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Hemispheric Music Processing and Cognitive Improvement by Working Aural Musical Memory Training in Its Optimal Cognitive Maturity Age

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ABSTRACT

Cognitive psychology of music, musical medicine and neuroscience became rapidly growing disciplines within the area of cognitive neuroscience of music. The goal of present experimental research is investigating the hemispheric music processing on basis of functional asymmetry of music perception in parameter - specific lateralization model and investigating the working memory span of music, during working aural musical (WAM) memory training with its influences on cognitive learning efficiency in school - subjects improvement and in homework time abridgement, at its age of optimal cognitive maturity. Participants were 108 children aged 12 (at age of optimal cognitive maturity of working memory), where 60 subjects with completed participation in the WAM memory training went into final selection for two equal experimental groups (musicians, non-musicians) with double psychologic measurement (before and after training) by psychological WAM memory test, and by training efficiency questionnaire at the end of experimental procedure Obtained results from research confirm the scientific data from background research of the physiology of music, of the cognitive psychology of working memory and learning, also of the neuropsychology of music. Empirical data verify existence of music - memory brain types in the asymmetry of music perception - so therefore of WAM memory and of aural working memory span for music as the constant cognitive features, with the possibility of positive cognitive functions' stimulation by the music. The positive effects, which music produce in aural working memory training for healthy human brain, might be important in the framework of cognitive neuroscience, cognitive music-therapy, neuro-rehabilitation by music stimulation, musical activity and professional music education.

Keywords: functional asymmetry of music perception, hemispheric processing of music, physiology of music, working aural musical memory span, working memory training, cognitive improvement.

INTRODUCTION

BRAIN FUNCTIONAL EVIDENCE FOR HEMISPHERIC MUSIC PROCESSING ASYMMETRY

The asymmetry of aural perception and processing concerns classification in the lateralization specialty, where the domain-specific lateralization differentiates speech and music, while the parameter-specific lateralization model differentiates temporal and pitch aural attributes of the music. The scientific evidence, obtained from behavioral dichotic-listening studies, high-resolution EEG, whole-head MEG, fMRI and PET investigations, suggests that 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;), what belongs to the domain-specific lateralization. Auditory area called planum temporale, with the anatomical localization in the upper posterior end part of the temporal lobe, underlies this functional asymmetry already in infancy (Dehaene-Lambertz et al. 2002; Heimer, 1994;). Therefore brain is asymmetrically organized for the processing of speech and musical sounds already at the infant level. The research data obtained by Mazziotta et al. (1982), Jaramillo et al. (2001), Mathiak et al. (2002) and Naatanen et al. (Naatanen, 1992; Tervaniemi et al. 1999;) suggest that verbal stimulation activated more wide-spread areas in the left hemisphere, while the non-verbal stimulation activated more wide-spread areas in the right hemisphere. Nicholls (1996) research disclosed temporal processing asymmetries between the hemispheres with higher temporal resolution of the left hemisphere being assumed as prerequisite to the sequential organization of language perception and production. Additionally for the sound parameters with low-high pitch alternating sequences the left auditory cortex is displaying stronger activity during rapid pitch alterations while the right auditory cortex is displaying stronger activity during slow and small pitch alterations (Zatorre and Belin, 2001;). So the left auditory cortex is tuned to process fast sound changes whereas the right auditory areas are more advanced to process tiny changes in pitch.

This pattern of hemispheric asymmetry is relatively stable during both attentive and pre-attentive levels of processing the single acoustical attributes, although the behavioral reaction in dichotic listening is influenced by attentional demands (Hugdahl, 1995; Hugdahl et al. 2001;). In that technique two different auditory stimuli are presented to the participant simultaneously, exactly at the same time, one to each ear, by using the headphones (Hugdahl, 1998; Kimura, 1967;). Participant is asked to attend to one or to both of the auditory stimuli and to report the stimuli heard, although often instructed to report only the item heard first or best (Hugdahl, 1999;). Also the ear dominance during a dichotic-listening task can be modified by simply changing the instruction to selectively focus attention to either the right or left ear, and by reporting only from that one ear (top-down intra-individual effect). Generally in the dichotic-listening tests the subject is given to report freely the hearing syllable. When the subject is instructed to selectively listen to the right or to the left ear, the results changed in a clear majority of the cases (Bryden et al. 1983; Hugdahl et al. 1986; Mondor et al. 1991;). So the pattern of lateralization seems to be sensitive to several sound parameters, with strong evidence for the existence of the brain lateralization in audition but also for its vulnerability (Bryden, 1988; Hugdahl, 2002;).

The rhythm and the pitch are two fundamental principles of music organizing (Krumhansl, 2000;). Since music perception for the melody includes simultaneous processing of the „rhythmical pitches”, what is opposite for the perception of single acoustical pitch or rhythm attributes. Music processing occurs bilaterally in the brain, where for musical functions the temporal and rhythmic processing is predominantly left hemispheric whereas the pitch, melodic and harmonic processing is predominantly right hemispheric functions (Dalla Bella et al. 1999; Hall et al. 2002;). It describes whether the left and right auditory areas are specialized to process rhythmical changes versus pitch changes, what belongs to the parameter-specific lateralization and to the functional asymmetry of music perception principle. Independent studies by Overy et al. (2005) from children aged 5 - 7 with or without musical training, acquired fMRI data that showed clear auditory activations and some evidence for differential specialization of pitch and rhythm processing. The research data obtained by Zatorre (2001) and Peretz (2001) suggested that the different degree of myelinization in the left versus right hemispheres is leading into differential speed of neural processing in the hemispheres, and underlies behind their complementary functions, what was confirmed additionally in anatomical evidence by research of Anderson et al. (1999) and Penhune et al. (1996).

Rhythm and pitch skills have often been found to be disassociated in tests of musical ability (Dennis et al. 2001; Hyde et al. 2004;), and they have also been found to show different hemispheric lateralization, with the pitch tending toward a right-hemispheric dominance and with the rhythm tending toward a left-hemispheric dominance (Samson et al. 2001;). The right auditory cortex is particularly involved in spectral processing for timbre and fine-grained pitch discrimination, also for the perception of melodic contour (Hyde et al. 2008; Stewart, L. et al. 2006;). The left auditory cortex is particularly involved in the perception of melodic rhythmic discrimination and for rapid temporal processing (Peretz and Zatorre, 2005;). So human auditory cortex is functionally segregated, such that different fields are selectively sensitive to temporal or spectral acoustic features and those differences exist in the temporal and spectral resolving power between corresponding cortical fields in the two hemispheres. In FMRI functional imaging distinct cortical fields are primarily responsive to temporal as opposed to spectral sound features and their response properties differ in the two hemispheres. Increasing the rate of temporal change are preferentially recruit left auditory cortical areas, while increasing the number of spectral elements engage preferentially right auditory cortical regions. When a listener hears a musical melody, the tones are not heard as separate and isolated occurrences but perceptually grouped into coherent units. Numerous cues can influence this sequential grouping process in the relative strength of grouping based on the pitch or temporal attitudes as competing cues, what is empirically verified in Hamaoui and Deutsch (2010) studies about music perception principles. According to Nielsen et al. (2013) neuropsychological research with applying the neuroimaging for evaluation of left - brain versus right - brain hypothesis the lateralized brain networks appear to show local correlation across subjects with only very weak changes from childhood to early adulthood and very small, if any, differences with gender factor.

