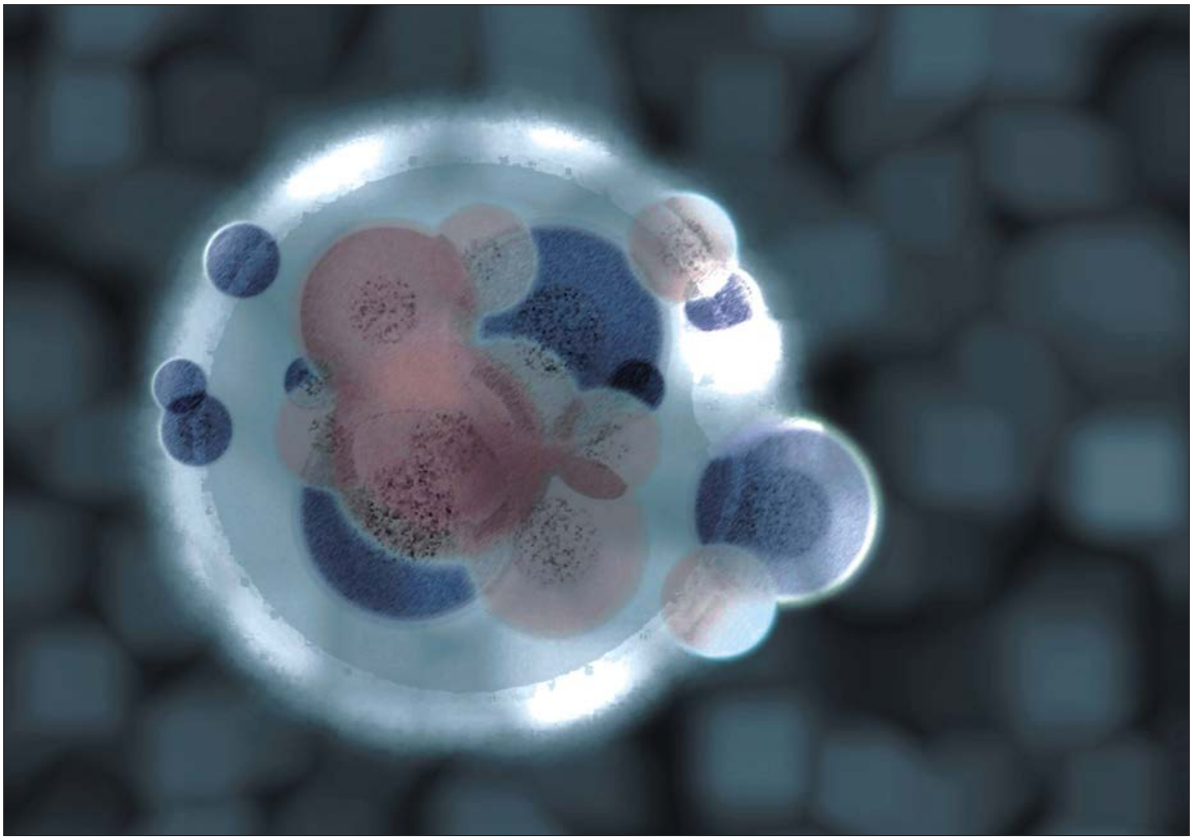

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The Musician's Brain

Wichian Sittiprapaporn
Faculty of Medicine, Mahasarakham University, Mahasarakham, Thailand

Abstract: Musician's brain is considered as an ideal model for plasticity studies: they start playing musical instrument usually in the early childhood and continue to improve their skills by practicing even when they have reached a professional level. Practicing to play involves accurate processing of temporal and spectral simple sounds as well as complex sounds or sound patterns. The result of long-term active and intensive music training does not affect only musical related skills and also in non-musical related skills i.e., verbal memory, mathematic and spatial ability. This review article cover music centre in the brain, musician brain in anatomical and functional aspects, enhancing of musical and non-musical related skills aspects, hypothesis of music and spatial ability and spatial mental imagery of music.

