Asian Journal of Humanities and Social Sciences
Volume 4, Issue 1, May, 2016
ISSN: 2320-9720

Mathematics Learning Efficiency and Working Aural Musical Memory Training in Its Optimal Cognitive Maturity Age

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ABSTRACT

Cognitive psychology of working memory and cognitive neuroscience of music became rapidly growing disciplines within the area of learning efficiency. The goal of the present quasi-experimental and correlational study is investigating the influence and relation of working aural musical memory training to mathematics learning efficiency, by psychometric measurement of working aural musical memory and diagnostic data of cognitive learning efficiency, with basis of music activity and of both hemispheric music and mathematics processing specifics with its relation to learning efficiency, in the frame of specifics of connections between music, mathematics, language, cognitive intelligence and working memory training influences on cognitive learning efficiency. Empirical income data included level of cognitive intellectual learning ability, of mathematics achievement and musical activity. Empirical outcome data included mathematics and language improvement state, working aural musical memory scores from before and after working memory training with its hemispheric income condition and outcome change-tendency. Research emerged 50 participants aged 12th into two equal experimental groups with presence and absence of the mathematics leaning improvement. Empirical results confirmed the existence of independent musical, mathematical and linguistic intelligences modalities, with significant evidences of musical activity general influence on the cognitive learning process efficiency with identifications in the frame of cognitive music psychology and of cognitive music therapy.

Keywords: hemispheric music and mathematics processing, working aural musical memory, working memory and musical training, musical and cognitive intelligence, musical activity, learning efficiency, mathematics ability and achievement.

The aim of the present research was to study how aural working musical memory training can improve mathematical learning efficiency during quasi-experimental and correlational research of intensive 3,5 months working aural musical memory training stimulation influence and of its relation to mathematics learning efficiency process, in two equal groups of children aged 12th with the difference in mathematics improvement state after training stimulation finished, with the support of factor analyses and of path analyses structural methods of empirical data, with the diagnostic data of the statements: 1) income cognitive intellectual learning ability developmental level, i.e. school grades' average with selected grade of mathematics ability level; 2) income of musical activity group (musician or non-musician); 3) outcome learning efficiency improvement in mathematics and language study in participants' announcement and controlled participants' school teachers' feedback confirmation; 4) income pre-test and outcome post-test of working aural musical memory results for scales: pitch memory, rhythm memory, common memory, total memory, asymmetry of memory, income classification of memory hemispheric-lateralization statement and outcome combination of memory hemispheric change tendency duration on basis of asymmetry of memory changed level.

CONNECTION BETWEEN MUSIC AND MATHEMATICS IN INTELLIGENCE STRUCTURE

Musical intelligence has been formed up and posited in the Gardner (1983; 1985) theory of multiple intelligences, where the music is considered as an autonomous intellectual realm with abilities to produce and appreciate rhythm, pitch and timbre, with the appreciation of the form of musical expression (Gardner et al., 1989). In the Gardner statement the most important are pitch (melody) and rhythm, because musical sounds are emitted at certain auditory frequencies and are grouped according to a prescribed system, with next in importance to timbre as qualitative characteristic of a musical tone. In the Gardner state (1999) musical and mathematical intelligences may share common thinking processes, where logical mathematical intelligence is defined as the sensitivity and capacity to discern logical, numerical and geometrical patterns, with the ability to handle relationships of long chains of reasoning, to understand complex mathematical concepts and to think logically, while musical training enhances logical thinking. It enables a human to perceive connections, to use abstract, symbolic thought and sequential reasoning skills with inductive and deductive thinking patterns, where logical reasoning is closely linked to fluid intelligence and to general intelligence (Gardner et al., 1989). Gardner established basic criteria for behavior to be posited as intelligence, where basic requirements concern about: the potential for brain isolation by brain damage, the part in scientific evolutionary history, the distinct development with individual differences' progression, the presence of brain and core operations, the existence of normal distribution in human abilities (especially existences of idiots, of savants, of prodigies and of other exceptional people) including support from psychometric findings and from experimental psychology. Fresh experimental studies confirmed that Gardner intelligences do correlate with the general *g* factor of cognitive intelligence, what is the basic support for a single dominant type of musical and mathematical intelligences (Visser et al., 2006).

Fresh CHC (Cattell – Horn – Carroll) psychological model of cognitive intelligence is the most comprehensive and empirically supported psychometric model of human's cognitive and academic abilities' structure (Flanagan et al., 2005), based on the confirmatory factor analysis of cognitive intelligence components with using the structural equation modeling (McGrew, 2005; Taub et al., 2008). The relationships among large number of distinct individual differences in cognitive ability can be derived in three level of classification cues: 1) basic general intelligence factor (*g*) which includes 2) ten independent separate bread stratum abilities (Flanagan et al., 2007):{- quantitative knowledge; - reading and writing; - comprehension knowledge; - fluid reasoning; - short-term memory; - long-term storage and retrieval; - visual processing; - auditory processing; - processing speed; - decision and reaction time-speed (not yet measured by intellectual ability tests)} with 3) over 60 abilities inside stratum groups (Schneider et al., 2012). Musical discrimination and judgement are the narrow abilities that located in auditory processing, while mathematical knowledge and mathematical achievement are narrow abilities located in quantitative knowledge. Memory span and working memory capacity, as synonyms, are the only narrow abilities located in short-term memory. Thus, musical aptitude is included in modern CHC cognitive intelligence model and comes to be a part of fluid intelligence based on aural perception, with several researchers reported evidences of associations between music training and cognitive abilities that do extend to pure measures of fluid intelligence (Dege et al., 2011; Forgeard et al., 2008; Hille et al., 2011; Portowitz et al., 2009; Thompson et al., 2004; Trimmer et al., 2008).

Although mathematical skills seem to belong to the crystalized intelligence on the basis of knowledge, the mathematical intelligence, identified firstly by Cattell (1963; 1971), is based mostly on fluid intelligence, i.e. the capacity to think logically and to solve problems in novel situations, independent of acquired earlier knowledge from the past (Jaeggi et al., 2008; 2014 a). Additionally fluid intelligence includes inductive and deductive reasoning; it is a factor of general intelligence *g* (Cattell, 1987) affected by a brain injury in cognitive disorders on neurological background (Cattell, 1963; Suchy et al., 2007) with acquiring maturity age in young adulthood and then slow steady declining (Lee et al., 2005), while crystalized intelligence is based on both knowledge and long-term memory, including language skills with vocabulary resources, with the improvement during life until advanced aging 65, then starts to decline (Cavanaugh et al., 2010). Thus mathematical intelligence and musical intelligence on the basis of aural musical aptitude do share common fluid intelligence matter, while mathematical skills and language skills do share common crystalized intelligence matter.

Studies on children aged 5 to 19, with using CHC hierarchical model of intelligence, revealed that selected broad cognitive ability factors such as fluid reasoning and processing speed (i.e. of fluid intelligence) with crystallized intelligence demonstrated statistically significant direct effects on the mathematics achievement, with a large consistent effect (>0.9) of *g* factor (Taub et al., 2008; McGrew et al., 1997; Keith, 1999). These conditions were found by the structural equation modeling using to investigate the relative contribution of individual cognitive abilities on mathematics achievement beyond *g* factor. The fluid reasoning is the ability to reason, to form up concepts, to solve novel and abstract problem, without relying on previously acquired skills or knowledge by using unfamiliar information or novel procedures. The processing speed is the ability to perform automatic cognitive tasks in condition when measured under time pressure to maintain focused attention. The crystallized intelligence is the ability to use knowledge, skills and experience by using information from long-term memory. Narrow abilities such as auditory processing, visual processing and short-term memory didn't demonstrate significant effects on mathematics performance in research guided by CHC model (Friedman, 1995), what is caused by that most of these variance attributable abilities may be accounted into several selected cognitive abilities measured simultaneously in different test tasks presented in the model (Fuchs et al., 2006), while fluid and crystalized matters are both crucial for the mathematics achievement.

The most semantic definition of the music's matter is presented in "On Music Dictionary" (http://dictionary.onmusic.org/), where the music is described as rhythmic, melodic, or harmonic grouping of sounds that is specifically composed and that forms a unity so as to convey a message and to communicate. Therefore, it presents the link with language functions, which include semantic ordered structures. Attributes of musical tones include tone frequency, time duration, timbre and loudness (Patterson et al., 2010). Additionally the music is made up from motives that form up melodies as semantic units in musical performances and songs (Deutsch, 2013), where the melody is a rhythmically organized sequence or succession of single musical tones related to one another, and forming a distinct particular phrase or sequence of phrases (Harvard Dictionary of Music, 2003). Therefore the melody is a combination of pitch and of rhythm, where the tones are organized in the systems based on the scales and octave registers, are grouped by time in bars with even or non-even meter, with different speed of exploration i.e. quicker or slower tempo (Snyder, 2000).

The structural music processing skill is related to short-term and to working memory, where the musical memory refers to the ability to remember music-related information, with both rhythm perception and pitch perception as music primary cues, with the presence of significant correlation with general mental ability (Law, 2012). Therefore musical perception and musical memory, as cognitive functions, are connected with general cognitive intelligence matter. The issue of music aptitude, distinct from other cognitive abilities, has close relation to multiple intelligences (Gardner, 1999) and to concepts of modularity organization principles (Peretz, 2006; 2009; Peretz et al., 2003), where the brain has specialized modules for processing different kinds of information, where domain-specific information is processed automatically by the appropriate module and each module function is independent of other modules (Fodor, 1983). All information contained in the melody, as an initial stimulus, is simultaneously sent to all modules, which are specialized in the analysis of particular types of information and are becoming activated in response to specific elements of the auditory information. Modules of mental music processing do have specific brain representation and are characterized by a rapid and automatic caring out the operations, directed towards specializing in the processing of specific information types and in the cognitive closure. They have congenital nature, with empirical evidence from neuropsychological researches by Balaban et al. (1998), with the disclosure of cerebral hemispheric asymmetry in the melody processing, what is presented already in infants with the resistance to functional changing during the stimulation by aural cognitive working memory training on the basis of musical material, with only very weak changes from childhood to early adulthood and without significant differences for gender at the level of behavioral responses in the form of recognition and reproduction of music (Zatorre, 2001; Zatorre et al., 2001 b).

The basic music aptitude defined by Gordon (1967; 2007) as discrimination of tonal, rhythmic and harmonic patterns of music based on aural perception of music, thus closely to Gardner musical intelligence definition, is fundamental for music achievement (Gordon, 2006) based on inborn innate resources and presented in each healthy human brain (Gordon, 1997) with normally distribution in general population similar to cognitive intellectual aptitude (Cutietta, 1991; Gordon, 2013). Therefore, it might be described as psychological feature and has completed Gardner state of musical intelligence. Gordon (2009) described general musical abilities by the audiation process which is the same to music what the thought process is to language, i.e. comprehension and internal realization of music (Kratus, 1994), which includes to learn, to make and to understand music and can be developed from birth up to approximately 9th age where a child obtain stabilized music aptitude and the audiation maturity level.

RELATION BETWEEN MUSICAL APTITUDE AND COGNITIVE INTELLIGENCE

Old scientific evidences noted that general intelligence supports the development of musical abilities (Radocy et al., 1979; Shuter-Dyson et al., 1981) with the assumption that academic intelligence is an essential component of the musical ability (Schoen, 1940; Wing, 1941), while in new direction the musical ability constitutes a basic aspect of intelligence that is largely independent from other primary mental abilities as suggested by Gardner (1983) theory of multiple intelligences where musical intelligence is primarily based on the ability to understand the structural aspects of music such as melody (harmony), pitch, rhythm and timbre, where musical and certain intellectual abilities might use similar cognitive functions, so that transfer effects can be assumed (Barwick et al., 1989).

Associations between music aptitude and general intelligence or academic achievement are based on proposals of modularity for music (Peretz, 2006; 2009; Peretz et al., 2003) and on the notion that musical ability represents a distinct independent intelligence (Gardner, 1999). While some studies confirmed the notion of a moderate positive relationship between musical ability and general intelligence (Cooley, 1961; Geng et al., 1969; Manturzewska, 1978; Rainbow, 1965), others argued against such an association (Brandler et al., 2003; Freeman, 1974, 2000). As an evidence examples, basic pitch and temporal discrimination abilities are associated with intelligence in adulthood (Helmbold et al., 2006), with an exception concerning individuals with mental retardation and at the same time with normal or superior musical abilities, as their degree of cognitive disability increases the music aptitude decreases (Anastasi et al., 1960; Braswell et al., 1988; Hermelin et al., 1989; Hopyan et al., 2001; Viscott, 1970; Judd, 1988). Additionally musical savants with good musical abilities and atypical cognitive development (e.g. autism) do represent a notable exception to the rule that musical aptitude is tightly coupled with general intelligence (Treffert, 2009). Also children with Williams' syndrome are often regarded as an exception, with low IQ (*intelligence quotient*) score and good musical abilities' scores. Nevertheless, their musical aptitude is well below the norms although not as poor as their spatial abilities or overall IQ score (Don et al., 1999).

The vast majority of empirical studies compared test scores on both musical ability and psychometric general intelligence in unselected samples (predominantly school children), where performance on sensory discrimination is positively related to psychometric intelligence. Such a relation has been supported by recent studies on auditory discrimination (Bazana et al., 2002; Deary, 1994; Lynn et al., 1989; Raz et al., 1983; 1987). Shuter-Dyson et al. (1981) in meta-analyses of more than 50 studies published in 1924 - 1979 years reviewed that nearly all of the reported correlation coefficients were positive but low, typically around 0.30 (10% of explanation). Correlations between aptitude and general intelligence are often small (Drake, 1954), primarily because some high-IQ score individuals perform poorly on tests of musical aptitude (Sergeant et al., 1974). Indeed, about 4% of the population may have amusia, performing poorly on tests of aptitude but with normal IQ score and hearing abilities (Peretz, 2008; Stewart, 2008; 2009). Small level of relation might be the case of its slippery background, of different research evidences, such as students who register in music courses in school sometimes do have average grades or IQ scores similar to those of students who do not take music courses (Cox et al., 2006; Dege et al., 2011). Costa-Giomi (1999, 2004) researches of cognitive abilities measured by standardized tests and by scholastic achievement at the end of a three year intervention were similar between the piano and control groups. In Zulauf (1993) study when the music lessons took the place of mathematics or language classes beginning at the sixth-grade level, the effect on cognitive performance was negligible statistically even after three years of the intervention. Schellenberg (2004, 2006 b) researches got evidence of small causal relationship between music training and IQ general score, where duration of music lessons was significantly low correlated (<10%) with IQ general score of Wechsler Intelligence Scale for Children and school grades' average among children aged from 6^{th} to 11^{th} , even after individual differences in general intelligence were held constant, with much weaker significant correlation (≈4-5%) between playing music in childhood and intellectual functioning among undergraduates, with equal variance level for perceptual organization, working memory, processing speed and lower variance level for verbal comprehension.