INFLUENCE OF MUSIC ON PHYSIOLOGY AND ON COGNITIVE FUNCTIONS

Physiology of Music

The relationship between the human body and the music is determined by the mechanism of physiological influence of music, what is equivalent to resonance and vibration effect (Galinska, 2000;). Classical music can change the EEG brain state, what can be traced throughout its sounding, after which its effect calms down (Leeds, 2001;). Maranto research revealed that the rhythm and the tempo cause physiological experience of music, which leads to the synchronization of biological rhythms of the human organism, such as the rhythm of breathing, heartbeat, blood pressure and brain waves, with the musical rhythm (Matera, 2002;). Muscular and vascular systems react on the rhythm, while the nervous system reacts on the sound height (pitch) and tonality (harmony). Listening to music in the slow pace, at which the rhythmic pulsation occurs at the rate of about 60 beats per minute, is corresponding to a quiet rhythm of the heartbeat. Musical phrases with rhythmic timing frequency of 6 cycles per minute can synchronize cardio - vascular rhythms regardless of the modulation of breathing (Grewe et al. 2005;). Listening to classical music with a slow tempo is accompanied by a decrease of the blood pressure, by slowing down the pulse and the proportion between low-frequency and high-frequency factors of changes in heart beating speed (Bernardi et al. 2006;). Neurologist B. Douglas (1953) applied auditory stimulation during general anesthesia in surgical operations with using the musical pieces «Claire de lune» by C. Debussy and first part of "Moonlight Sonata" by L. Beethoven. In contrary the rhythm and the tempo of «heavy metal» and «techno» music contributed for the development of arrhythmias and cardiovascular disorders (Burns et al. 1999;). According to clinical observations the classical music has most beneficial impact on humans: it soothes, relieves muscle tension and reduces anxiety (Leer et al. 2013;). A. Tomatis (1991) found that musical sounds with a frequency from 5000 till 8000 Hz are able to exert a therapeutic influence and to activate the mental alertness. At the same time the Mozart compositions are saturated with high frequency sounds, which strengthen microscopic muscles of the middle ear, which leads to an improvement of the hearing and speech. Mozart's music in the most amounts contains a high-frequency sounds that do have a therapeutic effect and do stimulate the brain: it is characterized by flow of "loud - quiet" sounds in the thirty-seconds range, which corresponds to the nature of biorhythms and biological currents of the human brain. Resonance in the cortex is caused by regular 20 - 30 seconds sequence of slow Mozart pieces, close to the time period of passing the EEG brain waves, and repeated in Mozart's music more frequently than in other music (Mozart effect. Segen's Medical Dictionary, 2011;).

Cognitive Music – Therapy: Listening to Music

The mental Alpha state has been found as optimal for effective learning process at an elevated mental focusing attention, it dominates in the music of the late baroque and of Mozart compositions (Mozart effect. Segen's Medical Dictionary, 2011;). This condition is a natural auto-synchronization of both hemispheres of the body and of deep relaxation in the range from 8 till 12 or 13 Hz, it takes place for a few minutes usually twice a day: early in the morning on waking up and in going to sleep at night, also in the conditions of deep sense concentration or of reverie.

It significantly increases the concentration of attention, the mental perception of new information and the memory (accelerated learning and remembering of new material), also the inspiration with creativity. Bach's music is also a safe, cheap and easy way to overcome insomnia by listening it for 45 minutes before bedtime to ensure reliable sleep (Harmat et al. 2008;). Listening to classical music and its performance has the same moderate positive influence on cognitive functions for both healthy individuals and patients with dementia (Witzke et al. 2008;). There have been identified four dominant groups of dementia symptoms on which classical music makes positive influence: auditory and verbal memory (Chan et al. 1998; Fujioka et al. 2006;), language functions (Barwick et al. 1989; Patel et al. 2007; Tallal et al. 2006;), emotions and mood (Omar et al. 2010;), neurosis and depression (Raglio et al. 2008;). Psychophysiological research of Gamon and Bragdon (2003) revealed that the music of late Baroque period increases dopamine release in the human brain, improves memory efficiency and promotes better hemispheric synchronization and increasing the alpha rhythms waves in the EEG of human brain. Its slow parts are filled with the sounds of the high frequencies and with the rhythms of 60 beats per minute which are ideal rhythms for the human heart working at the rest time when the work of human body and of human mind is synchronized. Listening to this music during the learning process improves memory, the memorizing of new foreign words and poems. The research of Mammarella et al. (2007) have shown that listening to "The Four Seasons" cycle of Vivaldi exerted a positive impact on the cognitive tasks performance by elderly people: memorization in working memory was better after listening to this music than in conditions of silence or white noise. The positive influence of Vivaldi music was also noted in solving problems of autobiographical memory by elderly patients with Alzheimer's disease (Irish et al. 2006; Thompson et al. 2005;).

Listening to music as a complex process activates simultaneously the functions of both hemispheres. According neuropsychologists L. Cuddy and J. Duffin (2005), it requires the integration of various components, including the pitch, rhythm, timbre, dynamic, music notation, on the base of sounding stimulus, also of visual, kinesthetic and emotional imageries. This activates the connection between the data of the behavior and the neurological processes of the human brain at the level of hemispheric affection. In the early stages of auditory processing of music (as well as in the process of playing on musical instrument) the hemispheric specialization is forming up. The right area of the auditory cortex is specialized in pitch analysis and in visual recording of musical notation; the left area of the auditory cortex is specialized in rhythm analysis and in time duration (Costa-Giomi 1999; Forgeard et al. 2008; Hassler et al. 1985; Rauscher et al. 1997; Rauscher et al. 2000;). Both hemispheres are involved in performance of complex musical tasks, and their simultaneous cortical reactions are integrating partially the modified and the healthy areas of human brain, what leads to rehabilitation and recovery of cognitive processes of the brain afflicted with dementia in the interchangeable brain substrates. Sound stimuli perceived by the ear during listening to music are transformed into neural impulses in the auditory nervous system, forming up the synchronization of neural impulses in the cerebral cortex, aligning their frequency, what corrects memory and attention, reduces muscle tension and fatigue syndromes, furtherly improves the coordination of movements (Drake et al. 2000; Kilgour et al. 2000;).

Association of analysis (left brain) and synthesis (right hemisphere) in information processing is arising in the inter-hemispheric synchronization (Palisca, 2001;). Additionally subcortical structures are spared out of the progressive destruction of the cortical tissue, thus they perform a correctional and rehabilitative role during listening to music. And the complexity of music as information material contributes to the preservation of the memory at the neuronal functional level and to the memorizing strategies development (Calvert et al. 1998; Cross, 2007;). By this way the classical music at the level of auditory influence does stimulate different types of memory and has an influence supporting the cognitive functions in patients with dementia, also performs a preventive role in reducing and deterring senile age-related changes in human cognitive sphere area.

Cognitive Music – Therapy: Music Performance Activity

Obtained in recent years neuropsychological data indicates a significant impact of musical activity on the human brain and on the life quality from early childhood till elder age (Elbert et al. 1995; Lotze et al. 2003; Sloboda, 2000;), also on the bilateral cortical reorganization (Hanna-Pladdy et al. 2011;) and on synchronous hemispheric activation (Schmithorst et al. 2002;). This leads to the improvement of sensorimotor functions development in young musicians instrumentalists (Fujioka et al. 2004; Meister, et al. 2005; Zatorre et al. 2007;). Early musical development also contributes to the earlier development of motor and cognitive functions (Costa-Giomi et al. 2001; Koelsch et al. 2005; Penhune et al. 2005;). Prolonged musical activity throughout the lifetime leads to the preservation of cognitive maturity in the elderly age for non-verbal memory and executive functions (Bangert et al. 2006;). Musical activity, including playing on the instrument and listening to music, stimulates different cognitive functions and, at the same time, can affect the neuroplasticity of the human brain that allows compensating the senile decline of cognitive functions (Monaghan et al. 1998; Zatorre et al. 2005;). Prolonged musical activity improves also the cognitive intelligence, it maintains cognitive maturity and flexibility in the elderly age (Schellenberg et al. 2008;), it reduces the eventual development of neurodegenerative process in the Alzheimer's disease (Johansson, 2002;). Performing music at home conditions, at work or at school can create the dynamic balance between more logical left hemisphere and more intuitive right hemisphere of human brain. The mental aging and age-related decline of cognitive abilities of instrumental performers of classical music slow down proportionally to the intensity of their music activities (Brodsky, 2011; Hanna-Pladdy et al. 2012; Wan et al. 2010;).

