The EuroBiotech Journal

REVIEW
Medicine and Biotechnology

The music in the brain hemispheres

Giulia Gizzi[1] and Elisabetta Albi[2]

Abstract

The mini-review provides an overview on the differences between the right and left hemispheres of the brain. Recent studies highlight the contribution of the two hemispheres to the physical and mental control, and the interaction language-music. We focused the attention on the behaviour of the right and left hemispheres about the music and on what happens when music areas are damaged.

[1]Department of Psychology, University of Torino, Torino, Italy

[2]Department of Pharmaceutical Science, University of Perugia, Perugia, Italy

Corresponding author: E. Albi
E-mail: elisabetta.albi@unipg.it

Published online: 27 October 2017
doi:10.24190/ISSN2564-615X/2017/04.01

Introduction

A look at the brain anatomy

The brain is contained in the skull and it is wrapped by three protective membranes: the dura mater, arachnoid and pia mother. The space between the arachnoid and pia mater, the subarachnoid space, is in communication with both the central canal of the spinal cord and the cerebral ventricles where the ependymal cells in the choroid plexus produces the cerebrospinal fluid. It circulates from the lateral ventricles to the foramen of Monro, third ventricle, aqueduct of Sylvius, fourth ventricle, foramen of Magendie and foramina of Luschka, subarachnoid space over brain and spinal cord and it is reabsorbed by the arachnoid granulations which protrude from the dura mater into venous sinus blood. The cerebrospinal fluid protects the brain against accidental impacts by distributing forces evenly to the total area thus preventing the contact with the bones of the skull and maintains constant the biochemistry of the brain. The trade between blood, brain and cerebrospinal fluid is controlled by the blood-brain barrier that does not act only as a physical barrier but also as a biological filter that monitors the placing of the necessary metabolites and the removal of toxic substances. The brain, thereby protected inside the skull, is constituted by three sections in posterior-anterior direction: the hindbrain, the midbrain, and the forebrain. The hindbrain consists of the cerebellum, pons, and medulla whereas the hindbrain consists of the tectum, tegmentum, ventricular mesocoelia, and cerebral peduncles. The largest and most complex part of the brain is represented by the forebrain or cerebrum. The cerebrum has right and left halves, called hemispheres, that communicate by a central band of nerve fibers, the corpus collosum. The two hemispheres consist of the outer layer of grey matter, called the cortex, supported internally by the white matter and of the inner part where sit the thalamus, hypothalamus, pituitary gland and basal ganglia. The cerebral cortex of each hemisphere is divided by two major furrows, the central sulcus or fissure of Rolando and the lateral sulcus or fissure of Sylvius, in four sections or lobes distinguished in the frontal, parietal, temporal, and occipital lobe. In each lobe there are different functional areas with specific localization such as the motor and sensory areas, the visual areas and auditory areas but a large amount of the primate cortex is called association cortex that coordinates the higher activities as learning and reasoning.

The contribution of the two hemispheres to the physical and mental control

The brain controls all bodily functions from thought, emotions and memories to the word, sight, hearing, touch and taste, from the beating of the heart to the circulation, digestion, respiration, formation and elimination of urine and function of endocrine glands, from the regulation of body temperature to the adaptation. To this end the brain sends back messages and forth to various parts of the body through the spinal cord and from there through the peripheral nervous system.

The two hemispheres appear macroscopically the one as a mirror image of the other. It is generally known that the left hemisphere controls most of the functions on the right side of the body, whereas the right hemisphere controls most of the functions on the left side of the body such as the perceptual information, the optical radiation and the control signals of motility.

However, this simplification is far from the true complexity of the functional asymmetry of the two hemispheres also related to the biochemical and ultrastructural differences. In fact, there are higher levels of the neurotransmitter norepinephrine and more white matter on the right whereas higher levels of dopamine and more grey matter on the left hemisphere.

It's generally believed that some people are more "right-brained" or "left-brained" while others are more "whole-brained," in relation to their behavior such as the hand preference. In addition to these general asymmetries, the two hemispheres have more different specific functions.

The left hemisphere, which in the majority of people is dominant, has the sites for systematic, logical interpretation and production of symbolic information such as language, mathematics, abstraction, reasoning and verbal memory. The right side is thought to be more intuitive, creative, and subjective. Thus the left hemisphere is dominant for analytic processing and the right hemisphere for holistic processing (1). In fact, it contains areas for holistic reasoning functions of language such as intonation and emphasis, for holistic picture of one's environment, for visual spatial skills and visual memory, for holistic functions such as music, dancing and gymnastics.