Key words: Brain, music, musician, musician's brain, cognition

INTRODUCTION

Brain area specialization for music does not entail that a "musical centre" must exist in the brain. Rather brain area specialization for music may lie in several distributed neural circuitries that are essential to the normal perception of the musical component and normal function of music related activities. Although the right hemisphere of the human brain has been traditionally viewed as the "musical hemisphere," there are evidences that the right auditory cortex is related for perceiving pitch and some aspects of pitch, melody, harmony, timbre and rhythm (Tramo, 2001). Previous evidence from patients who has focal brain excisions, they found that the right temporal damage has greater deficit than left side (Peretz and Zatorre, 2005). The brain lesion and neuroimaging studies, found that extraction mechanism of the pattern of changes in pitch locate in the superior temporal gyrus and frontal regions on the right hemisphere (Peretz, 2002). The right temporal cortex plays a particularly important role in the computation of pitch relations.

The brain areas relate to the harmonic component has been studied in several techniques. The studies of harmonic expectancies elicit the event-related potentials found the neural generators appear to be located in the inferior frontal areas (the frontal operculum) on both sides of the brain. The fMRI studies of harmonic expectancies also found the same areas; the inferior frontal areas (Peretz and Zatorre, 2005). The PET study of the structure components of musical perception in non-musician found that in the timbre discrimination task preponderate of metabolic activity in a right hemisphere and recognize rhythm task show metabolic activity in the insula area in left hemisphere (Baeck, 2002).

There is increasing evidence that musical functions recruit neural mechanisms in both cerebral hemispheres and also relate to multiple brain regions in each hemisphere. Patel and Balaban (2000) and Sittiprapaporn (2010, 2011) suggested that music processing may be distinguished by its characteristic dynamic activity and the pattern of brain interactions it engenders rather than by the particular brain regions that respond to it. The location of the music-specific neural networks may lie in the dynamic characteristics of their functioning and interaction (Patel and Balaban, 2000).

MUSICIAN BRAIN

Since the experience can shape the structure of cortical networks and enhance some brain areas depends on the level of structure of interest, there are evidences of size differences in brain regions of the musician's brain and relevant functions of the brain region, when compared to the brain of non-musician (Peretz and Zatorre, 2005).

Development of musician's brain: The size and temporal organization of brain representations of stimuli are continually shaped by experience. During playing a musical instrument requires the simultaneous integration of multimodal sensory and motor information with multimodal sensory feedback mechanisms to monitor performance. Musicians must translate music notation (visual-spatial-temporal information) into precisely timed sequential finger movements involving coordination of both hands, recall long passages of song pieces, bring meaning to music through the use of dynamics and articulation, transpose pieces to new keys and improvise melodies and harmonics based on existing musical pieces. Such musician's brain differences may well be due to musical training (Norton *et al*., 2005). Previous study support effect of music on developing brain (Shahin *et al*., 2003, 2004; Trainor *et al*., 2003) used ERPs technique to investigated the plasticity of auditory cortex. They found P2 component was lager in both adult and children who have extensive musical training than non-musician. The enhancing of P2-evoked response was observed in children as young as 4-5 years of age who have musical experience. Therefore, they concluded that the P2 is particularly neuroplastic of cortical sound representation that affect by auditory experience. This effect has been explained by Hebbian learning rules, 'cells that fire together, wire together'; that the brain is not as a static but as a dynamic system, strengthening of synaptic between neurons are formed depending on synchronous activation between pre-and post synapses.

Hebbian learning rules: Since the psychologist Donald Hebb attempted to account for learning and memory, in 1949, he wrote "When an axon of Cell A is near enough to excite Cell B and repeatedly or persistently takes part in firing it. Some growth or metabolic change takes place in one or both cells such that A's efficacy, as one of tow cells firing B is increased" This assumed the structural changes that produced memory possible has received much experimental support. Consequently, the result changes in the strength of the synaptic efficacy which alters the properties of groups of interacting neurons as a result of neural activity often are referred to as Hebbian plasticity (Lamprecht and Joseph, 2004). Likewise, Long-term Potentiation (LTP) is important as a leading candidate for a synaptic or cellular mechanism or a rapid learning. LTP was first demonstrated in the hippocampus and more in recently in the cerebral cortex. LTP is the "long-term" increase in synaptic strength between two neuron or two groups of neurons that followed high frequency stimulation of the first neurons or set of neurons, produces a greater response in the second neurons or neurons and the potentiation of the response can last at least hours and most typically during the duration of the experiment. These synaptic changes are thought to be the same one that occurs in learning (Lamprecht and Joseph, 2004). On the whole, LTP, as Hebbian mechanism of use-dependent modification in the strengths of pre-existing synaptic connection among neurons, therefore are seen as critically important in learning and memory storage.