Musicians in comparison to non-musicians have elevated level of melatonin (Hessler, 2000;), which is the main regulator of circadian rhythms in restoring the sleep cycle (Buscemi et al. 2004;), it slows the aging decline processes and increases the lifespan (Reiter et al. 2001;), also contributes to the rejuvenating effect (Anisimov, 2008;). As a result the professional musicians - performers of classical music preserve longer the cognitive abilities (Staud, 2003;) as well as the physiological resources which provide longevity. Gerontologists Zharinov and Anisimov (2014) analyzed the biographical data about the age of death and about the longevity among 8775 Russian musicians - representatives of different specializations and directions, separately for men and women, obtained on the base of electronic version of "Big Biographical Encyclopedia" (2005).

The analysis showed that the rock musicians were living shortest - the mean average age of death - MAD - for men was 45 years (n = 421) and for women was 37.7 years (n = 37). In another study among MAD of 1489 rock musicians and pop music performers of other countries that have achieved the popularity between 1956 and 2006, there were obtained similar results - 45.2 years in North America and 39.6 years in the European Union countries [(Bellis et al. 2012;). Significant differences were also revealed in the distribution type of MAD for groups of rock musicians and of musicians of classical genres for all countries. For classical musicians the index was close to the norm average - at the level of 73 years old, but for the rock-musicians the index was left-sized and obtained 27 years old. By this method it has been proved in independent studies that professional musicians - performers of classical music do live much longer than a rock-musicians and even jazz musicians (Spencer, 1991;). The analysis of bilateral statistical significance of gender difference of average MAD indices for the same type of musical activity did not reveal the influence of gender factor as differentiating MAD coefficient for professional musicians. According to these data the gender as a biological factor does not cause the predisposition for longevity in professional musicians. For the musical activity kinds there were revealed statistically significant differences at the level of $p < 0.0001$ between rock musicians (male = 0.45; N = 421; women = 0.377; N = 37;) and three groups of professional classical music performers: violinists (males = 0.7; N = 753; women = 0.774; N = 47;), pianists (male = 0.686; N = 924; women = 0.74; N = 231) and classical opera, choral singers (male = 0.676; N = 769; female = 0.718; N = 582;). Thus three types of professional classical musical activity were revealed that are the most favorable for human longevity (in contrast to rock musicians).

Cognitive Music – Therapy: Therapeutic Music Specification

The term "therapeutic classics" refers to the period of "golden century of classical music" (The Oxford Dictionary of Music, 2013;) and combines the music from Bach and Vivaldi - the late Baroque era (from 1710) with music created by composers who are called "early classics" - until 1790 (Bukofzer, 1947;). It includes the early classicism period and the end of Mozart's life as the Viennese classic, with the period of early works of Beethoven, as the later classicism. In terms of music theory and music medicine the Bach music grew up on the ideal harmonic basis where the voices are dependent on the rate of heartbeat and respiration (Katz, 2007;). The biological rhythms were taken into account in determining music tempo until the beginning of 19-th century - until the moment of inventing the metronome by G. Maelzel, firstly used by Beethoven for mathematically – calculated tempo designations. In the Baroque period and early classical period the tempo has been indicated by the Italian words and reflected the subjective understanding of the speed by each musical performer on the experience of its internal rhythms of heartbeat or breathing (Epstein 1995;). Music of the late baroque period and early classicism period is built on classical harmony, where the tonality is the organizing key factor (Marty, 1988;). The cycle of preludes and fugues of Bach "The Well-Tempered Clavier" might be a striking example of this, i.e. cycle of major and minor preludes and fugues for all 12 chromatic sounds that make up the musical alphabet in equal-tempered-musical-key-system (Ledbetter, 2002;).

The tonal music is devoid of dissonance (irritable harmonies) additionally and increases the level of serotonin and catecholamine which contribute to the increase of mental alertness. A melody in music of late baroque period and early classical period is prolonged and focused on the development, its rhythm tends to temporary regularity, the musical phrase tends to symmetry, the sound dynamics in compositions of that period is balanced, the effects of significant crescendo and diminuendo – i.e. dynamical increasing or decreasing the sound volume - were excluded (Kottick, 2003;). At the same time the absence of crescendo and diminuendo with presence of stable monotonic dynamic sonority is the key issue for the human physiology. The symmetrical structuring of the phrases and aligned rhythms, as well as repetitiveness and similarity of motives, contribute to the alignment of functional rhythms in the listener's human body. Music played on string instruments in the range within 5 - 8 kHz stimulates also the brain rhythms responsible for the mental activity of the human brain (Mockel et al. 1994;). Small loudness, regular rhythmic pulsation and structural repetitiveness contribute to the synchronization of organism rhythms with the pulsation of musical sound structures (Dritsas, 2003; Sakalak, 2004;). In the era of "therapeutic music" the sound range was used about of 30 - 35 db.

Six main parameters of the structure of music are the key for human physiology: 1 - timbre; 2 - melody; 3 - harmony; 4 - rhythm; 5 - dynamic; and 6 - tempo. The medical data medical research results published in the scientific literature allow supposing that physiologically neutral or therapeutic classical music is characterized by the presence of following six structural and acoustic properties: 1 - this music is extracted by stringed instruments or by wind instruments with high acoustic sound frequencies; 2 - this music is ordered in the pitch-organization of sounds, in equal – tempered –musical – key – system, in modal certainty – minor and major tonality; it is dominated by consonant(pure - sounding) harmonies and by non-irritating ear modulation transitions; 3 - this music contains the polyphonic relation between voices or the homophonic melody with the accompaniment organized on order of digital bass functions; 4 - this music has a uniform division of melodic phrases in four-bars or eight-bars periods; 5 - the tempo of this music corresponds to the physiological rhythms of human organs and systems, such as heart rate frequencies, ovulatory cycles, rhythms of hormones' secretion, release of internal fluids, rhythms of EEG brain waves, breathing cycles at the rest and at the moderate physical activity, rhythms of pedometers and of optimal speed of walking distance - in which one musical bar corresponds in the music sounding speed to the equal part proportion of the human physiological rhythms (such a tempo is typical for slow second parts of instrumental concerts of late baroque and early classicism periods); 6 - this music has dynamically aligned sonority in the lower register of the loudness in the range up to 50 dB, and a short time dynamical changes with small differences (small delicate increase or decrease of sounding), included in this range of the dynamic loudness and not going beyond this limits).

Classical music composers' compositions created after the golden age of therapeutic music period include also selected pieces corresponding to the relevant criteria described above. However, there is no presented list of classical musical pieces in scientific medical literature currently, which would be empirically verified and revised for the evidence of the positive physiological influence effect for widespread practical application, what requires further research in the field of music medicine.

WAM MEMORY TRAINING STIMULATION SPECIFICS

The field of neuroscience is well acquainted with the effects of short-term memory training and sensory enrichment, where immediate short-term training effects are seen in audio-motor areas as well as in auditory cortical-evoked responses (Anderson et al. 2013; Linkenhoker et al. 2002; Recanzone et al. 1993; Song et al. 2008;). The short-term auditory memory training leads to plasticity within auditory cortex regarding the task that is trained. The aural musical training has been shown to modulate uni-modal cortical processing and enhance neuronal co-activation of involved auditory cortical structures (Lahav et al. 2007; Pantev et al. 1998;). Several empirical studies investigated and verified effects of auditory training on auditory perceptual skills, where it is possible to induce plastic changes through specific and relatively short-term training (Zarate et al. 2010;). The frequency of aural discrimination training over the course of one week (Jancke et al. 2001;) or three weeks Menning et al. 2000;) led to fast behavioral improvements that were showing fast plastic changes in auditory cortex. Subjects who improved in the course of the musical aural training and showed improved auditory acuity also demonstrated decreased activity in auditory areas (planum temporale and superior temporal sulcus) in fMRI at the end of the training. However, a follow-up measurement in 1 week and in 3 weeks after the end of the training revealed that these changes are not lasting, what is not surprising in principles of music physiology influence which occurs only during the presence of music stimulation and in very short period after ending of its sounding.