One of the most studied functions of the brain but not completely clarified is the relationship language-music.

Can the language drive the music?

It is traditionally considered that the language is well organized in the left hemisphere; the understanding of language is located at the intersection of the superior temporal gyrus with the angular gyrus (Wernicke's area) whereas the articulation of language is located in the inferior frontal gyrus (Broca's area). However, the language requires a large number of elements beyond the dichotomy comprehension/expression such as phonology, syntax, spelling and composition semantics. Read a written word implies the involvement of many responses that range from the visually recognition of the word to the interpretation of how the word is written, to what concept it refers, to what is its sound and to how it is articulated. Li et al., 2000 (2) have demonstrated that the language stimulates the classical "language areas" in the left hemisphere but also other areas in the right hemisphere.

According to some researchers, the linguistic and musical intelligence are two independent cognitive activities because a schizophrenic may be a talented musician, as well as a great orator may be musically quite unable. An accidental injury of the brain can affect selectively the music perception saving the language or, on the contrary, preserve the music destroying the language.

Differently many researchers consider that the perception of music uses the mechanisms of language such as intonation and pauses whereas reading of the music uses the techniques for reading the written language as symbols and sounds.

The results of an electrophysiological experiment performed on patients with lesions in Broca's area or in the left anterior temporal lobe suggested that the left inferior frontal gyrus, known to be crucial for syntax processing in language, plays also a functional role in the processing of musical syntax (2).

How the right and the left hemisphere behave about music?

Scientists have for centuries tried to localize and define artistic talent. In nineteenth century the ability to recognize a musical composition in novice listeners has been located in the left hemisphere. Only in the '60s it has been shown that the functions delegated to the music comes mainly from right hemisphere. Osborne and Gale (4) have monitored the activity of both right and left hemispheres by EEG when non-musician subjects were presented with music, showing that the right side of the brain is most activated. Right hemisphere is associated with musical skills and good three-dimensional orientation (5) but musical processing requires a large cortico-subcortical network which is distributed throughout both cerebral hemispheres and the cerebellum (6). Ono et al., (7) have demonstrated a lateralization of the music areas in the two hemispheres depending on the education to the music. In fact, the authors have performed a study by magnetoencephalography in 8 musicians and 8 non-musicians showing the right-hemispheric dominance in non-musicians and symmetrical distribution in both hemispheres in musicians (7). Stewart, (8) has emphasized the musician as the model par excellence for studying the role of experience in sculpting brain processes. And so listening to music, learning to play an instrument, formal instruction, and professional training result in multiple instances multisensory, representations of music, which seem to be partly interchangeable and rapidly adaptive (9). The brain areas involved in the music are growing in number in relation to the type of involvement required that can go from listening distracted until the composition of a musical composition. As Tudor et al. (10) affirmed that the lateralization depends also on the cultural influence, so the Japanese process their traditional popular music in the left hemisphere, whereas Westerners process the same music in the right hemisphere. Males, irrespective of talents, are more lateralized than females (11).

Musicians differ from non-musicians in their many special skills (12) that induce the extension from the hemisphere of the novices (right) for not musically trained individuals to the dominance of expert hemisphere (left) for music professionals (13). In fact, musicians have more bilateral neural connectivity than non-musicians for the plastic developmental changes caused by extended musical training (14). In particular, in non-musician the music activates auditory temporal areas and deactivates prefrontal regions in the right hemisphere (15) whereas in musicians the ability to recognize music is different from the ability to respond to auditory stimuli as voices or noises and different musical elements like rhythm, melody, harmony, pitch, timbre, sound discrimination ability, musical memory are distributed on both hemispheres of the brain with a prevalence in the left hemisphere. For those who are musically literate is obligatory the reading of the written note, like the written word and specific learning-related changes were located in the superior parietal cortex and fusiform gyrus, for melody reading and rhythm reading, respectively (13). A study with functional transcranial doppler sonography of the middle cerebral artery to evaluate changes in cerebral blood flow velocity (CBFV) during different periods of music perception demonstrated that non-musicians show a significant increase of CBFV in the right hemisphere during harmony perception but not during rhythm perception whereas musicians show increased CBFV values in the left hemisphere independent on the type of stimulus (16). In subjects without musical training for rhythm and melody have unique neural signatures not only in the early stages of auditory processing, but also at the higher cognitive level of working memory (17). Vollmer-Haase et al. (18) have demonstrated that the melody requires a right hemisphere dominance even in musically sophisticated subjects (19) whereas the "musical semantic memory" defined as memory for "well-known" melodies activates the superior and inferior temporal area and middle frontal areas in the left hemisphere and the inferior frontal area in the right hemisphere (19). The perception of meter assessed in musically trained listeners through magnetoencephalography showed metrical processing among identical standard tones in the left hemisphere, with larger responses on strong than on weak beats (20) Many discussions are on the "perfect pitch," known in the scientific literature as "absolute pitch" (AP), is a rare phenomenon that has fascinated musicians and scientists alike for over a century (21). Some believe that AP is learned early in life through intensive musical training, others believe AP to be largely innate and others that AP may be relatively independent on musical experience and that there are different types of AP, each of which can be ascribed to discrete neurobiological mechanisms (21). In association with different levels of musical expertise, it has been demonstrated by diffusion tensor imaging that AP is characterized by a greater left than right asymmetry of fractional anisotropy in core fibres of the superior longitudinal fasciculus, by indicating that its plasticity is a function of musical expertise (22).

