Is music useful for the brain? Updates from research to practice and contrary

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Abstract

Between the medical humanities, music is a useful mean for investigating brain plasticity, since it involves multiple sensory, motor and executive systems. Particularly, in childhood, music training can result in long-lasting changes in brain organization. Moreover, in adult and elderly, music activities could protect brain and potentiate the cognitive reserve. During the past 10 years, a growing scientific research showed that Music Intervention plays a very important role among the drug-free treatment and rehabilitation in neurological diseases. We will report the data that are on the basis of all these evidences showing a strict interaction of the music with the brain.

Keywords: brain, cognitive reserve, functional magnetic resonance imaging, music, neuroplasticity, neurorehabilitation, structural magnetic resonance imaging.

Introduction

Music can influence the brain activity in many different ways. It makes you smarter, happier and more productive at any age. Listening music is good, but playing an instrument is even better.

During the ages, many authors expressed their opinion about the relationship between music and brain. Oliver Sacks wrote that humans are programmed to music through an auditory, neurological and emotional system and that in people's life music is likely to be similar to the language, involving many neural networks.[1]

Anthony Storr, in his excellent book *Music and the Mind,* stressed that in all societies, a primary function of music is collective and communal, to bring and bind people together. The power of sound has been recognized in all cultures and their therapeutic use has gone through the centuries, social and political travails, cultural movements, and scientific discovery without ever being questioned, representing a part of our heritage, genetic and experience, worldwide shared since the prenatal age.[2] Furthermore, music has a great power to involve many aspects of the human life, involving body and soul at the same time.

Music and language

Music represents a form of communication, alternative to the verbal one, appearing universal in all the people.[3] Likewise a language, it is possible to distinguish a phonology (language components), a syntax (the rules for combining components) and a semantic (attribution of meaning to language products). It is common to consider art and culture predominantly in a humanistic rather than a biological perspective, but music is an interesting involvement of neuroscience, from the ability to acquire motor learning to arousing emotions. Even listening to a simple note, requires the activation of complex auditory mechanisms, attention, memory/memory storage, motor-sensor integration.

Where is music processed in the brain?

Music processing is composed by a very complex systems in which each brain area plays a specific role. The acoustic signal is transmitted through and along the auditory pathways, descending the brainstem directly into the primary acoustic cortex in the upper temporal lap with an integration in other cortical and subcortical regions such as thalamus (for the audio-visual phenomena) and limbic system (for the emotional effects). The melody and timbre perception (non-verbal, global, intuitive and synthetic process) take place in the right brain hemisphere, the rhythm , tone and familiarity perception (verbally, sequentially, logically and analytically information processes) in the left one. On the one hand, temporal lobe (auditory cortex, hippocampus and amygdala) is the most involved in sounds impulses emotional responses and memory aspects processing. On the other hand, occipital lobe provides for visual processing, the frontal lobe facilitates planning to assist in music creation and writing, parietal lobe for the language processing and sound interpretation. Finally cerebellum manages the coordination and the balance needed for playing an instrument, dancing, clapping hands and tapping toes and brainstem is able to determine the location of sound origin and sound reverberation processes.[4,5]

Insight from functional magnetic resonance imaging studies

In the last few years, functional magnetic resonance imaging (f-MRI) allowed to study the different brain areas activation during a musical tasks (from listening to playing an instrument). Thus, music could represent and useful method for studying the brain plasticity, involving multiple sensory, motor and executive systems. Since music and language are closely related, many f-MRI studies have identified some brain areas most involved in both processes, syntactically and semantically (frontal operculum for the musical syntax, right hemisphere for the melody processing and superior temporal sulcus for the musical semantic).[4] Music is also able to produce an intense flow of the emotions in the human soul through the activation of limbic, autonomic nervous system and endorphins release.