The short-term auditory training with music can fundamentally alter the brain's representation of speech and other sounds, in the development of superior auditory skills extending auditory cognitive abilities, such as auditory and spatial working memory, selective and sustained attention, involving school-age children (Kraus et al. 2013; Trainor et al. 2003;). Cognitive behavioral studies have shown mixed evidence for positive transfer effects between music training and spatiotemporal abilities (Hetland, 2000;), 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) showed improved vocabulary knowledge and executive function in children after only 20 days of computerized musical training, and suggested that transfer effects on cognitive skills can occur over a very short period of time, since musical training requires individuals to learn to pay attention to several features of sounds, such as: pitch, timing and timbre. The brief aural musical training can also increase the blood flow in the left hemisphere of our brain, so can lead to the increased use of the left hemisphere of the brain. The areas responsible for music and language share common brain pathways for musicians and non-musicians (Spray, 2014;). Thus musical training results in a rapid change in the cognitive mechanisms are utilized for music perception and these shared mechanisms are usually employed for the language processing, so music and speech share common processes (Besson et al. 2007; Patel, 2003;) and brain networks demonstrated in neuroimaging research (Koelsch, 2005; Koelsch et al. 2002; Ozdemir et al. 2006; Patel et al. 1998; Schon et al. 2004;). Music processing typically engages the functioning of both cerebral hemispheres in musicians and non-musicians, so 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;).

It suggests that previous music exposure primes the brain for future learning. Therefore the training by music can enhance neural and cognitive functions, also can influence learning in other fields, providing a potential mechanism for 'near transfer' effects, and the broader cognitive and behavioral benefits of engaging the brain in music.

METHODOLOGY

Study Subject Description

The research subject – i.e. WAM memory is a measure of one's potential cognitive ability, process or feature, with presence of the natural distribution in population, based on the musical audiation. It is inborn, innate resource which is presented in each health human brain (Gordon, 1997; 2013;), while the amusia is based on brain disorders involving impossibility to perceive and to understand musical attributes (Peretz, 2002;). The maturity of this feature is determined by musical audiation and working memory development. Empirical studies of Gordon (1998) on musical audiation development revealed basic principles and verified that musical abilities are developed and stabilized around the age of 9 years old, after that period they cease to be influenced by the external environment. At that age of cognitive development there are crystalized the first constant symptoms of mature musical memory, especially aural perception and processing music, formed to the age of 10 years old. Empirical studies of Salthouse (1994), Cowan and Alloway (2008) verified that working memory capacity tends to get optimized and become mature around 12th age and remains stable until elder age. These data confirm earlier researches of music psychologists Thackray (1973) and Wing (1941). Additionally recent Baddeley, Hitch and Williamson (2003, 2010) studies, also Helmbold, Rammsayer and Altenmuller (2005) research on working memory span of musicians and non-musicians verified a close duration for such type of material as music and speech, for verbal and musical sequences, with similarities including limited capacity, without statistically significant difference between the groups and genders. Therefore the music activity, such as WAM memory training or musical education, does not influence and change the WAM memory span. It comes as independent evidence that this cognitive feature has biological limitations without the possibility of increasing during the professional training or activity. The WAM memory is the secondary feature formed on the basis of music perception, i.e. musical audiation, and it shows hemispheric specialization in music processing, where the music perception requires common simultaneous activation of both hemispheres.

The cerebral hemispheric asymmetry in the melody processing is formed up against the background of temporary and tone restriction of music processing by different hemispheres at its simultaneous functional involvement. It is presented already in infants and is resistant to functional changing during the stimulation by cognitive aural musical training, 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 and Peretz, 2001;). The dominant right hemisphere (discriminating the tonal attributes) is responsible for better WAM memory for pitch - existence of "right musical memory brain", while the dominant left hemisphere (differentiating the temporal attributes) is responsible for better WAM memory for rhythm - existence of "left musical memory brain" (Moore, 2012; Platel et al. 1997; Springer et al. 2001;).

The small value of hemispheric dominance in music processing brings no significant difference between levels of both hemispheric activation and forms up "homogenous musical memory brain". Fresh empirical research on subjects aged 12^{th} in sample of above 1300 children brought data about symmetrical distribution of the left-right musical memory brain types in population around 41% and 44 %, where 15 % subjects in the sample demonstrated the "homogenous musical memory brain", and volume of shared (synchronized) musical memory occurs around 10 % into separate pitch and rhythm scales (Dymnikowa, 2015;). Therefore the functional asymmetry of music perception determines the aural musical memory asymmetry, what was taken into account in constructing the test of the cognitive feature measurement, with preparation the scale "asymmetry of memory". The effective measurement of this feature is possible with using unknown material during aural psychological testing, as it is reserved for the methodology of working memory diagnosis and studies, and using the melody as semantic unit of music's structure and facture, based and prepared on musical solfeggio material (Davies, 1978;). The hemispheric music processing and WAM memory are constant cognitive features based on developmental maturity principles, and they are resistant to music education independently of length of musical activity and systematic training. It is not decisive for the musical memory development level (Dowling et al. 1971; Horbulewicz, 1963;). However by physiological influence of music on cognitive functions, especially on working memory, the aural working memory training increases the cognitive condition and influences the cognitive efficiency of learning process, which might be observed in school subjects' grades or in time abridgement of homeworking after school lessons. The research subject is measured by behavioral method, by psychological test with behavioral reaction on perceived acoustical stimuli during the serial recall method with completing the paper test.

Structure of the test includes two principles: I - 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 music perception and therefore of the WAM memory. Working memory comes after sensory memory as the continual temporary memory when perceived sensory information is being taken in by sensory receptors and processing out with involving attentional process (as synonymous of the working memory process). Aural working memory is activated after the sensory aural memory of sounds, i.e. echoic memory, which is capable of storing the auditory information that is retained for a short time period of 3 – 4 seconds, however slightly longer than for storing the sensory visual information, i.e. iconic memory (Carlson, et al. 2010;). Empirical evidences about time perception of duration representation integrate structures of perception and action into units (1–2 and so on), each of which does not exceed duration of up to 2–3 seconds (Szelag et al. 1996; Wittmann, 1999; 2013;), with maximal capacity (integration interval) of approximately 3 seconds (Mates et al. 1994;); II - melody range, with the 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;).

Objectives of the Study

The aim of the present research was experimental verification of positive influence of the WAM memory stimulation as dynamical part-time brain condition during aural music perception, on complex cognitive functions improvement, i.e. on learning process efficiency observed in selective school subjects, and in the time needed for preparing school homework inflicted in the educational process. The data of the training influence were obtained by the questionnaire procedure with open questions for qualitative scientific information at the end of training session after completing the post-test. The accompanied aim of the present study was scientific empirical verification of aural working memory span for music, and of functional asymmetry of music perception principle, and therefore of "asymmetry of WAM memory" as the constant cognitive features, where the asymmetry is also based on the brain organization of hemispheric music processing. Verification was realized during experimental procedure with WAM memory stimulation for 4 months, with 30 training sessions of 1,5 h duration twice per week, prepared with methodological principles of working memory training. The scientific data were obtained by the WAM memory test procedure with scales for musical memory and its asymmetry, in the form of the paper test completing answers. Test with duration for 11 minutes was presented twice during training procedure (in pre-test and in post-test). The experimental groups were differentiated by absence or by presence of musical activity and by the level of asymmetry of aural musical memory indices for dynamic tendency of changes between measurements by two test versions. The scientific qualitative data about learning process efficiency was obtained at the end of training, in completing the qualitative questionnaire with open questions.