There was no evidence in all age periods about significant relation of musical involvement with any specific selected aspects of cognitive abilities measured by subtests of Wechsler cognitive intelligence tests when general intelligence was held constant, and with no notable differences among the various IQ subtests scores one of which measured arithmetic abilities. In concluded Schellenberg state results indicated a small but general significant relation between music lessons and IQ general results with academic performance, that is long lasting and children with music lessons might have higher school grades' average.

To summarize the association between music aptitude and cognitive abilities extends beyond IQ testing to performance in school (Good et al., 1997; Gordon, 1969; Harrison et al., 1994; Rainbow, 1965), where the correlation between music aptitude and academic achievement can be substantially higher than the correlation between music aptitude and IQ general score (Hobbs, 1985), what explains that this relation might be less from adulthood age, on the case of childhood cognitive IQ score being predictive of both school grades and academic achievement (Gottfredson, 1997; 2002; Neisser et al., 1996) in the school age, especially according to Schellenberg (2006 b) state that music lessons taken in childhood appear to have a stronger association with IQ score when it is tested in childhood than in adulthood, where high-functioning children are more likely than other children to take music lessons and to perform well on most tests they take, where music lessons exaggerate these individual differences slightly. Thus associations between music aptitude and general cognitive abilities, including performance in school, are often strong and clear only in childhood.

RELATION BETWEEN MUSICAL ACTIVITY AND COGNITIVE INTELLIGENCE

The ability to engage with music in sophisticated ways is unique and universal human ability, where many musical-related skills are not explicitly trained, but are developed through repeated and focused engagement with music (Merriam, 1964). Several studies evidences were consistent with the notion of a positive relationship between musical and verbal abilities (Cooley, 1961; Hermelin et al., 1980; Munzer et al., 2002), between musical and mathematical abilities (Whellams, 1970), between musical and visual-spatial abilities such as perceptual speed tests assessing flexibility of closure (Barrett et al., 1973; Brochard et al., 2004; Geng et al., 1969; Hassler, 1992; Hassler et al.,1985; 1987; 1990; Manturzewska, 1978), with independent evidences of positive effects of musical training on specific cognitive abilities such as mathematical (Bahr et al., 2000; Cheek et al., 1999), visual-spatial (Bilhartz et al., 1999; Brochard et al., 2004; Gromko et al., 1998; Hetland, 2000 a), and verbal abilities (Hurwitz et al., 1975) with verbal memory (Chan et al., 1998; Ho et al., 2003; Jakobson et al., 2003). Thus non-musical associations with music lessons are strictly cognitive.

In cognitive intelligence research of Helmbold et al. (2005) and of Brandler et al. (2003) patterns of inter-correlations among primary mental abilities of musicians and nonmusicians were predominantly comparable, and principal component analysis revealed a similar factor structure of intelligence's dimensional structure for both musicians and nonmusicians, where portions of explained variance of extracted factors as well as their patterns of factor loadings showed obvious similarities, which argue against substantial differences in the conception of intelligence between musicians and nonmusicians. Thus musicians and nonmusicians do not differ significantly in overall intelligence, and differences in mental abilities between musicians and nonmusicians may be less pronounced than rather often assumed.

A major problem with most studies that examine the relationship between musical ability and cognitive abilities is the fact that musical ability can hardly be investigated independently from musical training, such as during listening to music processing. It seems to be an independent case of why the association between training and cognitive abilities breaks down often in comparison of real musicians with nonmusicians who also do listen to music. The link between music and cognitive intelligence stems from two separate lines of research - on passive listening to music and on formal music lessons (Schellenberg, 2003; 2005; 2006 a). According to Rauscher et al. (1993) research not only musical training, but also simple listening to music should have beneficial effects on intelligence. As a passive listening example, listening by adults to a recording by Mozart or Schubert can lead to improved performance on subtests (e.g. spatial) from standardized IQ tests (Nantais et al., 1999; Schellenberg et al., 2007; Thompson et al., 2001), while for 10th and 11th children listening to pop music (Blur - "Country House"; Mark Morrison - "Return of the Mack"; PJ and Duncan - "Stepping Stone"; - an updated recording of the Monkees' song from 1967) improves cognitive performance for the paper-folding task (Schellenberg et al., 2005), which might be depended on subjects' musical preferences. Music that is pleasant and enjoyed by a particular listener is the most likely to have positive impacts on the listeners' emotional states which can improve cognitive performance (Schellenberg, 2005; 2006 a), thus most positive benefits of music listening on cognitive abilities are most likely to be evident when the music is enjoyed by the listener.

Music listening expertise does not need to be taught and individual differences in musical listening patterns can affect also non-musical abilities (Chin et al., 2010). Listening to music is an active process, that engaging the listener in a process of parsing, segmenting and encoding a complex stream of auditory events, of extracting structure at multiple hierarchical levels requiring concerted neural activity across auditory association areas in the temporal lobes, across auditory working memory areas in the frontal lobes and across emotional centers in the limbic system (Peretz et al., 2005; Stewart et al., 2006), where certain aspects of musical listening can result in top-down interactions from cortical to subcortical areas in order to better encode the most relevant features of the incoming stimulus (Kraus et al., 2010). Music training is associated also with enhanced performance on a wide variety of listening tasks, musical or otherwise, with tendency to be a predictor of good performance across a wide variety of cognitive tests in childhood, including tests of memory, language, and visuospatial abilities (Deutsch, 2013), is associated also positively with general intelligence and school performance at school age period, with comparisons of adult musicians and nonmusicians often yield null findings, i.e. without significant differences.

The original listening to music effect (i.e. Mozart effect) implies that listening to Mozat music leads to higher intelligence and to an increase in spatial reasoning scores after listening to the first section of a Mozart piano sonata for two pianos in D major, K. 448 (Rauscher et al., 1993; 1995). Rauscher interpreted empirical results to conclusion that hearing the music caused the improvement through direct neural priming of spatial reasoning areas in the brain. This interpretation was used as the basis for their strong advocacy of exposure to music in schools to improve mathematics scores (Rauscher, 1997; 1999; Shaw, 2000).

At the same condition much more laboratories have been unable to produce and verify a Mozart effect with its difficulty to replicate (Bridgett et al., 2000; Carstens et al., 1995; Kenealy et al., 1994; McCutcheon, 2000; McKelvie et al., 2002; Newman et al., 1995; Ong et al., 2000; Steele, 2003; Steele et al., 1999 a; 1999 b; Stephenson, 2002; Stough et al., 1994; Weeks, 1995), with explanation that Mozart effect can be attributed to differences in arousal and mood generated by different testing conditions, that such enhancement is a consequence of the listener's arousal and mood level as of individual preference differences instead of musical priming of spatial reasoning areas of the brain (Chabris, 1999; Husain et al., 2002; Nantais et al., 1999; Steele, 2000; Steele et al., 1997; Thompson et al., 2001; Schellenberg et al., 2007). The basic idea was an assumption that any stimulus that improves how people feels can in turn improve how they do perform on a cognitive task. People do choose to listen to music because of the way it makes them feel (Juslin et al., 2008; Lonsdale et al., 2011; Sloboda, 1992). Thus it is clear that music listening can change one's emotional state, with empirical evidences that feelings influence on cognitive performance (Cassady et al., 2004; Isen et al., 2003, O'Hanlon, 1981), where positive affect is associated with the increase in dopamine levels, which may improve cognitive flexibility (Ashby et al., 1999), while negative affect such as boredom impairs cognitive performance (Cassady et al., 2004; O'Hanlon, 1981), so for function of preference and condition the performance was better in the preferred than in the non-preferred conditions. Only few published studies have examined the mathematical performance after listening to music. Bridgett et al. (2000) studies revealed that improvement from pre-test to post-test on a measure of mathematical ability was similar whether participants listened to Mozart, Bach or ocean sounds in the interim, while Jausovec et al. (2003) research noted that performance on a mathematical task was not significantly different after listening to Mozart than after sitting in silence. These opposite empirical evidences might be the case of musical structure difference which produces cognitive improvement during listening in simultaneous cognitive tasks processing. Despite the big amount of negative attempts to replicate Mozart effect, three separate scientific meta-analyses in music psychology found empirical evidences of the effect with total volume over six thousands participants, (Chabris, 1999; Hetland, 2000 b; Pietschnig et al., 2010). The first meta-analysis of the Mozart effect examined 16 published studies with more than 714 participants in total (Chabris, 1999). The second meta-analysis of the Mozart effect examined 36 independent experiments of visuospatial abilities with more than 2400 participants in total (Hetland, 2000 b). The most recent meta-analysis examined 39 studies (3000 participants in total) that contrasted listening to the original Mozart piece (K. 448) with listening to a nonmusical stimulus or sitting in silence (Pietschnig et al., 2010), where an overall Mozart effect was evident, although the authors revealed the low mean effect size (d=0.37), in the small range ($0.2<x<0.5$) of Cohen (1988) magnitude, which was similar in Hetland's (2000 b) meta-analysis when another piece of music (composed by Mozart or others) was contrasted with silence or a nonmusical stimulus. Thus the most recent and comprehensive meta-analysis confirms that there exists the Mozart effect, although that effect is also evident for other pieces of music, what might be the most specified reason for different music pieces which cause the same cognitive effect. Hallam et al. (2009) noted that a complete model of effects of background music on cognitive abilities needs to consider many variables and interactions among variables, which makes it difficult to test in methodological research design, as independent case of negativity for the effect replication.

Most clear psychophysiological research of Bragdon and Gamon (2003) revealed that music of the late Baroque period increases dopamine release in the brain, improves memory efficiency, promotes better hemispheric synchronization and increases alpha waves in the EEG of the brain. Listening to music in the mature baroque style during the studying improves memory, learning and memorizing of new foreign words and verses. The study of Mammarella et al. (2013) have shown that listening to "The Four Seasons" by Vivaldi had a positive impact on the performance of cognitive tasks by elderly people: memorization in working memory was better after listening to this music than in the conditions of silence or of white noise. The positive influence of music by Vivaldi was also noted in solving problems of autobiographical memory in elderly patients with Alzheimer's disease (Irish et al., 2006; Thompson et al., 2005). Additionally alpha mental statement was found as optimal for effective learning process at an elevated mental attention focus and it dominates in the music of Mozart and of mature Baroque period (Segen, 2011). This condition is a natural auto-synchronization of both hemispheres. It has several levels of mental activity such as memory (accelerated learning and remembering the new material), work with inspiration and positive thinking. Research of Jausovec et al. (2006) confirmed that during listening to Mozart's music before and after realization of cognitive tasks there increases mental activity including the learning process and according to the testimony of the EEG there is activated synchronization alpha and gamma brain waves.

To summarize the Mozart effect, with independent evidences on other musical pieces, is the consequence of music's ability to possibly improve the brain waves synchronization, and the arousal level with mood of the listener which when elevated might improve many aspects of cognitive processing, where temporary changes in arousal or mood caused by music listening can have a range of cognitive benefits and any music favored by the listener can also temporarily improve arousal or mood and elevate cognitive performance, what is the case for many contradictory data.

CONNECTION BETWEEN MUSIC AND MATHEMATICS STRUCTURE AND PROCESSING

Mathematical matter of music was born on the principle of the regular equal-tempered music sound with piano as musical string instrument invented by Bartolomeo Cristofori, in the baroque area, with the range of 7 and ⅓ octaves and of 88 semitone keys for the pitch order, and on the principle of the timing music with metronome invented by Johann Maelzel, firstly used by Beethoven, for mathematically – calculated tempo designations, where any device produces regular, metrical beats, settable in beats per minute, which represent fixed regular aural pulse, i.e. for the rhythm order (Dymnikowa, 2015 b).

Musical pitch is perceptual auditory property of musical sounds, as musical tones, that allow their ordering into frequency-related scales (Klapuri, 2006). Pitch defines the location of a tone frequency in relation to others frequencies, thus giving it a sense of being high or low in musical melodies' perception where a listener assigns them to relative positions on a musical scale (Plack et al., 2005). Musical pitch has harmonic frequency vibrations, which occur simultaneously at once (Olson, 1967). The vibration with the lowest frequency determines the fundamental frequency and musical pitch note, the rest of frequencies are harmonic overtones, greater and integer multiples of the fundamental frequency, kind of acoustic pre-sounds belonging to the spectrum of musical sound in which the height of the overtones is above the basic lowest tone pitch (Benade, 1990).

