly on a general review and observation whether all speakers responded to the stimuli and were able to repeat the speech material in the given time and accurately. It was noticed that almost all subjects encountered difficulty with at least one sentence.

In order to evaluate whether the task was not too difficult the Difficulty Factor, which optimal level equals 0.5 and which is usually used to check the proportion of respondents who were able to give the right answer to a given question or task, was calculated.

The difficulty factor may be calculated using the following formula:

$$D = c / n. \quad (1)$$

D - difficulty factor,
c - number of correct answers,
n - number of respondents.

As the main purpose of the study was to discriminate between different levels of performance, thus items with difficulty values between 0.3 and 0.7 would be most effective. In the study, the factor shows that the applied procedure and its difficulty were close to optimum and the task was feasible. Namely the factor equals 0.56, in case of musicians, and 0.39, in nonmusicians which means that the task was available for both groups of speakers.

Not all subjects were able to repeat all the stimuli. The mean number of correct repetitions (i.e. these very close to the original samples) was 45.95. It should be noted that data presented in the paper refer to the stimuli taken as whole word sequences. It means that even a very slight error caused to admit a production to be incorrect.

As showed in Figure 2, musicians encountered fewer difficulties in speech repetition and produced 56.53 of correct responses to 82 provided stimuli.

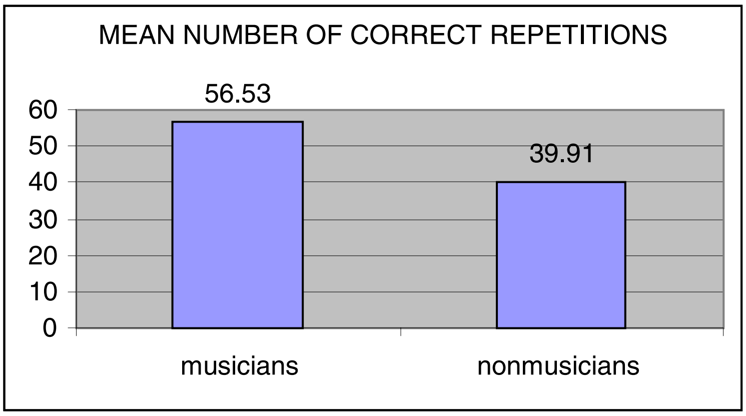

Fig. 2. Mean number of correct responses

Nonmusicians performed significantly worse than musicians and produced 39.91 of correct repetitions. It means that 65.53% of musicians' and 46.55% of nonmusicians' productions were rated as correct.

In Figure 3 below, the graph with all correct performances of all participants of the study is presented.

The presented data may suggest that musicians could have better memory, and this parameter enabled them to perform better during the whole study. They just encountered fewer difficulties with remembering speech passages thus it may be assumed that they encountered fewer boundaries with the task.

It was found that a number of correct productions differed among languages. It was reported that most musicians repeated all stimuli on time, however not all productions were fully faithful to the original.

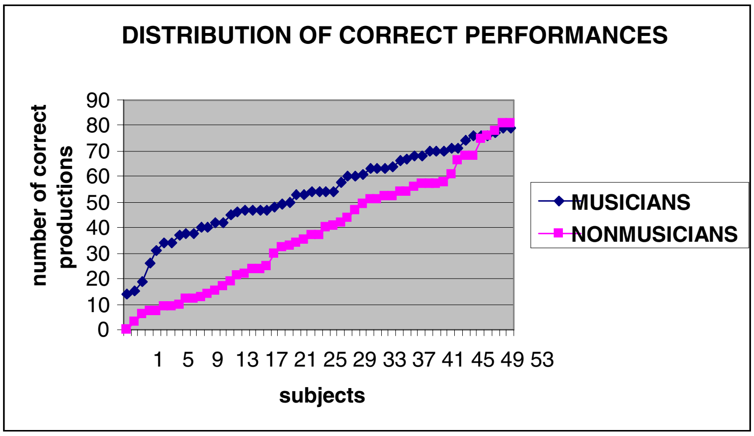

Fig. 3. Number of correct performances

Detailed analysis of all questionnaires revealed that 14 nonmusicians had had in the past some musical background. Therefore, all subjects were divided into four groups: without any musical training in the past, above 0 to 6 years of music education, from 7 to 12 years of musical expertise and more than 12 years.