Experimental Procedure and Participants

The experimental procedure includes aural working memory training with using the same facture as in psychological test, i.e. natural piano sound with the structure of training material prepared on the principles of therapeutic music prescriptions presented in introduction. It is based on forming up the "memory trace continuity" by consolidation of memory trace with differences in the range of stimulating aural musical solfeggio material, which is presented once or twice and repeated by several techniques for aural recognition of the material that has been memorized earlier. The continuity is possible to form up with using melody what has prolonged structure unlike selective units of musical tones or of rhythmic patterns. The memory training exercises are based on the techniques that are used in working memory tests in cognitive intelligence tests, with variants of manipulation of stimuli material presentation at the level of encoding and recognition levels in memorizing process. The training session includes internal break announced by participants or by trainer after behavioral reactions of their mental fatigue syndromes. The test material was recorded on CD, while the training material was presented on music instrument (piano). The experimental procedure involved children aged 12, who have got parents' acceptance for that cognitive activity and double testing process. Children who do not have enough development or skill level of musical audiation were expected to unsubscribe from further participation in the WAM memory training after perceiving first sessions. They could voluntarily resign at any moment of measurement and of training time without any consequences.

The final selection for the research group included participants who have presented internal motivation for WAM memory training activity and were participating all training sessions, even with delayed time in the case of absence at the time-table of the training schedule. Totally 108 children from primary schools and with additional professional music education were participating in the first training session, with the final selection into two experimental groups for 30 subjects (primary non-musicians and musicians). The psychological data were collected through aural paper - test survey and the paper qualitative questionnaire with open questions, encoded and analyzed by Statistica software.

Research Methods

The WAM memory test includes two versions with ten one-voice melodies. The tasks were performed on the tuned piano in the professional music studio in music conservatory with submission of sound directing of music material during recording the test. It measures the working memorizing with the recognition of the repeated original version among three reproductions, where one is correct and two are changed separately in pitch or in rhythm. The test completion is prepared for choosing the correct reproduction from three versions (original, with pitch change or rhythm change) which is similar to the original version presented at the beginning of the aural task. The time duration of each aural musical task is around 1 minute, with the range of 6 bars and time duration of original example presentation in the tasks for 9 - 12 seconds, what is located in aural working memory span for music. All examples of original version and of repeated variants are presented once in the test. The duration of silence break between the presented versions and tasks is around 5 – 6 seconds. The diagnostic material was prepared by studies of specific musical methodic literature on musical solfeggio. The test includes two basic primary scales: memory for pitch (correct answer or version with rhythm change), memory for rhythm (correct answer or version with pitch change), and two complex scales including neuropsychological aspect: index of common (shared) memory (i.e. correct answer) and index of asymmetry of memory with the difference relation between indices of memory for pitch and for rhythm. The information about coming each new task in test is presented by short high frequency acoustic signal (i.e. ultra-sound). Each melody is characterized by four independent musical attributes: ambitus - small, big (range between highest and lowest pitch in melody task); octaves' register - big, small, 1st, 2nd, 3rd; tonality - major, natural minor, harmonic minor, atonal; the meter - even, non-even.

The qualitative questionnaire with 3 open questions included contents:
1) - was the training of any help to the participant;
2) - did the participant note in last months the decrease of time spending for school homework and how much;
3) - did the participant start getting in last months the increase of grades from any school subjects and from which.

Research Methodologic Establishment

The verification of positive influence of WAM memory stimulation on the complex cognitive functions improvement, (i.e. learning process efficiency observed in selective school subjects, and in time needed for preparing school homework inflicted at educational process) was carried out by feedback data in the outcome open qualitative data from the questionnaire which was completed at the end of training after post-test. The obtained data was grouped in quantitative scales (time abridgment of school homework, two-point scale yes-no for selected school subjects and for training help) with frequency indices of obtained qualitative tendencies. The scientific empirical verification of the aural working memory span for music and of asymmetry of the WAM memory (as secondary result of the functional asymmetry of music perception) as constant cognitive features was carried out by analysis of variance between mean values and by analysis of correlation between total indices of test scales, including estimation of scale scores' distribution. The data from these verifications included categorization into two experimental groups - musicians (with additional music education) and non-musicians (without additional music education). Additionally scores with the difference index of the asymmetry of memory between two measurements (pre-test and post-test) were categorized into three qualitative empirical groups as types of the dynamic tendencies during working memory training influence on participants: without, with low and with high presence of asymmetry tendency. The obtained frequencies and qualitative combinations of grouping dynamic tendencies for basic musical memory scales of pitch and of rhythm were compared to the normal distribution for looking in tendencies of each dynamic category obtained in experimental research (Tabachnick et al. 2013;). The gender factor was checked by analyses of variance with the mean value of the test scale asymmetry of musical memory in two tests (pre-test and post-test).

EMPIRICAL RESULTS AND DISCUSSION

Normalized Statistics of Test Scales Scores' Distribution

The descriptive values of distribution by skewness and kurtosis obtained in research are represented by the normal distribution in both test versions in basic test scales (table 1) with expectance basic requirement of location within the numeral range [-0,5; 0,5], except pitch memory scale in version 1 (i.e. before training) with kurtosis index -0.7, which comes to normal distribution to kurtosis index 0.0 in version after training, what is the primary condition of psychological cognitive feature measurement.

Table 1. Descriptive normalized statistics for the test scales distribution

Version 1				
Scale	Mean	Standard deviation	Skewness	Kurtosis
Pitch memory	6.6	1.6	- 0.1	- 0.7
Rhythm memory	6.9	1.4	- 0.4	- 0.2
Common memory	3.6	1.1	- 0.2	- 0.3
Asymmetry of memory	-0.3	2.8	0.0	- 0.7
Version 2				
Scale	Mean	Standard deviation	Skewness	Kurtosis
Pitch memory	7.8	1.3	- 0.4	0.0
Rhythm memory	6.9	1.4	0.0	- 0.3
Common memory	4.8	1.2	0.1	0.1
Asymmetry of memory	0.9	2.5	- 0.1	- 0.6

The complex scale of "asymmetry of memory" reveals the decrease in the kurtosis index (from -0.7 to 0.6) and in the mean value (from -0.3 to 0.9) what describes the training influence which conditioned more equal hemispheric activity level. It is additionally noticed in the mean value of common memory (from 3.6 to 4.8) with the accompanying increase of pitch memory (from 6.6. to 7.8) with stable mean value for the rhythm memory (6.9), what is presented in positive tendency change for asymmetry of the memory index (+1,4), where the "+" means pitch memory improvement (significant difference p = 0.014 between pre- and post- indices of asymmetry of memory). Independent checking of the normal distribution of skewness indices (table 2) revealed right-size distribution (Mean>Median>Modal) only for the pitch memory scale and for the asymmetry of memory scale in 1st test version, what confirms independently that asymmetry of memory is described by the pitch memory in 1st test version, and revealed a little left-size distribution (Mean<Median<Modal) for the rhythm memory scale in 1 test version. In the 2nd test version (after training) all scales reveal normal distribution (Mean=Median=Modal), what is certificate of cognitive function principles during training influence, where improvement means aligned balanced development. It is independent confirmation of un-changeable WAM memory span during training influence (i.e. equal level), as stable cognitive attribute, since both test versions have the same melody range (Baddeley, Hitch and Williamson, 2003; 2010; Helmbold, Rammsayer, Altenmuller, 2005;).

Table 2. Skewness indices of the test scales distribution

	Version 1 – before training			Version 2 – after training		
Scale	Mean	Median	Modal	Mean	Median	Modal
Pitch memory	6.6	6.5	6	7.8	8	8
Rhythm memory	6.9	7	8	6.9	7	7
Common memory	3.6	4	4	4.8	5	5
Asymmetry of memory	-0.3	-1	-1	0.9	1	1

The normal distribution index of common memory, with statistical two-tailed significance of the mean values differences ($p < 0.001$) testifies additionally for the training influence, which contributed to a high level of hemispheric synchronization of musical memory, and so revealed development tendency to the "homogenous musical memory brain" state direction what seems to be additional confirmation of asymmetry of musical memory state as the cognitive process. In addition the mean value of the common memory scale is lower in both scales, in comparing to pitch memory and to rhythm memory single scales, what reveals the neuropsychological background of this scale, since it represents correct answers for both single scales, what might be expected at the lower level with taking into account its dependency on the asymmetry of music perception and therefore also asymmetry of musical memory, which demonstrated significant decrease during working memory training influence.