Each musical sound consists of a fundamental tone and its 15 harmonic overtones that produce a natural scale in which there is possible to calculate mathematically the frequency for each selective musical tone and the frequencies of sequential tones of natural scale that make up an arithmetic progression. The natural scale is formed by all 16 sounds whose frequencies are multiplies of the basic fundamental frequency of the primary lowest pitch tone. The presence of harmonic overtones is due to physical acoustic vibrations of a source of musical sound. Ten primary overtones are merging with one another in acoustically pure unity. Five others are heard bad or not listening at all (Roederer, 2008). At regular equal-tempered musical tuning each octave is sub-divided into mathematically equal intervals - twelve semitones. Tonality is derived from the modal system, where the tonic occupies a central place (the first major of 7 sounds of the scale, selected from 12 semitones of the chromatic octaves). The six others sounds of the scale are indirectly related to the tonic, submitted to it, and the rest of 5 from 12 semitones are not included in the range of scale and are the disturbed sounds for each particular tonality key, making dissonant, annoying hearing (Hyer, 2002). The affinity of tonalities is determined by the number of common sounds - the more amounts of them the more closely are they to each other. The degree of affinity of tonalities causes the possibility and nature of the modulation, i.e. the transition from one tonality to another tonality and to another mode – major (the joyful sound) or minor (sad sound). Structure of the musical string sound includes the mathematical proportion with twice frequency for each next same octave register's tone, where the piano lowest frequency range is specified by C of subcontract-octave with the frequency of 16.352 Hz and the piano highest frequency range is specified by B of five-lined octave with the frequency of 7902.1 Hz. As for example: I) C tones exist at frequencies: sub-contra-octave at 32.7 HZ; contra-octave at 65.41 HZ; great-octave at 130.81 HZ; small-octave 261.63 HZ; one-lined-octave 523.23 HZ two-lined octave 1046.50 Hz; three-lined octave 2093 Hz; II) A tones exist at frequencies: sub-contra-octave at 27.5 HZ; contra-octave at 55 HZ; great-octave at 110 HZ; small-octave 220 HZ; one-lined-octave 440 HZ; two-lined octave 880 HZ; three-lined octave 1760 Hz. Inside an octave twelve semitones have frequencies on fluid mathematical proportion for added differential indexes, with growing tendency to each next semitone, between adjacent semitones in the octave register, what comes as the reason of consonances and dissonances sounds structure in music perception, as the result of pitches sounding simultaneously, which do produce intervals (with two pitches) and chords (with ≥ three pitches), what is the main matter of the music harmony (Parncutt,1989) where sounds with definite pitches form up harmonic frequency (Olson,1967).

Musical rhythm is the controlled movement of music in time with the subdivision of a musical time space into a properly defined repeated pattern with grouped beats, i.e. regular pulsation of music, where the bar is the smallest metrical division of a music containing a fixed number of beats and accented beat usually comes in the first part count of the bar. The tempo is the rhythm speed of a music that is measured timely according to beats per minute, with speed range between <40 and >200 beats. The rhythmic measure is the foundation of human instinctive musical participation (Scholes, 1977), as when human divide a series of identical repeated clock-ticks into regular time duration going ("tick–tock") in the case of biological background of the rhythm perception (London, 2004).

The meter is organizing the beats into repetitive groups for rhythmic units, i.e. the music rhythmic structure, with dynamic of the strong and weak beat in regularly recurring measures at the tempo frequency, where each single metric unit is the single musical bar. The tempo of the music, i.e. music's pulse, is the speed or frequency of the bars, a measure of how quickly the beat flows, where the duration of any rhythmic unit is inversely related to its tempo, and the most frequently meters can be divided into a pattern of duples and triples, i.e. two or three beats to each musical bar (Hasty, 1997). When a listener establishing the metrical hierarchy then will maintaining that organization as long as minimal evidence would be presented, in temporality aspects (Yeston, 1976), where faster beats, i.e. metric levels faster than the beat level, are perceived in divided levels, while slower beats i.e. metric levels slower than the beat level are perceived in multiple levels (Cooper, 1973). The ¼ note is a commonly used unit for measurement of beats per minute (bpm) for music's tempo measure. Time scale of musical tempo includes mathematical duration periods which complete each other in ordered time-level of music's perception. For example there exist: 1) - five slow tempos: Larghissimo $\leq$ 25 bpm; Grave 25-40 bpm; Largo 40-60 bpm; Larghetto 60-66 bpm; Adagio 66-76 bpm; 2) - two middle tempos: Andante 76-108 bpm; Moderato 108-120 bpm; 3) - three quick tempos: Allegro 120–168 bpm; Presto 168–200 bpm; Prestissimo $\geq$ 200 bpm. All the rest of possible musical tempos are included in these time-periods (Epstein, 1995; Sadie et al., 2001). Thus in music the rhythm is built on the beats as the basic units of music time, where the pulse is created regularly repeating event of the mensural beat level, with strong (stressed) and weak (unstressed) beats, divided into bars organized by time speed by tempo indication (Berry, 1987).

Van Nes et al. (2007) noted that one could define a melodic pattern as a numerical or spatial regularity and the relationship between the elements of a pattern as its structure. If sound is considered in terms of space and of pattern then a musical piece is a spatial structure made up of patterns of sounds with standard notation in case of spatial structure with patterns of curves, dots and lines. The internal relation of different components of spatial sense may contribute to the development of children's number sense, such as the discernment of quantities and relationships between numbers. Mathematical abilities such as ordering, comparing, generalizing and classifying are supported by an ability to grasp spatial structure (Waters, 2004), where more complex operations such as addition, subtraction, multiplication and use of algebraic variables also benefit from a solid foundation in spatial reasoning (Van Nes et al., 2007). Every sound in music is spatial in some form, whether it is rhythmic, melodic, harmonic or tonal, thus it can be attached to a number. All musical components are located in a specific, measurable relationship to the others within its own category and between categories. An understanding of these spatial-temporal and numerical elements within a piece may at least contribute to an implicit understanding of the structure of a musical composition and of the patterns within this structure, where the spatial numerical connections within music may help to explain the structural connection between musical and mathematical understandings. Children with serious mathematical difficulties demonstrate tendency to use minimal levels of structuring (Mulligan et al., 2005). Thus once children can imagine a spatial or temporal structure, whether visually or aurally, of a certain number of objects or of sounds that have to be maneuvered, the emerging number sense, which includes knowledge of quantities and counting, should be then clarified and strengthened largely and smoothly, since spatial reasoning is the most important for mathematical development.

Music and mathematics have processing similarities in simultaneous activation of both hemispheres, on the background of temporary restriction of information functional processing by different hemispheres (Banich et al., 1994; Hellige, 1993 a) at its simultaneous hemispheric functional involvement, where hemispheric specialization is not conceptualized as a static difference in the processing capacity of two independent and isolated hemispheres but consists of their dynamic interactive partnership (Banich, 1995; Hellige, 1993 b; 2000; Liederman, 1998; Zaidel, 1995). Independent Gouzouasis et al. (2007) research examined cognitive performance on standardized tests of academic achievement among 150 thousands of 12^{th} - grade students that provided separate scores for mathematics and english, with the evidence that those who took music classes in 11th grade had higher scores in mathematics but not in english, what might demonstrate independently the similarity of hemispheric music and mathematics processing, where connection with low correlation between music training and general cognitive ability might be observed in school grades and extend beyond intelligence testing.

Simultaneous activation of two hemispheres responsible for the perception of separate components of music structure is influenced by the functional asymmetry of music perception due to the difference in hemispheric time resources for the rate of processing the auditory attributes of music and of musical information, that occurs bilaterally in the brain with dynamic cooperation between several cortical areas of both hemispheres (Beisteiner et al., 1994; Petsche et al., 1993; Schuppert et al., 2003; Altenmuller, 2003; Baeck, 2002) and is marked by higher cortical connectivity (Bhattacharya et al., 2001; Johnson et al., 1996), with neuropsychological evidence for that both pitch and rhythm are processed separately while identification of a melody involves recognition of both pitch relations and time organization. Clinical studies of patients with brain damage also suggest that the brain regions involved in music perception are different for each of major components of musical experience, whereas some brain damaged patients exhibit normal pitch perception but impaired rhythm perception while other patients show the opposite pattern (Thompson et al., 2002). Independence of evolutionary nature of functional asymmetry of music perception and of musical memory has been verified empirically additionally on people with cerebral brain injuries, where changes in the brain lead to the inability of analyzing pitch of musical sound while maintaining its time processing (Piccirilli et al., 2000) as well as to the inability of analyzing the duration of musical sound while maintaining its pitch processing (Di Pietro et al., 2004).

The strength of communication between left and right hemispheres of the brain predicts performance on basic arithmetic problems. In representation and processing of numbers the parietal cortex is central for numerical cognition, where the right parietal region is primarily involved in basic quantity processing and the left parietal region is involved in precise number processing and numerical operations (Dehaene et al., 1999; Ansari et al., 2006; Castelli et al., 2006; Prado et al., 2011). Independent neuropsychological studies demonstrated selective deficits in number processing in patients with parietal lesions (Warrington et al., 1967; Dehaene et al., 1991; Polk et al., 2001; Lemer et al., 2003).

Thus number processing activate bilateral parietal cortex, however studies also revealed the distinction between left and right parietal regions, where the right parietal cortex is basic for number sense and for innate quantitative competencies in infants and children (Cantlon et al., 2006; Izard et al., 2008; Hyde et al., 2010) and is innately organized as neural locus of basic quantitative competencies, which exist before the acquisition of the precise number system available to educated adults. The left parietal cortex is activated in addition to right parietal cortex in precise number processing such as in arithmetic tasks or in symbolic comparison, with representations of symbols, of learned arithmetic facts and of exact calculation operations (Dehaene et al., 1996; Chochon et al., 1999; Pinel et al., 2001), as behavioral functional performance in mathematics during mathematics problem solving (Rivera et al., 2005; Grabner et al., 2007; Delazer et al., 2003; Ischebeck et al., 2006). Thus in the numerical cognition process functional connectivity is enhanced between right parietal cortex involved in basic primitive simple numerical information representation and left parietal cortex involved in the complex precise arithmetic processing where individual differences in connectivity might predict the task performance's individual difference. Park et al. (2013) studied the interaction of left and right parietal regions in hemispheric mathematics processing in healthy adults during numerical cognition, based on the estimation of neural activity with using functional magnetic resonance imaging in participants performing numerical and arithmetic processing on dot arrays. They revealed the functional connectivity between the right parietal seed region and the left sensorimotor cortex based on task-resolving, also between the right parietal seed region and both the left parietal and right parietal cortex during subtraction process, which is critical for numerical processing that engages both basic number representation and learned numerical operations, where the degree of functional connectivity also correlated with behavioral performance across individual participants. They got evidence about the role of parietal functional connectivity in numerical processing, with data about individual participants who were faster in performing the subtraction task and also tended to have stronger functional connectivity between bilateral parietal regions, with the conclusion that arithmetic processing depends on crosstalk between and within the parietal cortex effective neural communication, where the crosstalk contributes to one's numerical competence, where inefficient or disrupted neural communication between the hemispheres may contribute to the impaired mathematics abilities such as dyscalculia (i.e. dyslexia's numerical equivalent).

Singh et al. (2004) neuropsychological study on interhemispheric interaction on males revealed that mathematically gifted adolescents showed no hemispheric differences, i.e. bilateral state, with the conclusion that enhanced interhemispheric interaction and superior coordination of cortical resources between the hemispheres is a unique functional processing characteristic of the mathematically gifted brain, with the evidence that the mathematically gifted brain may be functionally organized in a qualitatively different manner compared with those of mathematics ability average (O'Boyle, 2000). Another O'Boyle et al. (2002) research used functional magnetic resonance imaging to monitor brain activation in a group of mathematically gifted male adolescents, who were significantly more bilaterally and active overall than mathematically average ability adolescents, which finding suggestive of heightened processing capacity, who were able to cooperatively exchange information between the hemispheres, i.e. interhemispheric communication during global - local judgments, with the right hemisphere superior for global processing and with the left hemisphere superior for local processing (Robertson et al., 1993; Van Kleek, 1989), who in the bilateral cooperative condition were considerably faster compared with unilateral trials for both global and local processing.

Authors concluded that the brain of the mathematically gifted participants is inter-hemispherically integrated, relying on processing resources from both hemispheres irrespective of the nature of the stimuli to be analyzed or the hemisphere specialized for the task, that their interhemispheric interaction is more efficient perhaps relating to a difference in the size and in the shape of their corpus callosum in case of the number of interhemispheric connections between cortical areas is proportional to the corpus callosum size (Aboitz et al., 1992; Clarke et al., 1994) and overall corpus callosum volume exerts an influence on the speed and type of information transfer occurring among cortical areas (Hoptman et al., 1994). Mathematically gifted adults also seem to have more efficient interhemispheric communication, since no hemispheric specialization for global-local processing (i.e. no reliable left-right differences) was found in these olds when processing global or local information on unilateral trials, where similar result was obtained from high-ability young mathematically gifted adolescents and adults, thus they have a comparable functional brain organization and such enhanced interhemispheric collaboration increases the efficiency of brain functioning when the hemispheres are forced to cooperate during information processing.

Revesz (1954) asserted that music is a mathematical discipline since it has underlying mathematical properties based on a subject of mathematical analysis where at the same time the ability to create music may not require particularly high levels of mathematical thinking (Kahneman et al., 1972), as the evidence of possible distinct features. Additionally in fresh empirical data there is the absence of convincing evidence for a "special" link between music aptitude and mathematics, which requires that the association remains evident when general intelligence is held constant. As independent evidence from Haimson et al. (2011) study mathematicians with doctoral degrees are not any more musical than similarly qualified scholars from the humanities. Although adaptations in brain regions that are involved in musical tasks may have an effect on mathematical performance because of shared neural resources involved in the mental manipulation of symbolic representation, the relationship of musical training with improvements in mathematical and spatial skills remains still unclear (Forgeard et al., 2008; Hetland, 2000 a) or is quite small from Vaughn (2000) meta-analysis of correlational studies. Additional Haimson et al. (2011) study also didn't note the evidence for that music memory and music perception are on average stronger among mathematicians than among literature and language scholars, with conclusion that music training and music ability does not work synergistically with the quantitative skills and achievements of mathematicians to increase musical abilities.

To summarize the assumption that music lessons cause the increase in mathematics ability, with the relation between music training and mathematical abilities, seems to be more elusive and far from conclusive evidences what might be independent case of distinct music and mathematic intelligence in Gardner backgrounds classification of multiple intelligences. Probably when small associations between music training and mathematical ability are evident in correlational and quasi-experimental studies, they could be the consequence of individual differences in general intellectual ability, with taking into account Schellenberg state about high-functioning children being more likely than other children to take music lessons and to perform well on tests of mathematics, whereas the evidence of a special link between natural musical and mathematical abilities has no empirical support.

CONNECTION BETWEEN MUSIC AND LANGUAGE

General cognitive principles are involved both in language and music when aspects of syntactic processing in language are compared with aspects of harmonic processing in music, with analysis of the temporal structure led to similar effects in language and music (Besson et al., 2001). Children acquire musical and linguistic rules in a similar effortless way they are able to create new musical and verbal sentences by applying a rule system that they have been able to abstract without conscious intentions. Perception of both speech and music is mediated by the same neural mechanisms (Strait et al., 2011), phonemic perception is correlated with the pitch perception (Tsang et al., 2011), and music ability is associated with mastering the phonological aspects of a second language (Slevc et al., 2006).