Anatomical differences: The brain imaging studies which allow study anatomical detail in the human brain found the several brain areas shows difference between musicians and non-musicians. Gaser and Schlang (2003) via the method of voxel-based morphometry investigated the gray matter volume in two musician groups (professional and amateur) and non-musician group. They found an increase in of gray matter in primary motor and somatosensory areas, premotor areas, anterior superior parietal areas and in the inferior temporal gyrus bilaterally of musician groups when compare to non-musician group (Gaser and Schlaug, 2003). The asymmetry of the brain study in the planum temporale (the posterior superior temporal gyrus) of right-handed professional musicians and non-musicians by high resolution in magnetic resonance morphometry found the stronger leftward planum temporale asymmetry in musicians (Scheler *et al*., 1995).

Music-related functional perspective: The evidences of anatomical changes in the musician brains are observed and investigated by the behavioral difference between musician and non training person in both perceptual and cognitive aspects. In last decade, functional imaging and neuron-physiological studies on musical ability and associated brain structure and functionality demonstrated that different brain structure of musician corresponds with difference music-related data processing when compare with non-musician (Kizkin *et al*., 2006).

While listening to music only the synchrony in the gamma band that show significantly higher for musicians than non-musicians, while listening to the text has no statistically significant different. This higher synchrony was found in many cortical regions. The hemispheric dominance during musical tasks in musician is clearly in left-hemisphere, while non-musicians show right-hemisphere dominance (Bhattacharya *et al*., 2001). The event-related potential study show P2 and N1c components had larger response to the violin tones, piano tones and pure tones in highly skill musicians. The P2 and N1c of the Auditory Evoked Potential (AEP) have been shown to be sensitive to remodelling of the auditory cortex by training at pitch discrimination in non-musician subjects. This result may suggest that the tuning properties of neurons are modified in distributed regions of the auditory cortex in accordance with the acoustic training history of the subject (Shahin *et al*., 2003). The evoked potential studies of the ability to distinguish musical sounds pre-attentively and automatically by auditory P50 and N100 components between professional musician and non-musician. The result showed P50 wave but not the N100 wave is suppressed less in musicians than non-musicians (Kizkin *et al*., 2006).

The investigation of brain activity during listening to music in female musicians and non-musicians by using fMRI technique found a significant higher signal in the musician group was observed in the right superior and middle temporal gyri, the right inferior frontal gyrus and the left supramarginal gyrus (Seung *et al*., 2005). Pantev *et al.* (1989), using MEG has shown that brain responses to piano tones were 25% larger in musicians than in non-musicians (Peretz and Zatorre, 2005). The recruitment of different neural networks for harmony and melody processing in musician relative to controls using fMRI. In musical training person appears result in recruitment of addition cortical area such as inferior parietal lobules for both music processing (Schmithorst and Holland, 2003). The accuracy and reaction time studies found that the musicians performed better than the non-musicians in two timbre discrimination tasks (Chartrand and Belin, 2006). Previous studies on brain response to harmonically inappropriate chords between expert and novices musician by using event-related brain potentials. They found musical experts have clearly larger than novices. The ERAN is an ERP component that is elicited by violations of complex musical and the more specific representations of these regularities in experts led to a higher degree of violation in this musician group (Kizkin *et al*., 2006). Music training also effect to musical imagery task i.e., in the musical mental imagery and common sound imagery task, musician performs better than non-musician in both tasks. The authors suggested that musical training may improve musical and also non-musical auditory imagery task (Aleman *et al*., 2000).

IMPACT OF MUSIC TO OTHER COGNITIVE FUNCTION

Music can lead to short-term and long-term effect to non-music related cognitive.