In Figure 4 are presented scores obtained by participants of the study grouped in accordance with the length of musical training. The graphs reveal that even several years of musical education in the past affected the level of performance in the study.

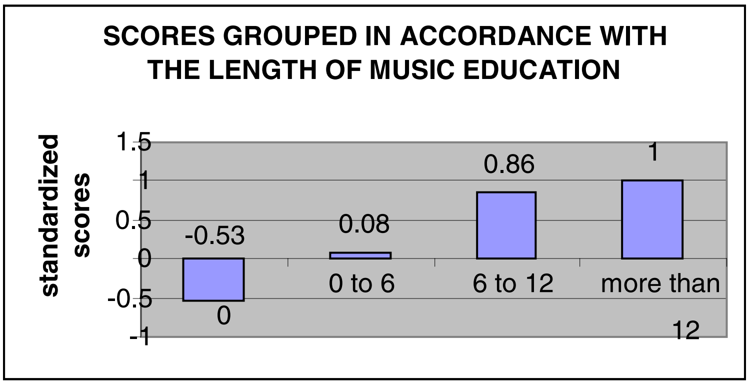

Fig. 4. Scores obtained by subjects with different musical background

This result clearly shows that music training influences humans' ability to perceive and produce foreign language speech sequences.

2.8 More Detailed Data Analysis

As one of the aims of the study was to establish what types of errors were produced by participants, the recorded data were listened to and as far as possible all inconsistencies and errors produced by the speakers were analyzed and assessed. Special attention was given to all mispronunciations that occurred systematically and in several speakers in the same words' or sounds' sequences.

Some mispronunciations and inconsistencies were observed at both segmental and suprasegmental levels, cf. [5]. It was determined that many subjects, more likely nonmusicians than musicians, changed several segments, repeated word sequences closer to Polish pronunciation, and did not follow appropriate production in foreign languages.

Moreover, it was observed that the modifications referred to vowels (e.g. their quality and length), consonants, and consonantal clusters as well. Interestingly, the least problems were encountered for intonation as both groups performed at similar level.

Several productions could be described as completely unintelligible in term of segmental level, however, with appropriate mimicry of speech melody. This may resulted of the so called phonemic restoration phenomenon observed in both music and in speech. Kashino [10], among others, claimed that "the sounds we hear are not copies of physical sounds” and “what we perceive is the result of [an] unconscious interpretation” [10]. This means that auditory perception is a subconscious process which is influenced by our experience and generally depends on the condition and sensitivity of our nervous system. In other words the previous experience can be used in supplying which phoneme or which tone is missing in a word or a music sequence, respectively. According to Aiello, “the occurrence of categorical perception and of restoration effects in speech and music demonstrates a certain level of commonality of processing across these two domains” [1].

Most commonly present mispronunciations that could be observed in almost all the word sequences were: lack of differentiation of the length of vowels occurring in a given sentence, change of vowels’ quality, difficulties with repetition of longer or more complex sentences, replacement of voiced consonants into voiceless ones and vice versa, respectively. In many cases subjects were not able to repeat either whole words or their parts (e.g. syllables, segments).

Errors of segmentation were an important source of mistakes. It was observed that mispronunciation of one segment (e.g. a consonant) resulted in other mispronunciations in neighboring segments (e.g. a vowel), and vice versa. It should be also pointed out that different types of errors occurred in almost all participants’ productions and almost all of them encountered some difficulties in appropriate realization of the task as a whole.

Subjects produced both errors of performance (slips of the tongue) and errors of competence (pronunciation) [30]. Moreover, in subjects’ mimicry occurred some both native and foreign interferences.

The significant discrepancy between the quality of performance on segmental and suprasegmental level was observed. This may suggest that segmental and suprasegmental features are processed separately and that musicians better than nonmusicians coordinate and consolidate the independent psychoacoustic processes.