Analyzes of Variance for Gender and Musical Activity of Test Scales Scores' Distribution

No significant two-tailed differences were revealed in musical test scales for the gender factor (28 males and 32 females) presented in table 3 ($p>0.05$ of all indices) what replicate the neuropsychological studies on hemispheric music perception and additionally reveals that present psychological test of WAM memory includes neuropsychological background in the construction of its measurement.

It is also independent empirical confirmation that functional asymmetry of music perception, and thus of WAM memory with the musical memory brain state type does not depend on the gender factor at the inborn level and in the output level during working memory training influence (Nielsen et al. 2013; Zatorre and Peretz, 2001;)

Table 3. Gender indices of the test scales distribution

	Male		Female		*p* stat. index
Test scales and versions	Mean index	SD index	Mean index	SD index	
Pitch memory in pre-test	6.695	1.294	6.555	1.887	0.742
Pitch memory in post-test	7.695	1.550	8.000	1.240	0.393
Rhythm memory in pre-test	7.000	1.477	6.962	1.372	0.918
Rhythm memory in post-test	6.913	1.592	6.962	1.315	0.896
Common memory in pre-test	3.695	1.105	3.518	1.155	0.548
Common memory in post-test	4.608	1.117	4.962	1.315	0.269
Asymmetry of memory in pre-test	-0.304	2.548	-0.407	3.091	0.889
Asymmetry of memory in post-test	0.782	2.938	1.037	2.192	0.702

No significant two-tailed differences were revealed in musical test scales for the gender factor (both 30 musicians and non-musicians) presented in table 4 (p>0.05 of all indices) except the significant difference (t_{58} = 2,598; df=58; 2-tailed p=0,012;) for common memory indices in pretest with significant higher level for that musical memory attribute in musicians' group (M = 3.96; SD = 0.978;) in comparison with non-musicians' group (M = 3.24; SD = 1.164;), with d Cohena effect ($2t/\sqrt{df}$) = 0,68 in the average effect size. These data confirm scientific studies about general equal level with basic musical memory attributes (memory for the pitch and for the rhythm) concerning working memory span for music (Baddeley, Hitch and Williamson, 2003; 2010;) and input musical memory development level (Dowling et al. 1971; Horbulewicz, 1963;). However common memory is neuropsychological scale of hemispheric synchronization of music processing, therefore it confirms scientific empirical evidences about physiology of music where music activity contributes to the higher level of hemispheric synchronization of aural working musical memory in the input level, and thus the higher volume of synchronization of musical memory in separate memory scales of the musical pitch and of the musical rhythm. Obtained empirical results verify empirical neuropsychological Palisca (2001), Cuddy and Duffin (2005) studies on influence of listening to music on simultaneous activation functions of both hemispheres, where it requires the integration of various components, such as the pitch and the rhythm aural attributes, so determines the inter-hemispheric synchronization (Schmithorst et al. 2002;). It also activates the connection between behavior and neuronal processes in the human brain at the level of hemispheric affection.

Table 4. Musical activity indices of the test scales distribution

	Musicians		Non-musicians		*p* stat. index
Test scales and versions	Mean index	SD index	Mean index	SD index	
Pitch memory in pre-test	6.76	1.451	6.48	1.805	0.510
Pitch memory in post-test	8.04	1.24	7.68	1.519	0.318
Rhythm memory in pre-test	7.2	1.19	6.76	1.588	0.229
Rhythm memory in post-test	6.64	1.577	7.24	1.234	0.106
Common memory in pre-test	*3.96*	*0.978*	*3.24*	*1.164*	*0.012*
Common memory in post-test	4.68	0.945	4.92	1.469	0.454
Asymmetry of memory in pre-test	-0.44	2.467	-0.28	3.195	0.828
Asymmetry of memory in post-test	1.4	2.677	0.44	2.346	0.151

No significant two-tailed difference for the common memory at the output level (after training) reveals that training has psychological specifics with possibility to improve common memory only until some limit level as arising from hemispheric conditions of functional asymmetry of music perception, and thus of aural WAM memory which are inborn and show very weak changes during working memory training influence (Nielsen et al. 2013; Zatorre and Peretz, 2001;). It might be confirmation of biological resources of synchronization of aural musical memory volume, which in musicians seems to be higher at the input level because of principle of physiology of music influence on aural musical memory brain condition, but these resources are able to get activated by psychological training of WAM memory also in non-musicians, who got the higher level of common memory development during training stimulation at the post-test measurement, in comparison to musicians. No significant difference for asymmetry of memory scales for the gender, musical activity and training factors reveals that this attribute is cognitive function of aural musical memory, with the equal stable level in human brain, as well in neuro-image scientific data, as in behavioral measurement by psychological test, with weak changes during training influence arising from physiology of music principles with hemispheric synchronization of neuropsychological resources.

Analyzes of Functional Asymmetry of Music Perception of Test Scales Scores' Distribution

Neuropsychological conditions for functional asymmetry of music perception has been checked on the whole experimental 60 subjects by two scales of different hemispheric music processing organization, by indices of memory for the pitch and for the rhythm, with using the two-tailed correlation analyses based on the Pearson values due to the normal distribution scores and quantitative scales in the test (table 5). In addition the normalized scale with equal norm range for both test versions [no significant difference between two structure indicators of size-level in <norm range (p=0.77) and in norm range (p=0.82)] of the common memory for 12th age became the grouping variable, which excludes a shared variance, i.e. the scores of points that are incorporated and included simultaneously into both scales. Therefore it allows and brings conditions for analyzing only the part of the score that was pointed to the selective scale as size – answers. The common memory scale is coefficient of the synchronization musical memory index which is included in separate different hemispheric scales – the pitch memory and the rhythm memory.

Table 5. Dependence statistics of pitch memory and rhythm memory scales in two test versions with two-tailed Pearson correlation indices for significance p < 0,001, determinacy index, variance of common memory level in separate memory scales, and undescribed level of scores in norm levels grouped by the norm ranges of the common memory with exclusion of shared variance.

Test version	Common memory norm range	Scale Points	Volume level of common memory scale	% of sample size	Pearson index	Standardized (for 2 scales) determinacy index in %	% of common memory in separate scale	% of variance undescribed by scale
1	< Norm	1 – 2	< 20 %	18	-0.984	97	≈ 20	3
	Norm	3 – 4	30 – 40 %	58	-0.939	88	≈ 45	12
	> Norm	5 – 6	50 – 60 %	24	-0.962	92	≈ 65	8
2	< Norm	2 – 3	< 30 %	16	-0.986	97	≈ 30	3
	Norm	4 – 5	40 – 50 %	60	-0.926	85	≈ 59	15
	> Norm	6 - 7 - 8	60 – 80 %	24	-0.823	66	> 91	7 – 14 *

* dependency in function: {(1-low \ high volume level of common memory scale) * standardized determinacy index for 2 scales+low \ high volume level of common memory scale};{1-[0.6\0.8]}*0.66+[0.6\0.8]; total range 0.86-0.93.

Obtained data include the values in the range higher than 0.7 or 0.8 as defining the very high level of correlation (Tabachnick et al. 2013;) dependence. The norm range of the samples (58% in the 1 version and 60 % in 2 the version) seems to be completed in the range of the 1st standard deviation in the Gauss distribution (68 – 69%), while the surrounding ranges are almost equal. Thus the obtained empirical values can be representative for 12th age in population. The negative direction in the correlation relation confirms the neuropsychological principle of asymmetry of music perception. The % of undescribed level by the test scales is lower than 15 %, therefore it might confirm the reliable diagnostic measurement in above 85 % of obtained empirical results. These results can reveal the scientific importance for justification of the functional asymmetry of the music perception and in consequence of the aural musical memory as the brain conditions.