In structural differences some perceptual properties of basic elements in music have no equivalent in language, as, for instance, the fact that octaves are perceived as equivalent in almost all cultures, which effect is linked with the finding that two notes separated by an octave are related by a simple frequency ratio 2:1, thus basically relationships between different pitches in a musical piece are much simpler than the relationships between different phonemes in a linguistic sentence, where all languages are organized according to a syntactic structure that may be universal with obvious verbs and nouns presence indeed (Chomsky, 1988). Music perception shares universal laws of auditory perception where perception of a musical phrase is automatically influenced by factors such as the grouping of discrete notes into sequences (i.e. melodic contour) and the feeling of closure that accompanies the playing of a cadence at the end of a phrase. Some of these factors are universally shared, just as verbal language, but musical grammar seems more flexible and ambiguous than the syntactic rules used in language (Aiello, 1994). Musical elements are most often played simultaneously to perceive and enjoy a musical piece and each element may have its own syntax. This vertical dimension of musical structure, commonly referred to harmony, is not presented in language, where different words produced at the same time by different speakers will only create an unpleasant cacophony, and the meaning of words is understood in relation to an extra-linguistic designated space (Kivy, 1991).While musical notes or chords have no extra-musical space in which they would acquire meaning and the internal sense of music may be conceived as something that goes beyond any objective reference structure and the possibilities of verbal language in case that music means itself (Meyer, 1956). At the processing level of constructive elements the music is differentiated by temporal, melodic and harmonic aspects, where each aspect involves different types of processing. Language differentiates into four processing levels: the phonetic-phonological level comprises both segmental (phonemes) and supra-segmental (prosody) levels, the morpho-syntactic level encompasses the combination of phonemes into morphemes and of morphemes into words, the syntactic level governs the relations between words, and the lexicosemantic level gives access to the meaning of words and of sentences, the pragmatic level with discourse organization and contextual influences represents an essential aspect of language. Thus semantic computations required to access the meaning of words and their integration within a linguistic context seem to be language specification.

In comparison of music with language distinct scientific neuroimaging evidence suggests that a degree of neuro resource sharing occurs during both working and short-term memory verbal and musical tasks (Brown et al., 2004; 2006; 2007; Gaab et al., 2005; Hickok et al., 2003), thus music and speech do share common processes (Besson et al.,2007; Patel,2003).

Koelsch (2005) with neuroscientists conducted firstly the fMRI studies to directly compare the neural architecture active during both verbal and musical short-term and working memory tasks, where the brain networks demonstrated common activated areas in neuroimaging researches and the patterns of activation were remarkably similar (Koelsch et al., 2002; 2005; 2009; Ozdemir et al., 2006; Patel et al., 1998; Schon et al., 2004). Also the areas responsible for music and language do share common brain pathways for musicians and non-musicians (Spray, 2014) where the short-term memory for musical tones had several similarities to the verbal memory in both groups, including limited capacity (Williamson et al., 2010). At the functional level music and language demonstrates independency, where the major evidences in neuropsychological studies has emphasized separate processing domains for speech and for music (Peretz et al., 2005). The most clear double neurocognitive dissociation evidence exists between amusia with a music perception deficit in the absence of difficulties with language, and aphasia with language processing difficulty in the absence of amusia (Ayotte et al., 2002; Luria et al., 1965; Marin et al., 1999; Stewart et al., 2006).

Berz (1995) proposed a working-memory model to explain the music processing, with link between the phonological loop and a new "musical loop", in the state of existence of separate stores for verbal and musical pitch sequences (Deutsch, 1970; Pechmann et al., 1992), as shared storage in working memory with a degree of an overlap in the processing of musical and verbal sounds (Salame et al., 1986; 1989; Semal et al., 1996), with research evidences about the link between music skills and phonological awareness (Anvari et al., 2002), about similarities between language and music processing (Patel, 2008; Williamson, 2008), with data about musicians and non-musicians showing a phonological similarity effect, where the storage of verbal items in memory is not influenced by the music expertise, and similarities across verbal and musical performance tasks would provide an argument for similarity in memory processes, where music activity does not make influence and changes on the aural working memory span for musical and verbal material (Williamson et al., 2010), while many of the brain areas are large enough to encompass two distinct processing systems (Marcus et al., 2003). The Gordon (2007, 2013) principle of normal distribution of musical aural attribute and Gardner (1983; 1985) state about musical intelligence are independent clear matter that musical activity might lose the diagnostic clarity as difference category since humans without musical activity still do have high level of sensitivity and of discrimination for music perception. Musicians have auditory memory span relative to nonmusicians for a range of both musical and nonmusical sounds (Hannon et al., 2007; Kraus et al., 2010; Patel et al., 2007), without significant gender differences in processing of music and in results scores of auditory working musical memory (Zatorre et al., 2001 a), also their visual memory performance doesn't differ (Cohen et al., 2011), while musical training improves spatial abilities in both groups (Schellenberg, 2005).

Evidence for independency and overlap between language and music functions might be explained and characterized by the hemispheric organization of its processes. The domain-specific lateralization differentiates speech and music: where speech sounds activate predominantly left-hemispheric neural networks, while musical sounds activate predominantly right-hemispheric neural networks (Alho et al., 1996; Tervaniemi et al., 2003; Zatorre et al., 2002), where verbal stimulation activate more wide-spread areas in the left hemisphere while the non-verbal stimulation activate more wide-spread areas in the right hemisphere (Mazziotta et al., 1982; Jaramillo et al., 2001; Mathiak et al., 2002; Naatanen, 1992; Tervaniemi et al. 1999).

The parameter-specific lateralization model differentiates temporal and pitch aural attributes of the music, in the frame of the functional asymmetry of the music perception principle, where music processing occurs bilaterally in the brain, with predominantly left hemispheric musical functions for temporal and rhythmic processing and predominantly right hemispheric musical functions for pitch, melodic and harmonic spectral processing (Belin et al., 2001; Dalla Bella et al., 1999; Hall et al., 2002, Hyde et al., 2008; Overy et al., 2005; Samson et al., 2001; Zatore, 2001; Zatore et al., 2001). So the left hemisphere is predominantly involved in both language functions and musical temporal rhythmic functions. The music processing typically engages the functioning of both cerebral hemispheres in both musicians and non-musicians, thus it occurs bilaterally in the brain and determines the metaplasticity state, which occurs when the activity of the brain regulates the expression of future plasticity at the level of both individual neuronal connections and connections between brain regions (Abraham, 2008).

Working auditory musical memory training leads to plasticity within auditory cortex regarding the task that is trained, with modulation of unimodal cortical processing and enhance neuronal co-activation of involved auditory cortical structures (Lahav et al., 2007; Pantev et al., 1998), with auditory perceptual skills improvement where it is possible to induce the plastic changes through a specific and relatively short-term training (Zarate et al., 2010), with independent evidences for the possibility of beneficial effects from musical training on the nonmusical abilities as a result of transfer effects or due to the neural plasticity (Bastian, 2002; Bilhartz et al., 1999; Gardiner et al., 1996; Ho et al., 2003; Jakobson et al., 2003; Laczo, 1985; Mohanty et al., 1992; Schellenberg, 2004). Short-term and working auditory memory training with music can alter the brain’s representation of speech and of other sounds by the development of certain auditory and cognitive abilities: auditory and spatial working memory, selective and sustained attention (Kraus et al., 2013; Trainor et al., 2003), spatiotemporal abilities (Hetland, 2000 a), mathematics (Costa-Giomi, 2004), reading (Bultzlaff, 2000), verbal memory (Ho et al., 2003; Kraus et al., 2010) and general intelligence (Schellenberg, 2004). Moreno et al. (2011) got evidence about improved language vocabulary knowledge in children after only 20 days of computerized musical training with the state that transfer effects on cognitive skills can occur over a very short period of time during training stimulation since musical training includes the hemispheric synchronization in music perception and requires individuals to learn to pay attention to several features of sounds, such as pitch, timing and timbre. Training efficiency is not lasting without its continuous stimulation, what is conditioned by the principle of music physiology influence which occurs only during the presence of music stimulation and for very short period after ending of its process.

To summarize music and language can be the expressions of the competence for human communication with different roles, both require substantial memory capacity for storing representations in order to account for the perception and comprehension of novel stimuli, both require the ability to integrate stored representations combinatorically in the working memory by means of a system of rules or of structural schemes (Jackendoff et al., 2006). Music has order rules that are similar to those of syntax in language (Koelsch, 2005; Lerdahl, 2001; Lerdahl et al., 1983), with similar mechanisms involved in the acquisition of musical and linguistic knowledge (McMullen et al., 2004).

Music and language both generate string continuity expectancies, as a specific word is expected within a specific linguistic context, so specific notes or chords are expected at a given moment within a musical phrase, where occurrence of the emitted potential of temporal structure within language and music also elicit similar effects and shows that both words, notes or chords are expected at specific moments in time (Patel, 2003). Thus when humans listen to language or listen to music they do expect words or chords with a specific meaning function to be presented on time. Most fundamental difference between language and music concerns their functions in human life, where language conveys propositional thought while music enhances affect with emotion. Music and language differ clearly also in the way they are thought to convey meaning, where words are linked to concepts in semantic memory, whereas music is typically considered to be a language of emotions (Janata, 2004), however unfamiliar musical passages have been shown to be prime concepts in semantic memory just as words do (Koelsch et al., 2004). In functional aspects both language and music rely on intentionality, require a theory of mind, involve memory, have temporal structure and rhythmic organization as fundamental roles, with the segmentation of the sound continuum into discrete units as pitches and phonemes (Arom, 2000).

RELATION BETWEEN WORKING MEMORY AND MATHEMATICS ABILITY

Working memory refers to a system for both temporary storage and manipulation of information required to carry out for a wide range of complex cognitive tasks such as learning, reasoning, comprehension, also do required to guide decision-making and behavior. Working memory is involved in selection, initiation, and termination of information-processing functions such as encoding, storing, and retrieving data (Baddeley et al., 1974). It's a core of executive functions with the control of attention, a cognitive memory buffer with a limited capacity that is responsible for the transient holding, processing, and manipulation of information, with parietal cortex and prefrontal cortex areas involved, with the dopamine as a central neurotransmitter (Malenka et al., 2009; Klingberg, 1998; Olesen et al., 2004). The difference to short-term memory is due to working memory is a short-term memory buffer that allows the manipulation of stored information, while short-term memory is only involved in short-term storage of information and does not entail the manipulation or organization of material held in memory (Cowan, 2008). Working aural musical memory is the secondary feature formed on the basis of music perception (i.e. musical audiation) with hemispheric specialization in music processing where music perception requires common simultaneous activation of both hemispheres. Music activity such as working aural musical memory training or musical education does not influence and change working aural musical memory span, thus this cognitive feature has biological limitations evidence without the possibility of increasing during the professional training or activity.

Working memory process with its capacity describes fluid intelligence individual differences, thus has close relation to fluid intelligence (Kyllonen et al., 1990; Friedman et al., 2006), which causes the learning efficiency process observed in grades of school subjects and provides background for ergonomic learning process as cognitive investment (Ackerman, 1996). The relationship between working memory capacity and standard measures of fluid intelligence by tests with the complex memory span tasks is mediated exclusively by the number of representations that can be simultaneously maintained in the working memory (Colom et al.,2005; Cowan et al.,2005 Daneman et al.,1980; Engle et al.1999; Turner et al.1989).

Specifically relation is disclosed when the task design prevents rehearsal and grouping processes that may skew a pure measure of storage capacity (Cowan, 2001; Cowan et al., 2004; Unsworth et al., 2007). Thus working memory pure storage capacity alone, in the absence of secondary processing loads, is linked to the broader construct of fluid intelligence (Fukuda et al., 2010). Spearman (2005) found the difference between educative and reproductive mental ability in behavior statement, where each intelligence factor type was defined as independent without affection of the other (Cattell, 1987), while other cognitive scientists have noted an apparent interdependence of the two (Cavanaugh et al., 2010), however mathematics ability is conditioned by both of fluid and crystallized intelligence matters.

Cognitive psychology researches revealed evidences of improvement in non-training cognitive and learning tasks, executive functions or attentional skills after working-memory training (Bryck et al., 2012; Diamond et al., 2011; Houben et al., 2011; Hussey et al., 2012; Lilienthal et al., 2013; Owens et al., 2013; Salminen et al., 2012), especially of n-back training (Buschkuehl et al., 2014; Hempel, et al., 2004; Schneiders et al., 2011; 2012; Schweizer et al., 2013), with transfer effects of fluid intelligence (Cowan et al., 2006; Engle, 2002; Engle et al., 1999; Jaeggi et al., 2014 b), which facilitates the learning process in a general sense, which is the most reliable predictor for academic achievement (Holmes et al., 2013; Shalev et al., 2007) and for successful performance in educational professional settings (Deary et al., 2007; Gottfredson, 1997), where transfer was observed to visual processes (Green et al., 2003; 2007), to language skills (Chein et al., 2010; Garcia-Madruga et al., 2013; Loosli et al., 2012; Novick et al., 2013), to reading comprehension (De Jonge et al., 1996; Gathercole et al., 2006, Passolunghi et al., 2001), to arithmetic and to geometric skills (Kroesbergen et al., 2014; Witt, 2011). Therefore working memory is a fundamental cognitive system that is highly relevant for success in or out of school and is an important predictor of the scholastic aptitude (Au et al., 2015).

Although several studies found improvements in fluid reasoning and transfer effects on cognitive processes after working memory training in the adult population (Borella et al., 2010; Schmiedek et al., 2010; Karbach et al., 2009; Basak, et al., 2008), at the same time other studies did not report significant improvements on fluid intelligence tasks, mainly done on the old adults (Buschkuehl et al., 2008; Carretti, et al., 2007; Minear et al., 2008; Li et al., 2008) and on the adolescents with a mild intellectual disability (Van Der Molen et al., 2010). The background of these contradictions is due to the principle of fluid intelligence and working memory improvement, where its maturity comes in the young adulthood, thus working memory training improvement outcome might not be noticed in the intelligence tests at the later age after that period. Most studies of working memory training transfer effects on cognitive functions and on fluid intelligence were conducted on children ranging from 4^{th} to 11^{th} age when their cognitive abilities were still developing and have not reached maturity for working memory, which comes around 12^{th} age (Fry et al., 2000), thus after that age improvement might be observed only in single separate cognitive functions processing.