2.9 Correlations and Statistical Analysis

Pearson correlations were performed in order to establish relationship between results achieved by speakers and their musicianship, results achieved in the memory test for music stimuli, number of years of music education, number of years of learning foreign languages, and results of the whole test of music abilities.

Table 2. Recapitulation of all correlations

Variable	Variable	Correlation vs. probability level
MUS	MEAN	r=.40, p<.0001
MEM	MEAN	r=.35, p<.0002
N/Y/MUS	N/ RES	r=.38, p<.0001
START/MUS	MEAN	r=.24, p<.01
MUS	N/ RES	r=.36, p<.0001
MUS/SKILLS	N/RES	r=.43, p<.0001
ATT	N/RES	r=.50, p<.0001

Legend: *MUS* – musicianship, *MEM* - memory, *N/Y/MUS* - number of years of musical training, *START/MUS* - the age of start of musical training, *MUS/SKILLS* - musical skills, *ATT* - attitude towards learning languages, *MEAN* - mean results, *N/RES* - number of correct responses.

Pearson correlation determines the extent to which values of two variables are related. Correlation coefficients can range from -1.00 to +1.00. The value of -1.00 indicates a perfect *negative* correlation of two variables while a value of +1.00 indicates a perfect *positive* correlation. A value of 0.00 reveals a lack of correlation.

Examined variables are positively correlated, however, the correlations are small and moderate. Table 2 contains recapitulation of all correlations.

Comparison of mean results achieved by the two groups under research revealed that their performances differed significantly. Both Median and Mean values obtained by the two groups are close to each other, which means that there were not many residuals in both groups of examinees (Median 54, mean 53.74 for musicians and 37 and 38.17 for nonmusicians, respectively).

In turn, more important differences between SD in nonmusicians suggest that this group was not very coherent, and in the group were many subjects who were able to deal very well with the task but also many subjects whose performances were very poor. In addition the higher IQR[5] in nonmusicians (39) suggested less coherence of the group and more differences between subjects' performance.

Table 3. Comparative descriptive analysis of mean scores obtained by two groups of examinees

	MUSICIANS		NONMUSICIANS	
n	53		53	
mean	53.74		38.17	
SD	16.71		23.11	
SE	2.29		3.17	
95% CI of mean	49.130	to 58.341	31.801	to 44.539

	Median	IQR	95% CI of Median	
MUSICIANS	54.000	26.000	47.000	to 63.000
NONMUSICIANS	37.000	39.000	24.000	to 51.000

To check the main hypothesis, that musicians should outperform nonmusicians in the repetition of sentences in a foreign language, the t-test for independent samples was performed, and its results are provided in Table 4, below.

The t-test for independent samples, which tests whether or not two means are significantly different from each other, proved that the two groups did indeed perform their tasks with different levels of accuracy. Results of the t-test suggest that the differences between performances of musicians and nonmusicians are statistically significant.

[5] The Inter-Quartile Range is a measure of the spread of or dispersion within a data set. The IQR is the width of an interval which contains the middle 50% of the sample, so it is smaller than the range and its value is less affected by outliers.

Table 4. Results of t-test for independent samples

N	106			
STAND/GEN by MUSICIANSHIP	n	Mean	SD	SE
0	53	-0.361	1.073	0.1474
1	53	0.361	0.776	0.1066
Difference between means	-0.723			
95% CI	-1.083	To -0.362		
t statistic	-3.97			
2-tailed p	0.0001			

3 Conclusions

Production scores obtained in the general analysis evidenced that musicians performed better than nonmusicians in the whole experiment. The trained people were able to repeat more sentences and word sequences and with fewer errors.

An analysis of results achieved by subjects in the study in relation to subjects' earlier musical expertise seems to confirm that music education affects second language acquisition and that the influence is not a myth but has thorough scientifically approved basis. Therefore, it seems important to include music lessons in education programs along with other subjects and activities such as reading, writing, and mathematics in order to enhance the cognitive capacities of all students.

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