The timbre does elicit differential brain activity from memory or from information processing systems in subjects with varying degrees of musical training (23). Musical imagery refers to the experience of "replaying" music by imagining it inside the head. Studies converge on the importance of the right temporal neocortex and other right-hemisphere structures in the processing of both perceived and imagined nonverbal music whereas perceiving and imagining songs that have words also involve structures in the left hemisphere (24). The analysis of EEG frequency bands has highlighted a significant high degree of phase synchrony in the gamma frequency range globally distributed over the brain in musicians compared with non-musicians, suggesting an high ability of musicians to retrieve musical patterns from their acoustic memory, which is a cogent condition for both listening and anticipating musical sounds (25).The magnetoencephalographic evidence indicated that the sound discrimination abilities may be differentially distributed in the brain in musicians and non-musicians (26). During music processing, age-related effects common to melodic discrimination (MD) and rhythmic discrimination (RD) are present in three left hemisphere regions: temporofrontal junction, ventral premotor cortex, and the inferior part of the intraparietal sulcus, regions involved in active attending to auditory rhythms, sensorimotor integration, and working memory transformations of pitch and rhythmic patterns (27). The age is important also for the lateralization of the music. In the right hemisphere, the activation pattern of children was similar to that of adults. In the left hemisphere, adults showed larger activations than children in prefrontal areas, in the supramarginal gyrus, and in temporal areas. In both adults and children, musical training was correlated with stronger activation in the frontal operculum and the anterior portion of the superior temporal gyrus (28). The age at which musicians begin their musical studies (29), the prolonged duration of musical training (12) are important factors for cortical reorganization that has benefits for other cognitive domains (30).

Recent neuroscience studies revealed that intensive learning experiences involve changes in brain anatomy and/or function. In fact, brain structural differences are present between professional musicians and non-musicians with respect to size, asymmetry or gray matter density of specific cerebral regions (31). Repeated practice optimizes neuronal circuits by changing the number of neurons involved, the timing of synchronization and the number and strength of excitatory and inhibitory synaptic connections (32). The enhanced auditory responses in musicians are accompanied by their enlarged cortical areas such as medial part of Heschl's gyrus (33) and the anterior part of corpus callosum (34). The voxel-based morphometric study in both hemispheres between musicians and non-musician showed that in musicians gray matter volume in the Broca's area increases significantly, specifically in the left pars opercularis (35).

When the music areas are damaged

In the past musical disorders caused by brain lesions were defined with the generic term of amusia. By the end of the last century some researchers included developmental or innate musical disorders (6) and/or musical disorders in the course of degenerative diseases (36) in amusia. Paradoxically degenerative diseases can either cause a musical deficit or improve musical function as occurs in patients with selective atrophy of the left hemisphere (36). Classification of amusia includes vocal amusia, instrumental amnesia, musical agraphia, musical amnesia, disorders of rhythm, and receptive amusia. There is correlation between type of amusia and site of lesion (37). Left-hemisphere-damaged patients show significant deficits in the discrimination of local as well as global structures in both melodic and temporal information processing. Right-hemisphere-damaged patients also reveal an overall impairment of music perception, reaching significance in the temporal conditions. Detailed analysis outlined a hierarchical organization, with an initial right-hemisphere recognition of contour and metre followed by identification of interval and rhythm via left-hemisphere subsystems. Patterns of dissociated and associated melodic and temporal deficits indicate autonomous, yet partially integrated neural subsystems underlying the processing of melodic and temporal stimuli (38).