Music listening: Music listening can lead to enhanced performance on variety of test of cognitive ability. The “Mozart effect”; refers to an enhancement of performance or change in neurophysiological activity associated with listening to Mozart’s music (Jausovec and Habe, 2004). Rauscher *et al*. (1993) found after listening to 10 min of classic music, the spatial IQ score of music condition group were higher 8-9 point from the silent and relaxation group. There have been several studies that replicated the Mozart effect, however the Mozart effect is very controversial and many studies have failed to replicate it. The meta-analysis study of Chabris (1999) motivated speculation that the Mozart effect could be explained as an artifact of arousal. Next two years, Thompson *et al.* (2001) propose the arousal-and-mood hypothesis that listening to Mozart is one example of a stimulus that influences the perceiver’s arousal level and mood which can affect performance on a variety of cognitive tasks.

Music training: Music lessons have collateral benefits that extend from musical benefits to cognitive functions that are not related to musical. Music lessons involve a multiplicity of experiences that could generate improvement in a wide range of abilities. During music training involve long periods of focused attention, daily practice, reading musical notation, memorization of extended musical passages, learning about a variety of musical structures and progressive mastery of technical skills and the conventions governing the expression of emotions in performance. This combination of experiences could have a positive impact on cognition, particularly during the childhood years, when brain development is highly plastic and sensitive to environmental influence. Many findings have been show music lessons have positive associations in intellectual ability such as verbal memory, spatial ability, visuospatial performance and mathematics achievement (Brochard *et al*., 2004; Schellenberg, 2005). Previous study show improvement effect of music training in full scale IQ, the Wechsler Intelligence Scale scores (WISC-III) was measured before and after the music lesson in children who received music lesson, drama lessons and no lessons. Comparison with children in the drama lesson and no lesson groups, children in the music groups exhibited increases in full-scale IQ of the WISC-III (Schellenberg, 2004).

Music training and verbal memory: Chan and Colleagues assessed the verbal memory between musician who received music training before 12 years old (at least six years) and no music training colleges. The music training group learned significantly more word of verbal memory than non-musicians. This evidence shows that music training may have a long-term effect on the improvement of verbal memory (Chan *et al*., 1998).

Music training and mathematics achievement: Eighth grade student who had private music lessons for 2 or more years performed significantly better on the composite mathematics portion of the Iowa Tests of Basic Skills (ITBS) than did students who did not have private lessons. It was found that students with 2 or more years of private lessons had a significantly higher mean mathematics score than did students with no private lessons. The students who received lessons on the keyboard had significantly higher ITBS score than did the students who had music lessons but not on the keyboard (Cheek and Smith, 1999).

MUSIC AND SPATIAL ABILITY

Psychological relationship: The relationship between music and spatial ability was investigated by Barrett and Barker Jr. (1973), the group of children aged 8 to 12 years were assessed with a musical performance test and with various tests of pattern recognition. The result indicated a positive significant correlation between music performance and the Hidden pattern test. Series studies of Hassler *et al*. (1985) demonstrated that acoustic structuring ability and spatial ability are analogous construction. Several versions of an Acoustic Structuring Test were assessed in subjects 6 years to adult. He found higher correlations of musical/spatial ability (0.33) than of musical/verbal ability (0.09). After he also found the different correlation of musical/spatial and musical/verbal according to the amount of their musical training; subjects with less than two years of training have higher musical/verbal correction, subjects with more than two years have higher correlation between musical/spatial ability (Hassler *et al*., 1985). Rauscher *et al*. (1997), after 6 months of private keyboard instruction and singing preschool children have higher score of an object assembly test of spatial-temporal reasoning than control groups. The control groups did only singing, computer instruction and no instruction. Early keyboard instruction, coupled with exposure to group singing enrichments, enhance on specific form of intelligence-spatial-temporal reasoning abilities. This study suggests that music training, unlike listening, produces long-term modifications in underlying neural circuitry in regions not primarily concerned with music (Rauscher *et al*., 1997). Previous study in children 4-6 years old who participate in a 30 week parent-involved music curriculum had shown score significantly higher control on the Bead Memory subset of Stanford-Binet Intelligence scale. The Bead memory subtest measures both visual imagery and sequencing strategies, mental process (Bilhartz *et al*., 1999). Early musical instruction has been advantage to the 2 subtest of spatial ability. The musicians who began music instruction before 5 years old obtained significantly higher scores in the hidden figure test and the object assembly subtest than did those who began later or never received formal music training (Costa-Giomi *et al*., 2001). The study of visuospatial perception and their imagery ability in adult musician and non-musician found that musician has significantly shorter reaction time in both perception and imagery condition of vertical discrimination task. Moreover, in imagery condition of discrimination on the vertical dimension task seems to be greatly improved on the musical expertise (Brochard *et al*., 2004).