Working memory and intelligence do share common variance and the same neural network and mental resources (Ackerman et al., 2005; Colom et al., 2003; Fry et al., 1996; Jurden, 1995; Kane et al., 2005; Oberauer et al., 2005; Stauffer et al., 1996; Tucker et al., 1996; Verguts et al., 2002), therefore engaging neural circuits may transfer to improvements in fluid intelligence by working memory training.

The process of maintaining the bindings between elements required attention is essential to working memory and to reasoning abilities (Halford et al., 2007). The relation is mediated by activities in the lateral prefrontal and parietal regions (Conway et al., 2003; Gray et al., 2003), that working memory span tasks activate regions in the prefrontal cortex when executive – control mechanism is recruited to combat interference during the maintenance and manipulation of information, where the dorsolateral prefrontal cortex could have a role in working memory especially related to attention control (Kane et al., 2002). Neuroscientific evidences for underlying mechanisms of working memory training were obtained by investigated activation changes with fMRI methods which revealed changes in: functional connectivity (Kundu et al., 2013), volume changes in gray matter (Takeuchi et al., 2011), fiber tracts via diffusion tensor imaging (Takeuchi et al., 2010), dopaminergic functions (McNab et al., 2009), effects of certain genotypes and polymorphisms on the working memory training outcome (Bellander et al., 2011; Brehmer et al., 2009). Thus the neural background of working memory training allows working memory improving during life including the aging period, with transfer effect outcome on basic cognitive functions which makes the condition for healthy cognitive aging.

De Smedt et al. (2009) longitudinal study of the relationship between working memory and individual differences in mathematics in 1^{st} and 2^{nd} grades revealed that working memory was significantly related to mathematics achievement and clearly predicts the later mathematics achievement. Independent additional studies of children with mathematical disabilities indicated that deficits in mathematics are linked to poor working memory (Bull et al., 1999; Gathercole et al., 2000 a; McLean et al., 1999; Passolunghi et al., 2004; 2007; Siegel et al., 1989; Swanson et al., 2001; 2004; Van Der Sluis et al., 2005). Studies of typically developing children also indicated that working memory plays an important role in individual differences in typical mathematics performance (Adams et al., 1997; Bull et al., 2001; Gathercole et al., 2000 b; Hecht et al., 2001; Homles et al., 2006; Swanson et al., 2007).

Some components of Baddeley's working memory indicate its specific role in mathematics performance (De Stefano et al., 2004) supported by converging evidence from brain imaging, neuropsychological and cognitive developmental studies (Baddeley, 2003). Evidence from those studies has consistently shown the involvement of the central executive in arithmetic processing, where this component is responsible for the monitoring and coordination of different steps during arithmetic problem solving (Furst et al., 2000; Imbo et al., 2007 a; 2007 b). The central executive is responsible also for the control, regulation and monitoring of complex cognitive processes, is generally investigated by means of complex span tasks that require both storage and simultaneous processing of information such as listening span task (Daneman et al., 1980) or counting span task (Case et al., 1982), is a unique contribution to mathematics performance (Gathercole et al., 2000 b; Swanson et al., 2007). Two additional subsidiary subsystems of limited capacity as slave systems both are in direct contact with the central executive and are used for temporary storage of phonological information (i.e. the phonological loop) and of both visual and spatial information (i.e. the visuospatial sketchpad). They are used only for passive information storage and can be considered as analogous to the original short-term memory concept, typically assessed by means of the classic digit - letter - number memory span recall task. The phonological loop plays an important role in arithmetic, in counting or in keeping track of the operands while calculating (Furst et al., 2000; Imbo et al., 2007 b; Noel et al., 2004).

Visual-spatial memory span was found by correlational and regression data analyses to be a predictor specifically of mathematics ability in preschool children that predicts later proficiency in the academic achievement at 7^{th} age (Bull et al., 2008; McKenzie et al., 2003), which includes number recognition, magnitude understanding and counting as precursors to mathematics (Geary et al., 1999; 2000), and might be as by-product of the dominance of the visual modality in humans over auditory modality (Bull et al., 2008). Younger children may have a greater reliance on visuospatial strategies to solve arithmetic problems, whereas older children may use verbal solution strategies, such as retrieval that do not require involvement of the visuospatial sketchpad. After preschool period the working memory predictor of mathematics achievement is changed to phonological span (Hecht et al., 2001),what might be defined as the background of mathematics learning process on the language basis, with evidence of individual differences in mathematical problem solving (particularly arithmetic) to inefficiencies in the utilization of the phonological system (Gathercole et al., 2000 a; 2004 a; Geary et al., 1991; Siegel et al., 1989; Swanson, 2006; Torgesen et al., 1997), with the role of the phonological loop being to encode and retain verbal codes used for counting or for retain interim solutions. Swason et al. (2007) research demonstrated that phonological storage was uniquely related to mathematics performance in 6-10 olds. Gathercole et al. (2006) study of 6-11 year olds also revealed a relationship between phonological short-term memory and mathematics, with data from growth curve analyses about better verbal short-term memory span in preschool results in a maintained advantage in mathematics and reading scores throughout early schooling. Holmes et al. (2006) noted that verbal short-term memory may be used on simple aural presented arithmetic questions where young children have used subvocal rehearsal processes to support the retention of problem information and direct retrieval of arithmetic facts from long-term memory.

The predictive value of the phonological loop might reflect an increasing reliance on verbally or phonologically coded information during calculation. Rasmussen et al. (2005) revealed that from preschool to elementary school children learn to use verbal labels for quantitative symbols and to employ their phonological working memory to store this information temporarily, thus the increasing importance of phonological processes may also reflect changes in children's strategy used for solving arithmetic problems. Arithmetic development is including dynamic change finger counting strategies toward more sophisticated verbal counting strategies and fact retrieval (Siegler, 1996) which are assumed to rely on phonological codes (Dehaene et al., 2003) and are supported by phonological loop (Lee et al., 2002). Noel et al. (2004) study got evidence that high phonological loop ability predicted higher frequencies of verbal counting procedures and fact retrieval with lower frequencies of finger counting, confirming that high phonological loop ability is associated with more mature addition strategies (Bull et al., 1997). Geary (1993) argued that phonological loop as concurrent storage would contribute to the development of problem resolving, of answer associations, and of arithmetic facts in long-term memory with better arithmetic fact retrieval, thus would positively affect general mathematics performance. Therefore the reliance on the visuospatial system changed to the reliance on the phonological system may reflect age-related differences in the strategy development going through visuospatial strategies (i.e. finger counting) to verbal strategies (i.e. verbal counting, fact retrieval).

Working memory learning opportunities also interact with a basic cognitive capacity for learning, as essential skills which allow us to engage in complex cognitive operations, and mathematical abilities can be referred also to fluid intelligence since they represent a biologically based ability to acquire skills and knowledge during the lifespan. Thus fluid cognitive capacities include general academic learning and can predict learning in evolutionarily novel contexts such as school and the workplace (Geary, 2007). Basic language skills represent crystallized knowledge built up on the basis of experiences and referenced by over-learned skills and knowledge such as vocabulary collected gradually in long-term memory (Gathercole et al., 2004 a; 2004 b). Thus language and mathematical skills are different independent factors of general intelligence, what has got empirical evidence in studies of children with poor mathematical skills who have revealed no significant limitations in verbal short-term memory or in limitations being due to a third factor such as processing speed or co-occurring reading difficulties (Bull et al., 1997; Geary et al., 1999; 2000). St Clair-Thompson et al. (2006) study on children aged 11 revealed that working memory and inhibition both uniquely predicted an attainment in mathematics and language, indicating that these skills support rather general academic learning than the acquisition of skills and knowledge in specific domains. Thus working memory is the predictor for both intelligence factors in childhood what provided got strong evidence in Gathercole et al. (2005; 2006) longitudinal studies, where scores on complex span tasks were highly related to learning achievement across the school period suggesting that capacity to process and to store material in working memory significantly constrain a child's ability to acquire skills during the early period of formal education. Summarize working memory is a predictor of later mathematics achievement and only the phonological loop storage remained as significant unique predictor of individual differences in mathematics ability at school-age level, what gives an additional reason for justified pragmatic usefulness of aural working memory training for 12th olds.

METHODOLOGY PROCEDURES, RESEARCH METHODS AND ESTABLISHMENT

Working aural musical memory as well as hemispheric music and mathematics processing are constant cognitive features based on the developmental maturity principles, resistant to the music education independently of length of musical activity and of systematic training, without gender differences. Thus it is not decisive for the working aural musical memory development (Dowling et al., 1971; Horbulewicz, 1963). However by influence with working aural memory training stimulation based on the music, as dynamical part-time brain condition during aural music perception with its neuropsychological and physiological basis, it enhances and increases the cognitive learning efficiency condition which might be observed in school grades in mathematics or language in the case of hemispheric specificity stimulation by music, including the hemispheric principles of mathematics and of language processing, with possibility of hemispheric aural musical memory dominance decreasing during simultaneous stimulation of both hemispheres in the working memory methodological tasks, based on memory trace continuity strengthen improvement, with independent evidence of childhood cognitive IQ score as predictor of school grades' and of academic achievement (Gottfredson, 1997; 2002; Neisser et al., 1996) in school age.

Present study examined the influence of initial working aural musical memory level and of aural working musical memory training on the association between initial level of cognitive development, of mathematics ability and outcome level of both mathematics and language achievement. Experimental procedure concerned the intensive working aural musical memory stimulation for continuous duration of 3,5 months (14 weeks), with 40 training sessions, except first and last meeting, stable in three times per week in duration approximately two hours including internal break for 30 minutes announced by participants or by trainer in the case of behavioral reactions of children mental fatigue syndromes, i.e. totally 60 hours of clear training stimulation (4,5h per week), in 42 meetings, with the training material presented on the piano. Additionally participants have got methodological instructions about both learning knowledge and memorizing strategies for effective studying the school material and have got possibility to go through diagnosis of learning styles or of cognitive styles with individual advices on their personal preferences as the accompanied possibility to improve consciously own self-learning efficiency. Experimental groups, after the training stimulation finished, were differentiated by both absence or presence of mathematics learning efficiency improvement in participants' announcement at the end of the training stimulation, in additional feedback confirmation from participants' mathematics and language teachers, with inner grouping by both absence or presence of language learning efficiency improvement (with the same feedback scheme as in the mathematics) with the combined mathematics-language improvement state, and by musical activity level. The gender factor was excluded in the case of scientific evidences about no its significant differences in aural working musical memory training influences and improvements by music stimulation. Scientific quantitative data of mathematics ability (i.e. mathematics grade) and of cognitive intellectual ability (i.e. mental level, cognitive learning ability in school grades' average) with inner grouping into top-down levels according to median level, also with qualitative data of musical activity condition (i.e. musician or non-musician) were collected at the beginning of the training stimulation. Scientific qualitative data about both mathematics and language improvement (i.e. working memory training influence on cognitive learning efficiency in mathematics and in language) were obtained from participants and their teachers at the end of the training after post-test completing, with short back-up note about did they begin to get higher grades in mathematics or in language during the working memory training stimulation continuity duration. Scientific data of aural working musical memory were obtained during twice psychological tested measure in experimental schema before and after of the working memory training stimulation. The object of measurement is defined as behavioral reaction on perceived acoustical stimuli during the serial recall method by psychological testing with completing answers in the paper test survey method, with tasks required making multi-alternative forced choice final answer decision where participants would hear once each melody sequentially and then choose the one of the reproduction variants which is the same with original on their estimation. The measurement has been done on children aged in the range from 12th and 5 months to 12th and 10 months with the evidence of aged normal medical analyses level of morphological components (acetylcholine, dopamine, glutamate) at the beginning of the training stimulation, important for cognitive process as working memory neurotransmitters (Dash et al. 2007; Freeman et al. 1988; Goldman-Rakic, 1995; Li et al.2001; Segovia et al.2001), without pre-selection for diagnosis of musical audiation presence, from 10 to 12 participants in small groups at public school in acoustically secured classrooms isolated from outside noises.

Children who did not have enough development or skill level of musical audiation were expected to unsubscribe from participation in the test at the beginning of diagnostic measurement procedure after perceiving first two trial examples of the test measurement or during the first working aural musical memory training sessions. They could voluntarily resign at any moment of the measurement and during training time without any consequences. The methodology of psychometric measurement involved the final selection by excluding the participants with methodological syndromes of psychological measurement disturbance, such as guessing, answering or correcting the choice after the test task stimulation finished, not completing all the test tasks with leaving empty fields in paper test answer blank, also with the absence in the training sessions, with final total empirical sample of 50 participants with equal experimental groups of mathematics improvement differences.

The aural working memory training included the same sound as in psychological test (i.e. natural piano) with the structure of training material prepared on the principles of therapeutic music prescriptions (Dymnikowa, 2015 b) with basis on forming up the "memory trace continuity" by consolidation of the memory trace with differences in the range, during stimulation based on worked-out aural musical methodologic solfeggio material, which was presented once or twice and repeated by several techniques for aural recognition of the material that has been memorized earlier, in the range from 3 to 8 single basic units, where the continuity effect is available to form up or to improve with using the melody which has prolonged structure unlike selective units of musical tones or of rhythmic patterns. The working memory training program included simultaneously processing and storing information mechanisms, with forward and backward span technique included directed and selected attention on the basis of the attention inhibition with perceptual skipping in selected encoding, with variants of stimuli material presentation manipulation at the encoding and at the recognition levels in memorizing process, designed for aural musical stimulation material, with the procedure of paper-written feedback answer decision included the numbers using of numerical aural material presented for memorizing. Stimulation material had forms of a single pitch or rhythm attributes and of short 1 - 2 bar musical motives (part-structure of melodies) with free or selected encoding, with three recall types - on estimation yes - no in reproduction with the change of some elements, on recognition the order - change reproduction, on estimation about which elements were incorrect (and why) in serial and order-change reproduction. N-back technique was used only for a single pitch or rhythm attributes in the range from 4 to 7 elements, with the same encoding and reproduction methods. Advances methods were based on the changed structure between encoding and reproduction, such as encoded single pitches reproduced in rhythmized motive, or encoded melodies reproduces in clear plane rhythm or pitch, with the reproduction change of octave register (pitch modulation) and meter (rhythm modulation) differences (separate and mixed).