Thus in executive amusia, the lesion generally occurs in the frontal lobe. In receptive amusia, the lesion is mainly in the temporal lobe (37). It is possible that aphasic right-handed professional musician with left hemispheric lesions has disturbed musical function, especially musical alexia and agraphia (39). It is possible that in a professional musician and composer, with a progressive aphasia and a severe anomia his musical competence is apparently totally preserved, and he continues his activity as a composer (40). The right brain lesion without dysphasia induces deterioration in musical abilities (41). If the brain lesions are due to a stroke, amusia is associated with general deficits in working memory and learning, semantic fluency, executive functioning, and visuospatial cognition, as well as hemisphere-specific deficits in verbal comprehension, mental flexibility, and visuospatial attention (42). During the stroke a dissociations between the music agnosia and auditory agnosia can be present (43).

In the period post-stroke, the brain can undergoes dramatic plastic changes that can be further enhanced by stimulation provided by the environment. Music listening during the early post-stroke stage improves the cognitive recovery and prevents negative mood more than the language (42). On the other hand, the recovery of music perception ability is related to the recovery of verbal learning, visuospatial perception and attention (42).

Conclusion

This review provides basic and meaningful information on language and music interaction in the brain. Fundamental understanding of the interplay between right and left hemispheres is crucial for the ability to learn music and for musical talent.

Conflict of interest statement

The authors declare there is no conflict of interest.

References

1. Bever TG, Chiarello RJ. Cerebral dominance in musicians and non-musicians. Science. 1974; 185:537-539.
2. Li E, Weng X, Han Y, Wu S, Zhuang J, Chen C, Feng L, Zhang K. Asymmetry of brain functional activation: fMRI study under language and music stimulation. Chin Med J 2000; 113:154-158.
3. Sammler D, Koelsch S, Friederici AD. Are left fronto-temporal brain areas a prerequisite for normal music-syntactic processing? Cortex 2011; 47:659-673.
4. Osborne K, Gale A Bilateral EEG differentiation of stimuli. Biol Psychol 1976; 4:185-196.
5. Bosnar-Puretić M, Roje-Bedeković M, Demarin V. The art: neuroscientific approach. Clin Croat 2009; 48:367-370
6. García-Casares N, Berthier Torres ML, Froudist Walsh S, González-Santos P. Model of music cognition and amusia. Neurologia 2013; 28:179-186.
7. Ono K, Nakamura A, Yoshiyama K, Kinkori T, Bundo M, Kato T, Ito K. The effect of musical experience on hemispheric lateralization in musical feature processing. Neurosci Lett 2011; 496:141-145.
8. Stewart L. Do musicians have different brains? Clin Med 2008; 8:304-308
9. Altenmüller EO. How many music centers are in the brain? Ann N Y Acad Sci 2001; 930:273-280.
10. Tudor L, Sikirić P, Tudor KI, Cambi-Sapunar L, Radonić V, Tudor M, Buca A, Carija R. Amusia and aphasia of Bolero's creator--influence of the right hemisphere on music. Acta Med Croatica 2008; 62:309-316.
11. Hassler M. Functional cerebral asymmetries and cognitive abilities in musicians, painters, and controls. Brain Cogn 1990; 13:1-17.
12. Dawson WJ. How and why musicians are different from nonmusicians: a bibliographic review. Med Probl Perform Art 2011; 26:65-78.
13. Stewart L. A neurocognitive approach to music reading. Ann N Y Acad Sci 2005;1060:377-386.
14. Patston LL, Kirk IJ, Rolfe MH, Corballis MC, Tippett LJ. The unusual symmetry of musicians: musicians have equilateral interhemispheric transfer for visual information. Neuropsychologia 2007; 45:2059-2065.
15. Alfredson BB, Risberg J, Hagberg B, Gustafson L. Right temporal lobe activation when listening to emotionally significant music. Appl Neuropsychol 2004; 11:161-166.
16. Evers S, Dannert J, Rödding D, Rötter G, Ringelstein EB. The cerebral haemodynamics of music perception. A transcranial Doppler sonography study. Brain 1999; 122:75-85.
17. Jerde TA, Childs SK, Handy ST, Nagode JC, Pardo JV. Dissociable systems of working memory for rhythm and melody. Neuroimage 2011; 57:1572-1579.
18. Vollmer-Haase J, Finke K, Hartje W, Bulla-Hellwig M. Hemispheric dominance in the processing of J.S. Bach fugues: a transcranial Doppler sonography (TCD) study with musicians. Neuropsychologia 1998; 36:857-867.
19. Groussard M, Viader F, Hubert V, Landeau B, Abbas A, Desgranges B, Eustache F, Platel H. Musical and verbal semantic memory: two distinct neural networks? Neuroimage 2010; 49:2764-1773.
20. Abecasis D, Brochard R, Del Río D, Dufour A, Ortiz T. Brain lateralization of metrical accenting in musicians. Ann N Y Acad Sci 2009; 1169:74-78 (PMID:19673756).
21. Ross DA, Gore JC, Marks LE. Absolute pitch: music and beyond. Epilepsy Behav 2005; 7:578-601.
22. Oechslin MS, Imfeld A, Loenneker T, Meyer M, Jäncke L. The plasticity of the superior longitudinal fasciculus as a function of musical expertise: a diffusion tensor imaging study. Front Hum Neurosci 2010; 3:76.
23. Crummer GC, Walton JP, Wayman JW, Hantz EC, Frisina RD. Neu-