Physiological relationship: The positive effect of music listening to spatial ability also has been study by the neurophysiological investigation i.e., electroencephalogram and fMRI. When use the EEG coherence technique investigated the effect of music listening on spatial-temporal task. The EEG was recorded during solved the spatial-temporal ability; paper folding and cutting task from Stanford-Binet battery after listening to text either Mozart K.448. The main cortical areas that increase degree of synchrony were right fronto-temporal, right temporo-parietal and centro-parietal in the both Mozart and text listening conditions. Addition more cortical synchrony activity of Mozart than text condition were appear in parietal, left occipital and left temporal. This mean some cortical area activity bilaterally during task after listening to music when compare to after listening to text (Sarnthein *et al*., 1997; Sittiprapaporn, 2010).

The combination of EEG with a functional brain mapping technique to localize neural activates that are correlated with EEG power spectrum. Beta power was significantly higher during listening to music than rest. There was a positive correlation of regional Cerebral Blood Flow (rCBF) with beta power in both music listening and rest condition in the premotor cortex and adjacent prefrontal cortices bilaterally, the anterior portion of the precuneus and the anterior cingulate cortex. An additional area for the music listening is the posterior portion of the precuneus bilaterally. Beta power spectrum during music listening may indicate the interaction of music with cognitive processes. The functional neuroimaging studies in humans suggest that the premotor posterior parietal connections are not only for motor control but also for cognitive processes. A mental object-construction task activated the bilateral premotor and parieto-occipital regions. The posterior portion of the precuneus (show in the blue area) is close to the parietooccipital sulcus. These positive correlation areas can be interpreted as premotor-posterior parietal connections. There may be an overlap of the neural networks for musical and spatial processing.

The previous fMRI study investigated the transferable benefit of music training to visuospatial task between professional orchestral musicians and non-musician. The results indicated that orchestral musicians showed enhancing of activation in Broca's area when performing a three-dimensional mental rotation (Sluming *et al*., 2007). The Broca's area as know as related in visuospatial network which researcher suggested during music practice may be an interaction between brain development and acquisition and maintenance of musical visuospatial skills which shape cortical tissue in Broca's brain area. These underlie mechanism in musician mediates faster mental representation and better accuracy of decision making of a three-dimensional mental rotation task (Sluming *et al*., 2007). The studies in both behavioural and physiological fields also caught attention in the relationship between music training and spatial ability, therefore researchers try to explain the hypothesis underling this phenomena.

RELATIONSHIP OF THE MUSICAL TRAINING AND SPATIAL ABILITY

Although, the relationship between musical and cognition skills has received some research attention, the music investigation and other cognitive skills are largely correlated in nature. In general, it appears that spatial and musical abilities are related.

Hemisphere lateralization: A possible explanation for the relationship between music and spatial abilities refers to the right-hemispheric dominance in both musical and spatial information processing. Barrett and Barker Jr. (1973) study a music performance test and various test of pattern perception. The results indicated the significant correlation between music talent and spatial visualization and positive correlation with spatial orientation. The Haussler's longitudinal study in 1985 investigated the relationship between music talent and visual-spatial ability. The Haussler's lab is one of the first groups that studied the relationship between music talent and visual-spatial. Hassler and his group design a longitudinal study in 2 stages; at beginning of puberty and one year later. The first stage, they demonstrated that children age 9-14 year old (beginning of puberty) has significant relationship between musical talent and spatial visualisation. One year later, they tested the same group of participant and found that musical talent remains significant related to spatial ability (Hassler *et al*., 1985). The meta-analysis of medical and psychological studies suggests that spatial information processing is also advantage functionally in the right hemisphere of the brain (Vogel *et al*., 2003). Previous studies concluded that high musical ability should be positively associated with better performance on cognitive tasks mediated by the right hemisphere (Brandler and Rammsayer, 2003; Sittiprapaporn *et al*., 2003, 2004a, b, 2005).