Structure of the working aural musical memory test of own authority includes two principles: I - the hemispheric music processing specifics by the psychometric construct of the melody measurement in test scales as a combination of pitch and of rhythm (Snyder, 2000), which attributes are processed simultaneously by hemispheric differentiation, what forms up the functional asymmetry of the music perception and therefore of the working aural musical memory as a secondary feature formed on the basis of musical audiation, with the tendency to right hemisphere dominance (discriminating musical pitch) responsible for better musical auditory working memory for the pitch or to left hemisphere dominance (differentiating musical rhythm) responsible for better musical auditory working memory for the rhythm (Springer et al., 2001; Platel et al.,1997);

II - the melody range with time - duration of 9 - 12 seconds and the volume of 6 bars, what belongs to the aural working memory span for music, appropriate for natural spontaneous memorizing of musical material at the age of the optimal development of this cognitive feature, verified earlier empirically by this test with the fulfillment of basic psychometric requirements (Dymnikowa, 2015 a). The tested material is presented on CD musical recording, has two versions with ten tasks used before (pre-test) and after (post-test) the working aural memory training stimulation, based on the unknown stimulated music solfeggio material with the time duration around ten minutes to each version. It includes working memorizing measure with the recognition of the repeated original version among three reproductions where one is correct and two are changed separately in the pitch or in the rhythm. The time duration of each aural musical task is around one minute with equal four variants once presented in each test task and with single short ultra-high sound of attention up before the incoming each selected tested task with 5-6 seconds silence breaks between test tasks. Each melody is described by four independent characteristics of musical attributes: two ambitus (range between the highest and the lowest pitch in melody task) - small or big; five octave registers - great, small, one-lined, two-lined and three-lined; four tonality - major, natural minor, harmonic minor, atonal; two meter - even or non-even. Additionally each task's melody has different name scale (from possible 12 semitones of tonality combination) as a qualitative attribute specification. Test includes seven aural musical memory scales with normalization for 12th age: I) two quantitative single separate point and norm scales - memory of pitch and memory of rhythm; II) three quantitative complex point and norm scales - of common memory i.e. correct answers for both single scales, of total memory in the function of sum of separate scales' scores and of asymmetry of memory in the function of difference between single separate scales' scores with qualitative norm range level (absence, low, high); III) two qualitative scales - income scale of hemispheric aural musical memory condition with three variants: of pitch dominance (right aural musical memory brain laterality), of rhythm dominance (left musical memory brain laterality) or of dominance absence (homogenous aural musical memory brain condition), and outcome scale of aural musical memory asymmetry change tendency in combination of single attributes (i.e. pitch and rhythm) with three variants: of both single attributes' equal change duration (↑|↑or–|–) i.e. absence of asymmetry of pitch-rhythm change tendency level; of different single attribute change duration with stable unchanged level of accompanied single attribute (–|↑↓or↑↓|–) i.e. low level of asymmetry of pitch-rhythm change tendency level; of both single attributes' different change duration (↑|↓or↓|↑) i.e. high level of asymmetry of pitch-rhythm change tendency level.

Research schema included the influence study with the difference of mathematics learning efficiency improvement factor during the aural working musical memory training influence (improvement presence or absence), and relation study with factor structure and path analysis study of obtained variables in whole experimental sample and its relation inside the grouped categories, with inner grouping level of the language learning improvement condition (presence or absence) and of the musical activity (musician-nonmusician), with musical data of the working aural musical memory obtained in psychological test (musical memory - of pitch, of rhythm, of common memory, of total memory, of asymmetry level, hemispheric asymmetry of memory at income condition and at outcome change-tendency duration), with data of learning efficiency process condition, also defined as academic ability or cognitive learning ability in school grades' average and mathematics grade with its inner distributed frequencies' groups.

The psychological quantitative and qualitative data were encoded and analyzed by "statistica" computing server, with using analysis of: 1) - normal distribution of quantitative learning and musical variables as the cognitive feature characteristics with possibility of the expectation of differential distribution arrangement of learning variables in case of their possible qualitative characteristics of the experimental 16 groups; 2) - differences of means' variables comparison between 14 groups; 3) - frequency distribution of qualitative structural variables' schemes inside 14 groups with total 23 variables (15 quantitative ordered, 8 qualitative); 4) - factor and path analyses of structural components of the obtained experimental data, with correlation analysis of whole sample and inside 14 groups, with total 34 quantitative variables.

The statistical indices of experimental data were confirmed to behavioral science principles of empiric data evaluation (Cohen, 1988). The verification of the normal distribution is expected to have the equal level of both mean, median and mode values, with the imposed possibility of different variants of the normal distribution in kurtosis forms in the case of a small size of experimental sample and groups (with values ≈0 in the range {–0.5; +0.5} tended for flattening of a distribution to normal size, while values <0.5 tended for flattening of a distribution to platykurtic size and values >0.5 tended for flattening of a distribution to leptokurtic size), with possible different skewness distribution for qualitative characteristics of group variables with the skewness index of the function {(Mean–Median)/Standard deviation}, which values ≈0 in the range {–0.5; +0.5} impose to normal distribution tendency, while values <0.5 impose to left skewed distribution tendency (with relation mean<median<mode) and values >0 impose to right skewed distribution tendency (with relation mean>median>mode).

The effect size estimation is based on: 1) Cohen's d value of means' difference with the function of difference between two means divided by the pooled standard deviation (*sd)* including the samples' volume (n) { (Mean^1 - Mean^2) / √ { ($^{1st}n – 1$) $*$ $^{1st}sd^2$ + ($^{2nd}n – 1$) $*$ $^{2nd}sd^2$ } \ (^{1st}n + $^{2nd}n – 2$), with the range thresholds interpretation: d<0.2 as no effect size (trivial in size), 0.2<d<0.5 as small effect size, 0.5<d<0.8 as medium (intermediate) effect size; d>0.8 as large effect size, and 2) Mann-Whitney u value based on the rank-biserial correlation for independent non-equal samples and for nonparametric data with the function { 1 - 2u \ (^{1st}n $*$ ^{2nd}n) }, where u value for sample volume (n) and large rang total (r) has the function { ^{1st}n $*$ ^{2nd}n + n^{larger} $*$ ((n^{larger} + 1) / 2) - r^{larger} } with alternative function of Mann-Whitney-Wilcoxon u value={ $r^{smaller}$ - [$n^{smaller}$ $*$ ($n^{smaller}$ + 1)] / 2 } for smaller both sample volume (n) and rang total (r) of the same score value, with included correlation thresholds interpretation.

The estimation of the correlation values, of Pearson index for parametric musical data and of Spearman index for nonparametric learning data, with the difference's frequency values includes interpretation ranges of magnitude of the effect: 0.0-0.1 as trivial, very small, tiny, insubstantial or practically zero; 0.1-0.3 as low, small or minor; 0.3-0.5 as moderate or medium; 0.5-0.7 as high, large or major; 0.7-0.9 as very high, very large or huge; 0.9-1 as practically perfect, nearly perfect or almost perfect. The path analyses based on correlation and determinacy effect size analysis includes one direct tendencies based on the evidence from analysis of means' differences of variables and two direct tendencies based on the evidence from correlation analysis without established the casual-effect state of the variables.

The exploratory factor analysis structure is based on the correlation with the common variance of data included in unique factors' account by adjusted the diagonals of the correlation matrix of the underlying estimated factors which influence responses on the observed variables as of linear factors' combinations of the underlying constructs that can be precisely interpreted in exposed model specification. It includes the principal factor analysis with obtaining the least number of factors which can account for the common correlation variance of a set of variables with central method application of factors' selection which tends to maximize the sum of the absolute values of factor loadings and extracts the largest sum of absolute loadings for each factor in turn, is defined by the linear combinations of weights around ± 1.0 values, forming up the clusters of attributes with relatively high inter-correlations within the clusters and relatively low correlations between clusters. It includes the normalized equamax orthogonal rotation, as complex of varimax rotation with maximizing the variance of the factor's loadings on all the variables in a factor matrix with the tendency for high or low variables' factor loadings and of quartimax rotation with minimizing the number of factors needed to explain each variable with high or low degree's loaded tendency, with hidden variables' eigenvalues ≥ 1 for the factor level from scree graph by Kaiser rule and with the minimal factor loading ≥ 0.5 value which squared form is the % variance (≥25%) of indicator variable explained by the factor. The commonality of the factor loadings, as the factors internal reliability based on *a*-Cronbacha index inside of each factor variables' content with the required level ≥ 0.7 as acceptable internal consistency, is the square of a standardized loading of a factor's variable where the squared factor loading is the percent of a variance of the variable explained by the factor. For the total variance all the standardized variables are accounted for by each factor, with adding the sum of the squared factor loadings for that factor, which factor's score is divided then by the number of variables, where the number of variables equals the sum of eigenvalues' values total index, and the factor's eigenvalue is the minimal number of hidden variables explained by the factor. An eigenvalue for a selected factor measures variance in all the variables accounted for the selected factor where the number of eigenvalues is equaled to the number of factors in factor analysis structural model.

EMPIRICAL RESULTS AND DISCUSSION

Normalized Statistics of Experimental Groups Variables' Distribution with Means' Indices

The descriptive normalized values of distribution obtained in research are represented by the normal distribution for musical variables (tables no. 1 - 3) while learning variables (table no. 4) are represented by tendency to non-parametric distribution with non-equal level of both mean, median and mode values, what might be conditioned by sample volume and by complex background of cognitive learning abilities in case of educational influence, while working aural musical memory is typical cognitive feature resistant to training influence (Dowling et al., 1971) in case of working memory span (i.e. capacity level). Comparing analysis of the same variables' means in 14 empirical experimental groups for musical data of 10 variables with 5 from pre-test and post-test, with total 910 comparisons (91 pairs of each variable (formula for groups' (x) pair compare amount=$\{(x\text{-}1)*x/2*\textit{amount of variables}\}$, didn't reveal differences between grouping categories, except of 1 difference concerning hemispheric principle evidence, thus the present research contributes to Gardner state concerning independence of musical intelligence, especially for no mathematics and musical activity factors influence on working aural musical memory scores in both income and outcome level, although with the possibility of the musical activity influence on the cognitive learning results.

Table 1. Descriptive normalized statistics for musical variables distribution in experimental learning groups

	Income pre-test data					Outcome post-test data				
Experimental group with variable	Mean	Median	Modal	Skewness	Kurtosis	Mean	Median	Modal	Skewness	Kurtosis
Math improvement pitch memory	6.68	7	6	-0.196	-0.553	7.8	8	8	-0.305	-0.541
rhythm memory	6.88	7	many	0.007	-1.117	6.96	7	7	0.252	1.98
common memory	3.56	4	many	-0.314	-0.835	4.76	5	5	0.509	1.23
total memory	13.56	14	many	-0.314	-0.835	14.76	15	15	0.509	1.23
memory asymmetry	-0.2	0	-1	-0.241	-0.771	0.84	1	1	-0.458	0.063
Math non-change pitch memory	6.56	6	many	-0.052	-1.137	7.92	8	8	-0.621	0.715
rhythm memory	7.08	7	8	-0.794	0.656	6.92	7	8	-0.092	-1.229
common memory	3.64	4	4	0.15	-0.415	4.84	5	5	-0.161	-0.27
total memory	13.64	14	14	0.15	-0.415	14.84	15	15	-0.161	-0.27
memory asymmetry	-0.52	-1	-2	0.388	-0.534	1	1	0	-0.057	-1.003
Math with language improvement pitch memory	7.11	7	7	0.128	-0.782	8	8	8	0	1.257
rhythm memory	6.33	6	6	0.536	-0.8	6.66	7	7	-0.857	-1.714
common memory	3.44	3	3	0.418	-1.538	4.66	5	5	-0.659	0.825
total memory	13.44	13	13	0.418	-1.538	14.66	15	15	-0.659	0.825
memory asymmetry	0.77	1	3	-0.487	-0.932	1.33	1	1	0.412	0.261
Math improvement + language non-change pitch memory	6.43	6	6	-0.073	-0.748	7.68	8	9	-0.277	-0.972
rhythm memory	7.18	7	7	-0.382	-0.803	7.12	7	7	-0.086	0.971
common memory	3.62	4	4	-0.728	-0.093	4.81	5	5	0.585	0.874
total memory	13.62	14	14	-0.728	-0.093	14.81	15	15	0.585	0.874
memory asymmetry	-0.75	-1	many	0.063	-0.797	0.56	1	many	-0.309	-0.539
Math non-change + language improve-ment pitch memory	6.78	6.5	6	-0.211	-1.164	7.92	8	8	-0.77	0.892
rhythm memory	6.71	7	many	-0.603	0.287	6.78	7	8	-0.486	-1.012
common memory	3.5	3.5	many	0	-0.57	4.71	5	5	-0.432	0.746
total memory	13.5	13.5	many	0	-0.57	14.71	15	15	-0.432	0.746
memory asymmetry	0.07	-1	many	0.104	-0.772	1.14	0.5	many	0.025	-0.789
Math with language non-change pitch memory	6.27	6	many	-0.073	-1.383	7.9	8	8	-0.196	-0.109
rhythm memory	7.54	8	8	-0.392	-1.182	7.09	8	5	0.050	-1.769
common memory	3.81	4	4	0.037	-0.468	5	5	5	0	-1.05
total memory	13.81	14	14	0.037	-0.468	15	15	15	0	-1.05
memory asymmetry	-1.27	-2	many	0.35	-1.343	0.81	1	-3	-0.203	-1.299

Significant difference was found for rhythmical musical memory at the income level score between two different non-overlapping empirical groups' volume (*n*) of math-language improvement factor, where the group without of both mathematics and language improvement during training stimulation obtained significant (p=0.027) higher mean value (m) of memory for rhythm [m=7.545; sd=1.128; n=11] at income (*pre-test*) level than the group with both mathematics and language improvement during training stimulation [m=6.333; sd=1.118; n=9], with the large difference's effect size level of Cohen's d value = 1.07 and of Mann-Whitney u value = 0.546 [u=22.5; r^{larger}=142.5; $r^{smaller}$=67.5].