In a recent work researchers through f-MRI and positron emission tomography imaging experiments were able to map neural changes under the most popular music *(Gangnam Style)* and light music in healthy controls. Significantly increased f-MRI signals were found in the bilateral superior temporal cortices, left cerebellum, left putamen and right thalamus cortex, left superior temporal gyrus and left putamen, under the *Gangnam Style* compared with the light music condition.[6] Another group of researchers using binaural beats phenomenon (that occurs within the cortex when two different frequencies are presented separately to each ear) during a visuospatial working memory task demonstrated an increased response accuracy, but also modified strengths of the cortical networks during the task.[7]

Effects of musical training in children

In children music is able to bring benefits in many areas of learning, playing an important role in brain development. In fact, children who underwent to music exposure had higher cognitive skills, showing a higher intellectual quotient and memory scores.[8] Playing a music instrument, mostly starting at an early stage, would significantly improve brain sensitivity not only of sounds but of language as well Music training could induce structural brain changes in early childhood suggesting that long term music intervention programs can promote the neuroplasticity.

Also, in the scientific literature, many MRI study (functional and structural) described same differences between musicians and non-musicians brain. Indeed, some brain regions seem to be more developed in musicians. Among them, worthy of note, the planum temporale, the auditory cortex, the corpus callosum, the arcuate fasciculus and the motor cortex, the latter, being involved in the control fingers during the piano exercises, appear largest in keyboard players.[5]

Music efficacy in the clinical practice

During the past ten year, an increasing number of controlled studies have assessed the potential rehabilitative effects of music interventions, in several neurological diseases.

Generally, music intervention is focused on the relationship between body language and sound, such as interaction between perception and action, but above all it represents a communication form alternative to the verbal one. It also excites emotions by taking into account some sound parameters (height, intensity, duration, and timbre) and others of dynamic type (mode, genre, executive style). A wide spectrum of music intervention programs (interactive or passive) are known: singing songs of the repertoire of light and popular music, music/movement association (from physical relaxation to free gestures or structured in rhythmic sequences dancing and dancing popular), instrumental improvisation, and listening music tracks.[2]

The goal is not to acquire musical skills, but to use the language of sound to open alternative communication channels.

In a recent review, Aleksi Sihvonen et al.[9] performed a comprehensive meta-analysis and meta-regression of all available randomised controlled trials (RCT) in some neurological diseases, such as dementia, Parkinson, multiple sclerosis and epilepsy, evaluating the effects of different type of music intervention in the clinical practice[9] and summarized in Table 1.

In stroke patients, fMRI studies conducted during music interventions, especially listening, reported connectivity changes in different brain networks, enhancing the motor recovery (gait, balance, rehabilitating arm paresis; 8 RCT) , cognitive and mood functions improvement (memory, attention, executive functions, depression; 2 RCT) and speech gain in chronic aphasia (2 RCT).[9]

In dementia music listening coupled with cognitive elements (reminiscence and attention training) or physical exercises, improved overall cognitive performances (4 RCT) and neuropsychiatric symptoms (6 RCT) versus the standard care. In one clinical trial singing enhanced short-term and working memory.[9] Cognitive benefits were observed only in the early stages of the disease and that might be related to the cognitive reserve, the use of alternative networks and cognitive strategies to cope with advancing impairment.

In Parkinson disease (2 RCT) rhythmic movements and dancing (conducted by metronome beat, rhythmic clapping or stomping, dancing tango and waltz), improved overall motor performances and quality of life.[9]

In multiple sclerosis only 2 RCT conducted, showed an improved functional use of the hand and decreased double-support time (gait parameters) after 2 weeks of music intervention (keyboard playing, rhythmic auditory stimulation).[9]

Only one RCT conducted in epilepsy showed a decrease of the frequency after one year of Mozart sonata exposure.[2,9]

There are numerous mechanism underlying the rehabilitative effect of music. The activation of different brain networks with increases blood flow through the medial cerebral artery should provide favourable circumstances for recovery, leading to functional neuroplastic changes and neural reorganization, also using specific regions not directly affected by the diseases (alternative neural networks).[10]

Conclusions and future perspectives

Music could be very useful for our brain and all data are concordant to indicate that an early music exposure in childhood may influence many intellectual parameters. Small musicians, in fact, boast much more memory than children who are not familiar with notes and violin keys. The educator should provide opportunities for students to sing, play, talk, reflect, write, work in small group, in order to give them opportunities to observe skillful modelling of the targeted task.