Correlation indices revealed no significant two-tailed differences between test versions in the low and middle norm ranges (in <norm level p=0.72; in norm level p=0.59;) what certificate no significant differences in level of asymmetry of memory of training participant, which didn't reduce the volume of that cognitive feature during training stimulation. Significant two-tailed difference was revealed between test versions in the high norm range (>norm level p<0.001;) what is conditioned by high level of musical memory hemispheric synchronization (common memory) variance in separate memory scales' scores' (of the pitch and of the rhythm) of participants obtained during training stimulation. Additionally determinacy index of the pitch-rhythm dependency in the volume of 0,66 is described only by 20 – 40% of separate memory scales in the case of common memory level in this norm range around 60 – 80% of scale's score, where the total level of the common memory in separate memory scale is described exactly between 91% and 122% (so over 100 %), with dependency relation function: {% of common memory in separate scale * determinacy index in % = low / high volume level of common memory scales}. Thus asymmetry of the memory indices measured in separate memory scales in this norm range are highly suppressed by high level of accompanying common memory scale. It seems to be independent verification that the training stimulation contributes to the higher level of aural musical memory hemispheric synchronization in participants with income high level (>norm) of common memory, which is arising especially from musical activity state. The frequency distribution of common memory pre-post level for the norm-range scale reveals this principle (2% with 1-1 code, 16 % with 1-2 code, 60% with 2-2 code, 20 % with 2-3 code, 2 % with 3-3 code). Nobody got second number lower than the first number in the code, where 80 % of experimental subjects obtained norm-range of common memory after the training stimulation (1-2 and 2-2 codes). The >norm range for the common memory is reserved mainly for 20 % of subjects who improved to 3 level from the norm range (with only 2% i.e. 1 subject with high common memory level at the beginning of experimental training studies, what is symmetrical in the 1-1 code tendency), but there is no two-tailed significant difference between two structure indicators (for N=60) in comparison to the volume of 16 % subjects who improved to 2 level from the <norm range (p=0.5685). Thus frequencies of common memory tendency changes reveal the normal distribution and allow to look for specifics of dynamical changes during WAM memory training influence at the norm scales (table 6) for empirically revealed qualitative tendency changes in separate scales for memory of the pitch and of the rhythm, that allow to find training influence for the hemispheric asymmetry of WAM memory principle tendencies in revealed directions.

Table 6. Frequency distribution of 16 variants of dynamical changes tendency at the norm range separate scales of pitch memory and of rhythm memory of pre-test and of post- test scores

<table>
<tr><td colspan="6">Tendency change: 1 – decrease; 2 – stability; 3 – increase; P - pitch memory R - rhythm memory;
Qualitative combined code of test scores in norm-range scale: P-pre; R-pre; | P-pos; R-pos;</td></tr>
<tr><td colspan="2">Qualitative change tendency code in norm - range pitch - rhythm separate memory scale</td><td colspan="2">Qualitative change tendency code in norm-range pitch-rhythm separate memory scale</td><td colspan="2">Qualitative change tendency code in norm-range pitch-rhythm separate memory scale</td></tr>
<tr><td colspan="2">P1 – R3 and P3 – R1</td><td colspan="2">P2 – R1 and P2 – R3</td><td colspan="2">P1 – R2 and P3 – R2</td></tr>
<tr><td>Qualitative code
P-R-pre | P-R-pos</td><td>Frequency level</td><td>Qualitative code
P-R-pre | P-R-pos</td><td>Frequency Level</td><td>Qualitative code
P-R-pre | P-R-pos</td><td>Frequency level</td></tr>
<tr><td>1 – 3 | 2 – 2</td><td>5</td><td>2 – 2 | 2 – 3</td><td>6</td><td>1 – 2 | 2 – 2</td><td>5</td></tr>
<tr><td>2 – 2 | 3 – 1</td><td>5</td><td>2 – 1 | 2 – 2</td><td>4</td><td>2 – 2 | 3 – 2</td><td>5</td></tr>
<tr><td>3 – 1 | 2 – 2</td><td>3</td><td>3 – 1 | 3 – 2</td><td>2</td><td>3 – 2 | 2 – 2</td><td>4</td></tr>
<tr><td>1 – 2 | 2 – 1</td><td>2</td><td>1 – 3 | 1 – 2</td><td>1</td><td>Total range in %</td><td>14 = 23 %</td></tr>
<tr><td>2 – 3 | 3 – 2</td><td>1</td><td>2 – 2 | 2 – 1</td><td>1</td><td colspan="2" rowspan="3">Qualitative change tendency code in norm-range pitch-rhythm separate memory scale</td></tr>
<tr><td>Total range in %</td><td>16 = 27 %</td><td>Total range in %</td><td>14 = 23 %</td></tr>
<tr><td colspan="4" rowspan="2">Asymmetry of memory dynamic change tendency in revealed combined distribution of qualitative relations groups</td></tr>
<tr><td colspan="2">P2 – R2 and P3 – R3</td></tr>
<tr><td>Asymmetry tendency group</td><td colspan="2">Dynamic tendency change P-R</td><td>Frequency Level</td><td>Qualitative code
P-R-pre | P-R-pos</td><td>Frequency level</td></tr>
<tr><td>Absence</td><td colspan="2">same direction 2 – 2 or 3 – 3</td><td>27 %</td><td>2 – 2 | 2 – 2</td><td>13</td></tr>
<tr><td>Low level</td><td colspan="2">stable/change level–2 with 1or 3</td><td>46 %</td><td>1 – 2 | 2 – 3</td><td>2</td></tr>
<tr><td>High level</td><td colspan="2">opposite direction 1 – 3 or 3 – 1</td><td>27 %</td><td>3 – 2 | 3 – 2</td><td>1</td></tr>
<tr><td colspan="4">Total norm range of absence + low level groups: 73% = M±1.2SD</td><td>Total range in %</td><td>16 = 27 %</td></tr>
</table>

Dynamic changes tendencies of the pith memory and of the rhythm memory norm-range scales between 2 test measures in combined scores reveal the normal curve of tendency groups, with equal range 23 % for two groups with 1st stable attribute and 2nd changed attribute ("P2-R1 and P2-R3" + "P1–R2 and P3–R2"), where asymmetry tendency groups complete symmetrical two-tailed distribution with the "absence group" presented in the central tendency distribution of homogenous aural music working memory improvement during training stimulation influence. Obtained empirical frequencies of qualitative changes have no two-tailed significant difference between two structure indicators (for N=60) in comparison to the revealed central range distribution (73 %) with the normal curve middle range 68 % (-1SD; + 1SD) (p=0.548) and in relation of the 13.5 % (half-volume of "high level asymmetry tendency group") to the normal distribution of one-size range from 1st SD to 3rd SD for 16 % (p=0.699), with ordered equal range scale:{1) "R↑P↓" for 13 % (High level asymmetry tendency for pitch and rhythm changes); 2) "R–P↑↓" for 23 %; (Low level asymmetry tendency for pitch change); 3) "R–P– and R↑P↑" for 27 % (central range of normal distribution, Absence asymmetry tendency level, homogenous pitch memory and rhythm memory dependency state, 4) "P–R↑↓" for 23 %; (Low level asymmetry tendency for rhythm change); 5) "P↑R↓" for 13 % (High level asymmetry tendency for pitch and rhythm changes)}. No two-tailed significant differences were found in all tendency groups in the dependency between pitch memory and rhythm memory scores in pre-test and in post-test measurements, also between 3 groups for separate pre-test and post-test levels. These data reveal independency of asymmetry of WAM memory brain condition on training influence of dynamic tendency change, and its' quite stable level unchangeable during training stimulation. The improvement of common memory during training was revealed in all groups with significant increase in post-test, therefore is not the factor for changes' explanation, but of general widespread training stimulation effect.