Trion model: Relationship of music and spatial-temporal reasoning can predicate by a structured neural model of cortex. Dr. Gordon Shaw and his group constructed the Trion model. The Trion model is a highly structure mathematics realization of the Mountcastle organization principle with the column as the basic neuronal network in mammalian cortex. The inherent spatial-temporal firing patterns of interconnected groups of neurons have the built-in ability to recognize, compare and find relationship among patterns (Sarnthein *et al*., 1997). Musical acts as an exercise for exciting and priming strengthen of neural firing pattern that has same firing patterns are used in spatial-temporal reasoning task (Jausovec and Habe, 2004).

Multiple skills during musical training: The association stems from the constellation of abilities that music lessons train and improve abilities including focused attention and concentration, memorization, reading music, fine-motor skills, expressing emotions and spatial ability (Schellenberg and Hallam, 2005). During play musical instrument, musicians use multiple modalities such as visual, auditory and motor to produce the music. That involves reconstructing a pattern in which the elements, the notes, are organized in a highly specialized spatial-temporal code. The encoding of music, musicians encode both position of notes and their temporal sequence of musical events that related to pitches, melody and rhythm (Gromko and Poorman, 1998). Musical training may affect the development of neural pathway relevant to abilities that are influenced by environmental stimulation, such as certain spatial abilities. The overlap of skills required for music and spatial cognition may form the basis for refers to as cross-sensory perception and response which involves "relating information entering through one sense mode to analogous information in another mode" (Rauscher and Zupan, 2000).

Cross-modal interactions: Mini review of Zatorre and Halpern (2005) proposed the "cross-modal interactions" processing in one sensory modality can affect processing in another, either by increasing or suppressing activity. Similar interactions also appear to occur if one or both tasks are based not on perceptual but on imagined information. Also, Lotze *et al*. (2003) investigated actual and imagined performance of Mozart's violin concerto in G major (KV216) tasks in amateurs and professional violinists. They found professionals exhibited higher activity of the right primary auditory cortex during execution may reflect an increased strength of audio-motor associative connectivity. The authors also suggested about development aspects of musical skill acquisition which have observed cross-modality functional coupling with musical training. During music training, the combined auditory feedback and motor training on the musical instrument results in the co-activation of cortical auditory and sensory-motor hand regions (Bangert *et al*., 2006). It might be that such cross-modal coactivations will be strengthened with increased musical training (Lotze *et al*., 2003; Sittiprapaporn *et al*., 2005, 2006; Sittiprapaporn, 2010, 2011, 2012a, b). This hypothesis was supported by many present studies i.e. the study in preschool children who have 4 months of music training, students demonstrated improvement of their overall score on the music task over time. The authors offer that music lesson seemed to have a specific transfer effect on one particular type of spatial skill, visual-motor integration. Also, they propose that the practice of fine movement/visual perception in music practice association involves similar skills use in copying geometric form. They suggested that music playing and practice likely strengthens this co-ordination of visual and auditory sensory input and motor output. A cross-modal theory of early music experience, music seems to be a medium that strengthens the integration of auditory, visual and motor co-ordination (Orsmond and Miller, 1999).

A cross modality hypothesis of relationship between music and spatial ability was supported by another 2 neurophysiologic studies. The ERPs result of musician when judge whether the last note of a five-note auditory musical sequence match or mismatched the information simultaneously provided on a visual score show that mismatch conditions differed from matching conditions. The ERPs amplitude of early and late negative and positive component was larger for the unstable than the stable ending condition. Moreover, electrophysiological data showed that the auditory mismatch effect found in modulated by the expectations built from the score. The authors gave explanation about these results of musician that it seem to exist between visual and auditory musical code, so that the representation built from the visual score interfere with the auditory perception of the musical sequence (Schon and Besson, 2003). The study of brain responses to the violations of visually induced auditory expectation. Subjects were performing the symbol-to-sound matching paradigm.

In the symbol-to-sound matching paradigm, subjects indicated whether the visual and auditory sequences were congruent or not by pressing the button. The comparison of the ERPs data of to incongruent and to congruent auditory events showed a bilateral frontal negativity and a mastoidal positively of the incongruent events at about 110-120 msec after the onset of the sounds. This incongruence response was followed by an N2b-like and a P3a-like deflection. Their results showed that the brain reacts very quickly, after around 100 msec, to a violation of an expectation induced by visually presented information by input received through the auditory modality (Widmann *et al*., 2004).