The obtained empirical result provides the evidence of the principal perfect large specific key role of left hemispheric processing in both of musical rhythm (Belin et al., 2001), language (Alho et al., 1996) and complex numerical mathematics (Prado et al., 2011) functions. Thus the children with higher income level of working aural musical rhythm memory are supposed to have the higher level of left hemispheric improvement activity development than the children who did improve in both mathematics and language learning efficiency in case of their lower level of resources at the income level, what is independent reasonable explanation of different working aural memory training influence with including the children individual differences. Since right hemispheric is included principally only in music and mathematics functions, therefore its income development level is not so clearly predictive as of the left hemispheric for precise learning-efficiency improvement during the working aural musical training stimulation influence. No significant differences were found in musical variables for learning grouping empirical categories. So such musical skill and musical function as working aural musical memory is rather independent from the influence of the learning - efficiency process. No significant difference was noted in the homogenous bilateral musical brain condition at the income level including the gender category [Males: m= –0.086; sd=0.792; n=23; Females: m=-0.037; sd=0.854; n=27; Cohen's d value=0.05; Mann-Whitney u value=0.04 for u=301; $r^{females}$=698; r^{males}=577] and additionally frequency structural index in the group homogenous musical brain condition at income level [Males n=8; *structural frequency*=0.4706; Females n=9; *structural frequency*=0.5249; sample n=17; p=0.731] so gender wasn't the key differentiated factor.

Table 2. Descriptive normalized statistics for musical variables distribution in experimental mus. activity groups

	Income pre-test data					Outcome post-test data				
Experimental group with variable	Mean	Median	Modal	Skewness	Kurtosis	Mean	Median	Modal	Skewness	Kurtosis
Math improvement musicians pitch memory	6.81	7	9	-0.058	-1.313	7.9	8	8	-0.663	0.198
rhythm memory	7.18	7	8	-0.422	-0.293	6.81	7	7	0.378	2.446
common memory	4	4	5	-0.557	-1.111	4.72	5	5	-0.766	-0.035
total memory	14	14	15	-0.557	-1.111	14.72	15	15	-0.766	-0.035
memory asymmetry	-0.36	-1	-1	0.256	-1.133	1.09	1	1	-0.647	2.444
Math improvement non-musicians pitch memory	6.57	6.5	6	-0.385	0.333	7.71	8	many	-0.123	-1.091
rhythm memory	6.64	6.5	5	0.379	-1.097	7.07	7	7	0.541	-0.146
common memory	3.21	3	many	-0.157	-0.623	4.78	5	5	0.935	1.66
total memory	13.21	13	many	-0.157	-0.623	14.78	15	15	0.935	1.66
memory asymmetry	-0.07	0.5	1	-0.624	-0.156	0.64	1	2	-0.387	-0.886
Math non-change musicians pitch memory	6.71	6.5	6	0.333	-0.695	8.14	8	many	0.06	-1.271
rhythm memory	7.21	7.5	8	-0.193	-1.096	6.5	6.5	5	0.164	-1.519
common memory	3.92	4	4	-0.541	-0.146	4.64	5	5	-0.486	-0.226
total memory	13.92	14	14	-0.541	-0.146	14.64	15	15	-0.486	-0.226
memory asymmetry	-0.5	-1	-2	0.364	-1.149	1.64	1	5	-0.144	-1.445
Math non-change non-musicians pitch memory	6.36	6	many	0.07	-1.951	7.63	8	8	-1.62	2.781
rhythm memory	6.9	7	8	-0.942	0.753	7.45	8	8	-0.369	-0.411
common memory	3.27	3	3	1.098	1.672	5.09	5	7	-0.469	-0.778
total memory	13.27	13	13	1.098	1.672	15.09	15	17	-0.469	-0.778
memory asymmetry	-0.54	-1	many	0.414	-0.913	0.18	1	1	-0.376	-0.767

Table 3. Descriptive normalized statistics for musical variables distribution in part-learning experimental groups

	Income pre-test data					Outcome post-test data				
Experimental group with variable	Mean	Median	Modal	Skewness	Kurtosis	Mean	Median	Modal	Skewness	Kurtosis
Average of grades top level pitch memory	6.44	6	6	0.208	-1.217	7.8	8	8	-0.578	-0.275
rhythm memory	7.2	8	8	-0.899	-0.754	7.12	7	8	-0.314	-0.279
common memory	3.64	4	5	-0.483	-0.973	4.92	5	5	-0.077	0.655
total memory	13.64	14	15	-0.483	-0.973	14.92	15	15	-0.077	0.655
memory asymmetry	-0.76	-1	many	0.473	-0.654	0.68	1	1	-0.042	-0.46
Average of grades down level pitch memory	6.8	7	many	-0.515	0.129	7.92	8	many	-0.133	-0.897
rhythm memory	6.76	7	many	0.091	-1.04	6.76	7	7	0.272	0.059
common memory	3.56	3	3	0.494	0.144	4.68	5	5	0.332	-0.28
total memory	13.56	13	13	0.494	0.144	14.68	15	15	0.332	-0.28
memory asymmetry	0.04	0	-1	-0.345	-0.329	1.16	1	many	-0.244	-0.715
Math grade top level pitch memory	6.3	6	6	0.553	-0.56	8.2	8	8	-0.051	-0.593
rhythm memory	7.2	7	7	0.027	-0.773	6.8	7	many	0.084	-0.433
common memory	3.5	3.5	5	-0.252	-1.09	5	5	5	0.321	0.331
total memory	13.5	13.5	15	-0.252	-1.09	15	15	15	0.321	0.331
memory asymmetry	-0.9	-1	many	0.264	-1.12	1.4	1	many	-0.235	0.149
Math grade down level pitch memory	6.83	7	many	-0.536	-0.477	7.63	8	8	-0.538	-0.015
rhythm memory	6.83	7	8	-0.41	-0.501	7.03	7	7	-0.063	-0.134
common memory	3.66	4	4	0.128	-0.37	4.66	5	5	-0.093	0.003
total memory	13.66	14	14	0.128	-0.37	14.66	15	15	-0.093	0.003
memory asymmetry	0	-0.5	-1	-0.109	-0.691	0.6	1	many	-0.097	-0.889

Table 4. Descriptive normalized statistics for learning variables distribution in experimental groups

	Average of school grades					Mathematics grade				
Experimental group with variable	Mean	Median	Modal	Skewness	Kurtosis	Mean	Median	Modal	Skewness	Kurtosis
Math improvement	4.36	4.5	3.5	-0.637	-0.692	4.04	4	5	-0.825	-0.746
Math non-change	4.53	4.69	5.1	-0.367	-0.401	4.28	4	4	0.531	0.299
Math with language Improvement	4.14	4	many	0.334	-1.141	3.55	4	4	-0.418	-1.538
Math improvement with language non-change	4.49	4.68	many	-1.24	0.588	4.31	5	5	-1.164	0.03
Math non-change with language improvement	4.63	4.73	many	-1.044	0.035	4.35	4	4	1.687	2.213
Math with language non-change	4.41	4.2	many	0.238	-0.297	4.18	4	4	0.345	-0.587
Math improvement Musicians	4.43	4.7	4	-0.926	-0.151	4.36	5	5	-1.583	1.743
Math improvement Non-musicians	4.31	4.45	3.5	-0.508	-0.937	3.78	4	5	-0.484	-1.254
Math non-change Musicians	4.67	4.79	5.1	-0.299	-0.954	4.64	4.5	4	0.73	-0.637
Math non-change non-musicians	4.36	4.3	many	-0.359	-0.086	3.81	4	4	0.027	0.412

Comparing analysis of the same variables' means in 10 empirical experimental groups for learning ability data of 2 income variables, with mathematics improvement and non-improvement (2) grouped into musical activity with musicians and non-musicians (4) and mathematics-language improvement state (4), with total 90 comparisons (45 pairs in each group), revealed six differences between grouping categories with the cues of musicians without mathematics improvement and of the group with the language improvement without mathematics improvement.

The group of musicians without mathematics improvement during training stimulation obtained significant higher mean value (m) of mathematics grade [m=4.642; sd=0.744; n=14] at the income level than three other groups such as: - two non-musicians groups with mathematics improvement [m=3.785; sd=1.118; n=14; p=0.03; with the large difference's effect size level of Cohen's d value = 0.9, and with the moderate effect size level of Mann-Whitney u value = 0.37 for u=61.5; r^{larger}=239.5; $r^{smaller}$=166.5], and without of mathematics improvement [m=3.818; sd=0.603; n=11; p=0.006; with the large difference's effect size level of Cohen's d value =1.2, and of Mann-Whitney u value =0.56 for u=34; r^{larger}=225; $r^{smaller}$=100], during working memory training stimulation, and the group with both mathematics and language improvement during training stimulation [m=3.555; sd=1.236; n=9; p=0.015; with the large difference's effect size level of Cohen's d value = 1.13, and with the medium effect size level of Mann-Whitney u value = 0.48 for u=33; r^{larger}=198; $r^{smaller}$=78]. Also that group obtained significant (p=0.022) higher mean value (m) of school grades' average [m=4.675; sd=0.494; n=14] at income level than 3rd compared group of both mathematics and language improvement during training stimulation [m =4.142; sd=0.528; n=9; with the large difference's effect size level of Cohen's d value = 1.05, and of Mann-Whitney u value = 0.57 for u=27.5; r^{larger}=203.5; $r^{smaller}$=72.5].

The obtained significant difference confirm the evidence of the large principal role of professional musical activity on the income level of mathematics ability level, conditioned by both hemispheric importance value for mathematics and music processing (Altenmuller, 2003; Castelli et al., 2006), and on the general intelligence factor level (g) according to the Hobbs (1985) state of the existed relation between the academic achievement, as of school grades' average, and the music aptitude condition improved by the musical activity state in childhood, where additionally general cognitive IQ score in childhood is also the predictor of the school grades and of the academic achievement (Gottfredsob), especially to Schellenberg (2000 b) state that professional musical activity in childhood, such as music lessons, has a stronger association with IQ score, thus also with school grades' average. Thus children with musical activity do have tendency to high development level of mathematics ability at the income level than non-musicians, and to the better functional connectivity between left and right hemispheres that correlates with mathematics performance across individual humans (Perk et al., 2013). Thus the working aural musical memory training causes probable bigger influence on the non-musicians' improvement than on the musicians' improvement in case of their constant high level contact with the music stimulation.

The group with the language improvement without mathematics improvement during training stimulation obtained significant (p=0.024) higher mean value (m) of school grades' average [m=4.632; sd=0.434; n=14] at the income level than the group with both mathematics and language improvement during training stimulation [m=4.142; sd=0.528; n=9; with the large difference's effect size level of Cohen's d value = 1.04, and of Mann-Whitney u value = 0.54 for u=29.5; r^{larger}=201.5; $r^{smaller}$=74.5], where the frequency distribution of the group with both mathematics and language improvement (77%) revealed grades' average located in the down level, while the group of the language improvement without mathematics improvement (71%) got opposite distribution of grades' average located in the top level, with additional significant (p=0.041) higher mean value (m) of mathematics grade [m=4.357; sd=0.633; n=14] at the income level than non-musicians without mathematics improvement during training stimulation [m=3.818; sd=0.603; n=11; with the large difference's effect size level of Cohen's d value = 0.86, and with the moderate effect size level of Mann-Whitney u value = 0.4 for u=46.5; r^{larger}=212.5; $r^{smaller}$=112.5], where the frequency distribution of the group with the language improvement without mathematics improvement included 64 % of musicians while both groups revealed tendency (71%, 90%) of mathematics grade located in down level. These empirical evidences suggest the principal key role of left hemisphere in the language processing (Tervaniemi et al., 2003) and in complex numerical mathematics (Ansari et al., 2006) functions, the improvement of which during working memory training stimulation influence is valuable and important for the cognitive learning efficiency state, where the musical activity might also influence on the mathematics learning efficiency process.

Qualitative Frequency Distribution Specifics of Empirical Experimental Groups

The qualitative analysis of frequency distribution of qualitative structural variables' schemes of 14 empirical experimental groups revealed specific characteristic of learning variables frequency tendencies explaining additionally the obtained significant differences. According to factors of income musical brain hemispheric condition and of musical memory for rhythm level three groups revealed the hemispheric state of the rhythm dominance (i.e. left lateraled working aural musical memory brain condition) at the income (pre-test) level (before training beginning) - the group of both non-change in mathematics and language improvement (54%), the group of non-musicians with mathematics improvement (57%), the group of grades' average top level (50%), while the group of both mathematics and language improvement demonstrated the high frequency (66%) of homogenous hemispheric state at the post-test level (after training finished) i.e. homogenous working aural musical memory brain condition. Therefore significant difference was obtained between 1st and 4th group in case of the tendency of hemispheric rhythm dominance or homogenous state of working aural musical memory, where mathematics ability (representative also for general school grades' average) is the key role of the left hemispheric function improvement during complex mathematical tasks. According to the outcome level of asymmetry of aural musical memory change tendency in combination of single attributes (i.e. pitch and rhythm), the group of mathematics improvement revealed the high frequency - 60% of different single attribute change duration with stable unchanged level of accompanied single attribute (–|↑↓or↑↓|–), i.e. low level of asymmetry of pitch-rhythm change tendency level, while the group of non-musicians without mathematics improvement revealed the high frequency (54%) of aural musical memory asymmetry change tendency in combination of single attributes (i.e. pitch and rhythm) of both single attributes' different change duration (↑|↓or↓|↑), i.e. high level of asymmetry of pitch-rhythm change tendency level.

Thus probably absence of mathematics improvement might be the case of low level synchronization activity between two hemispheres which might produce different change tendency of musical memory single attributes belonging to the different hemispheric functions in music perception processing, where non-musicians might be not influenced by music hemispheric processing so deep as musicians.