ral processing of musical timbre by musicians, nonmusicians, and musicians possessing absolute pitch. J Acoust Soc Am 1994; 95:2720-2727.
24. Halpern AR. Cerebral substrates of musical imagery. Ann N Y Acad Sci 2001; 930:179-192.
25. Bhattacharya J, Petsche H. Musicians and the gamma band: a secret affair? Neuroreport 2001; 12:371-374.
26. Tervaniemi M, Sannemann C, Noyranen M, Salonen J, Pihko E. Importance of the left auditory areas in chord discrimination in music experts as demonstrated by MEG. Eur J Neurosci 2011; 34:517-523.
27. Ellis RJ, Norton AC, Overy K, Winner E, Alsop DC, Schlaug G. Differentiating maturational and training influences on fMRI activation during music processing. Neuroimage 2012; 60:1902-1912.
28. Koelsch S, Fritz T, Schulze K, Alsop D, Schlaug G. Adults and children processing music: an fMRI study. Neuroimage 2005; 25:1068-1076.
29. Baeck E. The neural networks of music. Eur J Neurol 2002; 9:449-456.
30. Trainor LJ, Shahin AJ, Roberts LE. Understanding the benefits of musical training: effects on oscillatory brain activity Ann N Y Acad Sci 2009; 1169:133-142.
31. Bangert M, Schlaug G Specialization of the specialized in features of external human brain morphology. Eur J Neurosci 2006; 24:1832-1834.
32. Fujioka T, Ross B, Kakigi R, Pantev C, Trainor LJ One year of musical training affects development of auditory cortical-evoked fields in young children. Brain 2006; 129:2593-608.
33. Schneider P, Scherg M, Dosch HG, Specht HJ, Gutschalk A, Rupp A Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. Nat Neurosci 2002; 5:688-694.
34. Schlaug G, Jäncke L, Huang Y, Staiger JF, Steinmetz H Increased corpus callosum size in musicians. Neuropsychologia 1995; 33:1047-1055.
35. Abdul-Kareem IA, Stancak A, Parkes LM, Sluming V. Increased gray matter volume of left pars opercularis in male orchestral musicians correlate positively with years of musical performance. J Magn Reson Imaging 2011; 33: 24-32.
36. Midorikawa A. Amusia. Brain Nerve 2007; 59:865-870.
37. Berman IW. Musical functioning, speech lateralization and the amusias. S Afr Med J 1981; 59:78-81.
38. Schuppert M, Münte TF, Wieringa BM, Altenmüller E. Receptive amusia: evidence for cross-hemispheric neural networks underlying music processing strategies. Brain 2000; 123:546-559.
39. Brust JC Music and language: musical alexia and agraphia. Brain 1980; 103:367-392.
40. Tzortzis C, Goldblum MC, Dang M, Forette F, Boller F. Cortex. Absence of amusia and preserved naming of musical instruments in an aphasic composer. 2000; 36:227-242.
41. Mostafa M, Kotby MN, Barakah M, el-Sady S, Allosh T, Elshobary A, Saleh M. Dominant functions of right versus the left hemisphere. Acta Otolaryngol. 1989;107:479-484
42. Särkämö T, Tervaniemi M, Laitinen S, Forsblom A, Soinila S, Mikkonen M, Autti T, Silvennoinen HM, Erkkilä J, Laine M, Peretz I, Hietanen M. Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. Brain 2008; 131:866-876.
43. Vignolo LA. Music agnosia and auditory agnosia. Dissociations in stroke patients. Ann N Y Acad Sci 2003; 999:50-57.