SPATIAL ABILITY

The term "spatial cognition" is broadly defined as a specific type of mental processing involving objects that exist in space. Neurologists examining spatial deficits in adults have shown that the spatial factor is not a unidimensional concept but includes spatial perception, memory, operations (e.g., rotation or reflection of spatial representations) and construction (putting the parts of an object together to create a whole) (Rauscher and Zupan, 2000). In filed of music, one type of spatial ability (spatial-temporal reasoning) plays important role. One has to be able to create, maintain, transform and relate complex mental images when playing music. From a meta-analysis the over all result, the right hemisphere most involve in spatial tasks. When focus on the handedness variable and spatial task. The right-hander shows the strongest advantage in the right-hemisphere. The spatial visualization tasks showed no hemispheric preference. On the other hand, the spatial orientation and the manual manipulation tasks show advantage on Right hemisphere. This suggests that not all spatial abilities are located in the right hemisphere (Vogel *et al*., 2003). Within the field of mathematics, it has been argued that mathematics and spatial ability are highly correlated with success in mathematics education by using visual images to help for all sorts of mathematic problems (Van Garderen, 2006). Hegarty and Kozhevnikov (1999) have suggested that two different types of visual images exist, visual imagery and spatial imagery. The visual imagery (pictorial) refers to the representation of the visual appearance of an object, such as its shape, colour or brightness, whereas the spatial imagery refers to the representation of the spatial relationships between the parts of an object and the location of objects in space or their movement. It has been suggested that all mathematical tasks require spatial thinking (Hegarty and Kozhevnikov, 1999).

Higher level of visual processing: The higher level of visual processing composes of two main cortical visual-spatial pathways; ventral pathway and dorsal pathway. The ventral pathway carries information what an object is; static object properties such as shape and colour. This pathway compose of the inferior longitudinal fasciculus of axon that run out from the primary visual cortex and terminating in the inferior temporal. The dorsal pathway carries information regarding where an object is dynamic object properties such as motion and spatial relationships. This pathway composes of the superior longitudinal fasciculus of axon that runs out from primary visual cortex and terminating in the posterior parietal cortex.

Gender and spatial ability: Visual-spatial ability show fairly well proven sex difference in favour of male. Previous studies supported these phenomena. Study in the students of Ghana and Norway Universities by using 4 visual spatial ability tests, one spatial perception and spatial visualization and 2 mental rotation tasks. The result demonstrated significant sex difference in superiority of males were found in both Ghana and Norway sample on spatial perception and 2 mental rotation visual-spatial ability categories (Amponsah and Krekling, 1997). Previous study of three spatial memory tasks in 61 undergraduate students, researchers found that males perform significantly better than females on the mental rotation task and in finding a hidden platform in the virtual Morris water task (Astur *et al.*, 2004). This has been explained with reference to differences between the sexes in hemisphere functioning, with males performing better than females on typical right hemisphere processing tasks (Hugdahl *et al.*, 2006).

Spatial mental imagery task: The experiment of Mellet *et al.* (1996) spatial mental imagery task was image construction task from both picture and propositional. That was designed for subject to do the constructing mental imagery of object in form three-dimension cube assemblies from verbal commands. The generation of visual images does not result from the reactivation of previously stored memories but does result from on-line construction of internal representations in the basis of the processing of verbal instructions and their encoding in a visuospatial format. This method was designed to call strongly on visual imagery. The results of the paradigm elicit activation of posterior regions clearly distribution along an occipitoparietal axis. These brain activated area; superior occipital and partial regions represent the dorsal route which has role in the spatial processing of external visual stimuli.

CONCLUSION

Brain area specialization for music lie in several distributed neural circuitries that are essential to the normal perception of the musical component and normal function of music related activities. Musical functions recruit neural mechanisms in both cerebral hemispheres and relate to multiple brain regions in each hemisphere. Music processing may be distinguished by its characteristic dynamic activity and the pattern of brain interactions it engenders rather than by the particular brain regions that respond to it.

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