The different tendencies for probable independence between language and mathematics learning were revealed totally in 10 empiric experimental groups with the opposite frequency tendency directions: 1 - two groups with both mathematics and language improvement (77% with 66 % of non-musicians) or non-change statement (63%) revealed both grades' average with mathematics grade located in the down level, while the group with mathematics improvement and language non-change statement (62%) demonstrated mathematics grade located in the top level; 2 - the high frequency of children with non-language improvement was revealed in three groups - with mathematics improvement (64%), of musicians with mathematics improvement (72%) and with top level of mathematics grade (50%), while two groups got opposite tendencies such as musicians without mathematics improvement (64%) revealed language improvement, and the group of language improvement without mathematics improvement (71%) got opposite distribution of grades' average located in the top level with mathematics grade located in the down level; 3 - the group with both mathematics and language improvement (66%) revealed tendency of non-musicians presence, while the group with language improvement and mathematics non-change statement (64%) revealed tendency of musicians presence. Thus observed significant difference might be the case of the hemispheric state which is not included in the empiric experimental groups' differences, except of 2 groups significantly differed in this factor. According to musical activity and learning efficiency factors the frequency tendencies revealed Schellenberg state that musicians (*m*) are more likely to have higher learning abilities than non-musicians (*n*), in four clear high distribution tendencies with the same direction, where for both mathematics improvement (*m*-63%; *n*-64%) and non-change statement (*m*-64%; *n*-90%), also for school grades' average (*m*-60%; *n*-60%) and for mathematics grade (*m*-70%; *n*-63%) musicians revealed the union tendency in the top level, while non-musicians revealed opposite tendency to the down level, therefore musical activity factors is the key point for significant influence on the learning efficiency process, although with small level for general cognitive intelligence factor (*g*) in the case of separate independent musical intelligence nature with its own principles.

Structural Exploratory Factor Analyzes Data of Empirical Variables

The exploratory factor analysis of 34 empirical variables' data (26 basic, 8 complex) with using the principal factor analysis method and the central method application of factors' selection included the normalized equamax orthogonal rotation revealed six independent hidden eigenvalues of factors' structure, with total eigenvalue - 26.74 (i.e. the explanation of 26 - 27 variables), with 4 musical factors and 2 learning factors, with total variance of empirically obtained model at the level of 78.6 % [1^{st} eigenvalue = 7.2 with 21.2 % of total variance; 2^{nd} eigenvalue = 5.74 with 16.9 % of total variance; 3^{rd} eigenvalue = 4 with 11.8 % of total variance; 4^{th} eigenvalue = 3.7 with 10.9 % of total variance; 5^{th} eigenvalue = 3.75 with 11 % of total variance; 6^{th} eigenvalue = 2.33 with 6.8 % variance]. The factors' loadings and content with the commonality, i.e. of factors' internal reliability with % of the variance explained by variables for each factor is presented in table no.5. The revealed structural exploratory model includes the research scheme with musical and learning data ordering.

Table 5. Factor analysis content of structural exploratory model of experimental empirical musical-learning data

Factor's structure with variables' content and the commonality of factors' loadings
1st Factor content: *pre-test single scales with language improvement* Factor's commonality≈59% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.897; *a*-Cronbacha standardized value for factor's variables with (–) loading value=0.855; Factor's variables with (+) loading value rhythm pre: {point=0.916; norm=0.745;} pitch change: {point=0.689; norm=0.641;} Factor's variables with (–) loading value: pitch pre: {point= –0.88; norm= –0.825;} asymmetry pre: language improvement = –0.307; {point= –0.963; hemispheric type= –0.885;} rhythm change: {point= –0.702; norm= – 0.655;}
2nd Factor content: *post-test complex scales* Factor's commonality ≈64% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.913; Factor's variables with (+) loading value: common post: {point=0.904; norm=0.792;} common change: {point=0.777; norm=0.624;} total post point=0.904; total change=0.777;
3rd Factor content: *pre-test single scales* Factor's commonality ≈75% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.933; *a*-Cronbacha standardized value for factor's variables with (–) loading value=0.713; Factor's variables with (+) loading value: rhythm post: {point=0.865; norm=0.789;} Factor's variables with (–) loading value: pitch post:{point= –0.879; norm= –0.781;} asymmetry post:{point= –0.969; hemispheric type= –0.902;}
4th Factor content:*income learning state with hemispheric change type* Factor's commonality ≈54% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.821; Factor's variables with (+) loading value: hemispheric change tendency type=0.208; school grades' average:{point=0.908; top-down level=0.744;} mathematics grade:{point=0.831; top-down level=0.762;}
5th Factor content: *pre-test complex scales with musical activity type* Factor's commonality ≈65% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.836; Factor's variables with (+) loading value common pre:{point=0.942; norm=0.812;} total pre point=0.942; musical activity level=0.406;
6th Factor content:*mathematics learning efficiency improvement state* Factor's commonality ≈85% *a*-Cronbacha standardized value for factor's variables with (+) loading value=0.997; Factor's variables with (+) loading value mathematics improvement=0.931; mathematics-language improvement group=0.919;

The pitch has the opposite loading tendency to the rhythm in case of the hemispheric processing difference. The opposite loading tendency between language and mathematics might account for its hemispheric processing difference or probable small level of independence, where the combined group of mathematics and language improvement is mostly described by single mathematics improvement. The musical activity variable and language improvement variable are the only with low factor loading (0.406 and 0.307) in structural factor analysis model, thus these variables might be independent and single in research model, i.e. without significant grouping into the hidden factors of empirical variables' data in the case when factor grouping requires at least two variables. The musical activity is described by the 5th factor of income common and total musical memory with 16.5% of variance, while the language improvement is explained by the 1st factor of income separate hemispheric musical memory with its internal relation on income hemispheric musical brain condition with 9.4% of variance. The training influence is described by the 1st factor for the language improvement and by the 6th factor for the mathematics improvement with total 96% of variance, where the mathematics grade is the representative large key factor for school grades' average revealed by Pearson correlation value r=0.793; with p<0.001 in the whole empiric sample. Different factorial grouping of these variables might be the evidence of independence of these learning abilities. The hemispheric change tendency type variable has the low factorial loading in case of the only one complex scale in musical test's structure based on the combined relation of single musical scale of the pitch and of the rhythm change tendencies.

Path Analyzes of Empirical Factors of Working Aural Musical Memory Training Influence and Relation to Mathematics Learning Efficiency

Correlation analyses of language and mathematics improvement dichotomous integer variables revealed the significant high negative Spearman correlation value between these learning efficiency variables only in the group with the top level of school grades' average (*n*=25) with determinacy level 28% [*r*= –0.529; *p*=0.007], so for humans of the narrow population with the high level of the cognitive maturity learning, what might be the evidence of a local tendency of the inverse relation in the case of mathematics and language hemispheric processing difference, while in general population tendency these learning abilities are rather mostly independent what is in conformity with Gardner state about verbal-linguistic and logical mathematical separate intelligences modalities, with the factor analysis data of the language improvement factor loading with the negative value and in frequency structural indexes of the four naturally emerged combined grouping level by both mathematics and language improvement in the empirical sample (n=50) as the training influence's effect [single mathematics improvement (I)=0.32; single language improvement (II)=0.28; both mathematics and language improvement (III)=0.18; both mathematics and language non-change (IV)=0.22] with no significant differences [*p(I-II)*=0.662; *p(I-III)*=0.106; *p(I-IV)*=0.26; *p(II-III)*=0.234; *p(II-IV)*=0.488; *p(III-IV)*=0.617].

Correlation analyses of the music activity level binary integer variable and of both income common and total aural musical memory point scores according to 26 empirical groups [whole sample (1), both school grades' average and mathematics grade top - down level (4), both single and combined mathematics and language improvement state (8), both income and outcome hemispheric brain condition state (6) and its change-tendency state (3), combined musical activity and mathematics improvement (4) state] revealed the significant medium positive Spearman correlation value between these variables in whole empirical sample (*n*=50) with determinacy level 11% [*r*=0.333; *p*=0.022] and additionally in 3 empirical groups: with top school grades' average level with determinacy level 18.2% [*r*=0.427; *p*=0.034; *n*=25], with down mathematics grade level with determinacy level 17.7% [*r*=0.421; *p*=0.034; *n*=30], with single language improvement with determinacy level 21% [*r*=0.459; *p*=0.031; *n*=23], without significant difference between correlation indices of all four empirical groups [*p(I-II with I-III)* = 0.671; *p(I-IV)* = 0.576; *p(II-III)* = 0.979; *p(II-IV)* = 0.898; *p(III-IV)* = 0.873]. Therefore the musical activity influence moderate relation on the hemispheric homogenous musical processing and on the hemispheric activity with interhemispheric interaction and collaboration which increases the efficiency of brain functioning when the hemispheres are forced to cooperate during information processing in cognitive learning process, especially in the language learning decrease, on the background of enough sufficient cognitive learning maturity high level with normal or low level of the mathematics learning ability (i.e. grade level) in the case of probable low level of interhemispheric activity stimulated during music's influence, independently of working aural musical memory hemispheric laterality dominance type, as well in the income and outcome level as in the hemispheric change-tendency during working aural musical memory training influence, where the medium level of influence is conditioned by the low relation between musical intelligence and cognitive general intelligence factor (*g*) with cognitive intelligence general IQ score in individual human differences.

Correlation analyses of the mathematics learning efficiency improvement during working aural musical memory training influence, with total 20 quantitative variables in 20 empirical groups with 10 grouping categories (including grades' average and mathematics grade top - down level, combined musical activity and mathematics improvement, single language improvement state, income and outcome hemispheric musical brain condition state with its change-tendency state, gender factor) revealed general independence between the mathematics improvement and the musical variables, what has evidence in Gardner musical and mathematical intelligences modalities and in the factor analysis grouping of the present research where the mathematics variable was obtained as independent factorial category. However selected learning groups revealed the significant important key factors for training influence conditioning. Two groups with mathematics grade down level (n = 30) and with single language improvement without mathematics improvement (n = 23) obtained mathematical improvement during training influence by small negative relation with the low income school grades' average (N30: r = –0.431; p = 0.017; explained variance = 18.5%; N23: r = –0.468; p = 0.024; explained determinacy variance = 21.9%), where 1st group obtained also the low income mathematics grade (r = –0.462; p = 0.01; explained determinacy variance = 21.3%), so the participants with the lower cognitive learning ability (i.e. average of grades) have got higher mathematics improvement during working memory training influence, where mathematics grade is the representative key factor for school grades' average so usually is located in the same range level. While the group with the mathematics grade top level (n=20) obtained mathematical improvement during training influence by the high positive relation with aural musical memory for rhythm in the normalized scale at the outcome level (r = 0.677; p = 0.001; explained variance = 45.8%), and also by the high negative relation with the asymmetry of musical memory point scale at the outcome level (r = –0.54; p = 0.014; explained variance = 29%) where the inverse relation confirms the small level of hemispheric asymmetry between two single musical memory attributes for the pitch and for the rhythm conditioned by the hemispheric music processing difference. This group was characterized by the higher frequency tendency of pitch dominance hemispheric musical brain condition at the income level, so the working aural musical memory influenced the improvement of musical memory for the rhythm with additional minimizing the asymmetry of musical memory in point scale (i.e. the difference between two single musical memory attributes of pitch and of rhythm in point scale). Additionally the empirical group with the pitch-dominance hemispheric musical memory brain condition with state at the outcome level (n = 19) obtained mathematical improvement during training influence by the large negative relation with aural musical memory for rhythm in the point scale at the income level (r = –0.521; p = 0.022; explained variance = 27%) and by the large positive relation with this factor at the outcome level in the point scale (r = 0.539; p = 0.017; explained variance = 29%) and in the normalized scale (r = 0.688; p = 0.001; explained variance = 47.3%). These results suggest the principal key role of working aural musical memory training influence for the hemispheric alignment during music processing where the improvement of working musical rhythmical memory is the background for asymmetry of memory decrease for conditioning the tendency for the bilateral homogenous musical memory state for single musical memory attributes, where 8 participants in this group (42.2% of group frequency) obtained also the language improvement with the high probability in the case of the musical rhythmical memory increase, since musical processing for rhythmic temporal attributes of the music and the language processing both belong to the left hemispheric function.

CONCLUSION

The effects of background of music on the cognition are dependent on many factors. Even for the same cognitive intelligence task the background of music can facilitate, can impair or have no effect on cognitive task performance. The case might be located in the individual differences, in the musical activity level, in the musical preferences included the mood reaction predisposition and past experience of listening to the different and certain music style composition, and in the cognitive intelligence task type. Any music favored by the listener can temporarily improve arousal or mood and elevate cognitive performance, where physiological background of musical processing is independent case of the cognitive processing improvement explanation with listening to the specific music that forms up the EEG alpha brain state or the higher cognitive activity condition of the human brain and such evidences are located in the study with using the music from later baroque area and from earlier classics area. Working memory has principal key role in the learning efficiency process, academic achievement, and especially in the ergonomics of working learning at the school age, where aural perception comes more valuable for effective learning in the childhood period, where language factors such as reading comprehension are independent from mathematics learning ability in the evidences of the phonological loop in the working memory studies. Cognitive studies of working memory training background revealed several significant evidence of neuronal basis for its cognitive process influence on the general cognitive intelligence and on the learning efficiency process. Music aptitude is associated with the linguistic abilities, including the phonological processing and the facility in acquiring a second language, whereas the notion of a special link between musical and mathematical abilities does not have empirical support, including the principal different separate musical and mathematical intelligence modalities. However the specific background of music training can cause improvements in better cognitive mathematics performance and in higher mathematics ability among childhood period, including bilateral hemispheric processing of the mathematics and of the music, where neuroplasticity is the key role of the positive influence by music stimulation on the cognitive learning efficiency process. The musical training in the childhood tends also to be a good predictor of the high performance across a wide variety of cognitive tests, including tests of the working and the short-term memory, of the visuospatial abilities and of the language functions. Music training is also associated positively with general intelligence and with school performance in childhood where working memory training on the basis of musical stimulation might influence cognitive learning efficiency improvement. Children with higher general intelligence in childhood tend to the better school academic performance and to take music lessons which give influence on a variety of tests of cognitive ability and on the academic achievement. Music neuroscience has become a rapidly growing field within the area of cognitive neuroscience of music which is currently underway investigating the biological foundations of the musical cognition, of the musical ability and of the musical intelligence based on cognitive process, drawing on combined fields of genetics, of developmental and comparative research, of neurosciences and musicology. A better comprehension of the biological processes involved in the musical activities such as musical instrumental playing, and in the cognitive activities on the basis of musical activity of plane listening to the specific therapeutic music may have implications not only to the professional musical development, but also to the cognitive education in childhood, for the cognitive health care during all life and for the healthy cognitive aging on the basis of cognitive music therapy principles.

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