The qualitative indices of combined normalized asymmetry of memory level scale in pre-test and post-test can describe obtained empirically asymmetry tendency groups. The group of the absence asymmetry tendency of WAM memory improvement (27 % of sample) i.e. with the same change direction for both pitch memory and rhythm memory scores – stability (↔) or increase (↑) – revealed "homogenous musical brain" tendency in asymmetry of memory level in both measurements for 37.5% of group (N=16) i.e. equal or aligned scores of pitch memory and of rhythm memory, with difference only for 1 point between two attributes, while the group of low level asymmetry tendency (46 % of sample) revealed the same tendency with lower level and significantly different (p=0.03) frequency for 11% of group (N=28), and the group of high level asymmetry tendency (27 % of sample) didn't reveal that tendency. Totally 15 % of subjects in empirical sample (6 and 3 in 60 subjects) demonstrated "homogenous musical brain". Obtained coefficient confirms independently the same level as revealed earlier by independent research with over 1000 participants (Dymnikowa, 2015;), thus might be representative for population level, and might demonstrate principle of developmental tendency of WAM memory in participants presenting "homogenous musical brain" at the income and outcome level, which contribute to stability or increase during working memory training influence (with the same tendency change for pitch memory and for rhythm memory in 10 % of humans, with mixed tendency of stability and increase in 5 % of humans). In addition this frequency was revealed and confirmed twice in present empirical research, thus it might confirm independently "aural musical memory brain state" principle as of cognitive feature with stable state unchangeable during working memory training influence.

WAM Memory Training Influence on Cognitive Improvement in Learning Efficiency Process

The empirical data of qualitative questionnaire, with open questions concerning contents of WAM memory training influence on cognitive improvement in learning efficiency process revealed that training was helpful for 90 % of participants by their estimation. The time abridgment for school homework was revealed 78 % of participants. They declared also improvement in learning process by obtaining the higher grades during WAM memory training period, in four school-subjects during WAM memory training in math (50%), language (45%), history (28%) and biology (30%). The distribution in gender and musical activity groups revealed quite aligned frequencies (table 7), thus the improvement in learning efficiency process is not conditioned by this factors. Obtained qualitative data confirm earlier scientific results of cognitive behavioral studies concerning positive transfer effects of aural music training on mathematics (Costa-Giomi, 2004;), reading (Bultzlaff, 2000;), verbal memory (Ho et al. 2003; Kraus et al. 2010;), language (Moreno et. Al., 2011;) and general cognitive intelligence (Schellenberg, 2004;). Music and speech share common processes (Besson et al. 2007; Patel, 2003;), revealed in brain networks of neuroimaging research (Koelsch, 2005; Koelsch et al. 2002; Ozdemir et al. 2006; Patel et al. 1998; Schon et al. 2004;).

Table 7. Frequency distribution of learning efficiency attributes in gender and musical activity groups

Learning efficiency attribute	Musicians	Non-musicians	Males	Females
Training helpful function	0.43	0.47	0.42	0.48
Time abridgement for homework	0.4	0.38	0.37	0.41
Improvement in math	0.22	0.28	0.23	0.27
Improvement in language	0.23	0.22	0.22	0.23
Improvement in history	0.1	0.18	0.13	0.15
Improvement in biology	0.17	0.13	0.12	0.18

The qualitative analyses of combined school-subjects learning improvement tendencies revealed six main combinations with equal frequency levels: {math = 18%; language = 16 %; math and language=18%; math and biology =16%; language and biology =18%; history and biology = 16 %;} with the structural relation → \\ Math ↨↔↨Language \\ with total 52 % variance for math and for language (50 % for biology).\\ Biology ↔ History \\ The revealed index of two-tailed correlation between biology and history (r=0.369; p<0,01; r^2= 0.13) indicates its small linear structural dependence. Considering learning improvement specifics for asymmetry tendency groups of dynamic tendency pitch - rhythm change the group with high level asymmetry tendency revealed increase in language study, while two groups of absence asymmetry and with low level asymmetry tendency revealed development in math study, with quite aligned qualitative frequencies of simultaneous improvement in math and language studies only in these groups. Obtained data confirm that math improvement during WAM memory training influence is conditioned in dynamical tendency change by increasing or stable level of pitch memory and of rhythm memory changes (P-R change tendency variants: ↑|↑; ↔|↔; ↑|↔; ↔|↑;) in the norm range scale. Thus opposite duration change (↓with↑) of memory indices during training influence (high level asymmetry tendency group - 27 % of sample; P-R change tendency variants: ↑|↓ and ↓|↑) doesn't form up brain condition for math learning efficiency process, while language learning improvement is not distributed (unsettled) by opposite tendency change between pitch memory and rhythm memory during working memory training stimulation. All participants (10 % of sample) who didn't observe helpful training influence belong to this asymmetry tendency group, they also didn't declare math improvement. Thus this principle got double confirmation in revealed empirical data. The qualitative empirically revealed group, that declared simultaneous improvement in math and in language, includes the group with "homogenous musical brain" state (15 % of sample, on the basis of asymmetry of memory norm range scale indices), and participants who obtained that state at the post-test. Thus it seems that both language and math learning efficiency requires high level of hemispheric synchronization in WAM memory state, so equal level of pitch memory and of rhythm memory indices (with possible difference in 1 point between two scales).

The main level of time abridgement for school homework decreased till 30 minutes (73,5% of sample). The group that declared improvement in time abridgement for school homework is described by hemispheric synchronization music processing with 67 % of empirical sample, includes the group with "homogenous musical brain" state (15 % of sample) and participants who obtained that state only in pre-test (23,5 % of sample) or in post-test scores (28,5 % of sample). No significant differences for mean values of time abridgement for school homework were revealed for gender and for musical activity factors, so this cognitive improvement attribute has general disseminating, since musical training requires individuals to learn to pay attention to several features of sounds, such as: pitch, timing and timbre. The auditory training with music can fundamentally develop the superior auditory cognitive skills, such as auditory and spatial working memory, selective and sustained attention, involving school-age children (Kraus et al. 2013; Trainor et al. 2003;), thus can develop complex attentive processes and contributes to the decrease of time abridgement in general learning process efficiency.

CONCLUSION

Music neuroscience has become a rapidly growing field within the area of music medicine. Music is particularly well suited for studying neuronal plasticity in the human brain because musical training is more complex than most other daily life activities. Physiology of music has some clear and reliable empirical evidence of the sound and structure specificity for assume about therapeutic music form that has been used in the musical training material in the present experimental study. Music has increasingly been used as a tool for investigation of human cognition and its underlying brain mechanisms. Music is related to many brain functions like perception, cognition, learning and memory, therefore music is an ideal tool to investigate how the human brain is working and how different brain functions interact. The present research confirms findings obtained in the field of induced cortical plasticity by musical training of aural working memory. The stimulation by music processing, based on the memory trace continuity effect by using the melody, contributes the leaning process efficiency with functional asymmetry decreasing effect during the training process, so contributes to the hemispheric synchronization. The functional asymmetry of music perception, and therefore of WAM memory, comes as cognitive feature with normal distribution in the income level and in developmental tendencies during training stimulation. Therefore the WAM memory training seems to be helpful to form up the brain state more close to the "homogenous musical brain" with minimization of the asymmetry level between aural memory of pitch and aural memory of rhythm, what needs further longitude study with longer period of the working memory training stimulation influence. The preparation of meta-memory strategies for memorizing music in the "memory performance process", during experimental verification, seems to be reasonable with including the "left-right-homogenous" aural musical memory brain state. It seem to be useful especially in study for detection of the optimal part of musical piece in volume of musical bars, that might be located sufficiently and smoothly in the long-term musical memory each day after learning new music material, in longitude study with using the different difficulty level of musical compositions included in professional music education process.

The present study confirmed also the possibility of changing the brain condition for more aligned hemispheric state in the aural music processing. Short-term musical training of the auditory function in memorizing and discrimination the music acoustic attributes is very promising for the study of training effects also on other complex auditory tasks. The positive effects, which music in its various forms has on the healthy human brain, found for children in the age of the optimal biological maturity for the working memory as the cognitive feature, with stable aural working memory span for music without the differences between musicians and non-musicians, with decreasing the level of asymmetry of WAM memory in both experimental groups, are important not only in the framework of basic neuroscience, but they also might strongly affect the practices in neuro-rehabilitation, in the cognitive music therapy area, especially in hemispheric synchronization process during the aural music perception stimulation and during the WAM memory training, for the cognitive functions efficiency and improvement in general cognitive development and in health cognitive aging.

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