In the clinical practice, music intervention could play and important role among the drug-free treatment and rehabilitation of patients with neurological disorders. Moreover, being non- invasive, free of adverse events and not requiring an expensive training, it can be delivered easily and successfully. Indeed, the medical staff should be trained to perform a wide spectrum of music intervention in the clinical practice.

In the future, collaboration with other disciplines and professional figures such as psychology, psychology of art, music therapist, psychotherapists, doctors, and musicians will be mandatory. Consideration should also be given to validation of methods in order to identify global strategies and techniques to apply for each clinical setting. The evaluation must be related to a methodological process that involves common targets, controlled variables, data collection and interpretation, used tools, and interpretation, verifying methods, and performed techniques.

Table 1. *Randomised controlled trials assessing various music-based interventions in neurological rehabilitation. Adapted from Lancet Neurol. 2017;16:648-60.*[9]

	Studies (n)	Participants (n)	Music therapist involved	Blinding
Dementia				
Multisensory stimulation *vs* music listening	1	18	No	No
Music listening *vs* singing *vs* standard care	3	83	Yes	Single

Primary outcome	Overall duration of intervention	Main results
Neuropsychiatric symptoms and cognition	16 h in16 weeks	Multisensory stimulation showed positive effects on anxiety symptoms and dementia severity that were not observed in the music listening group.
Emotional parameters; clinical, demographic, and musical background factors influencing the cognitive and emotional efficacy of caregiver-implemented musical activities; quality of life, mood, and cognition	15 h in10 weeks	Both music listening and singing groups improved in behavioural disturbances ($p = 0.04$, $d = 0.42$) and physical signs ($p = 0.008$, $d = 0.52$) more than the control group. Effects not present 6 months after the intervention; singing was beneficial, especially in improving working memory in people with mild dementia and in maintaining executive function and orientation in young people with dementia. Music listening was beneficial in supporting general cognition, working memory, and quality of life, especially in people with moderate dementia not caused by Alzheimer's disease who were in institutional care. Both music interventions alleviated depression, especially in people with mild dementia and Alzheimer's disease. The musical background of people with dementia did not influence the efficacy of the music interventions; music listening improved the patients' mood ($p = 0.001$, $d = 0.80$), orientation ($p = 0.005$, $d = 0.71$), episodic memory ($p = 0.036$, $d = 0.54$), attention and executive functions ($p = 0.039$, $d = 0.48$), overall cognitive performance ($p = 0.041$, $d = 0.47$), and the quality of life ($p <0.001$, $d = 0.99$). Singing resulted in additional improvement in short-term memory and working memory ($p = 0.006$, $d = 0.75$), and improved caregiver wellbeing ($p = 0.026$, $d = 0.85$).

Continue

	Studies (n)	Participants (n)	Music therapist involved	Blinding
Music therapy and music listening *vs* standard care	1	98	Yes	Single
Music listening, singing, improvising, and talking *vs* standard care	1	13	Yes	No
Group music therapy *vs* standard care	1	100	Yes	Single
Music therapy (listening and singing) *vs* other activities	3	76, 77 59	Yes	Single
Music therapy (listening, playing and singing) *vs* cooking	1	37	..	Single
Music therapy *vs* standard care	2	50, 50	Yes	Single
Favourite music *vs* standard care	1	52	No	No

Primary outcome	Overall duration of intervention	Main results
Behavioural and psychological symptoms of dementia	10 h in 10 weeks	No significant differences between the groups.
Neuropsychiatric symptoms, well-being, and carer–resident interaction	11 h in 22 weeks	Music group showed improvement in symptoms ($p = 0.002$, $d = 2.32$) and in levels of wellbeing ($p < 0.001$, $d = 3.85$). Staff in the intervention group reported enhanced caregiving techniques as a result of the programme.
Mood and cognition	6 h in 6 weeks	Group music therapy decreased depression ($p = 0.001$, $d = 0.21$) and delayed the deterioration of cognitive functions, especially recall ($p = 0.004$, $d = 0.72$). The effects were present 1 month after cessation of the intervention.
Neuropsychiatric symptoms; agitation; behavioural and psychological symptoms	21 h in 16 weeks 15 h in 16 weeks	Neuropsychiatric symptoms decreased significantly in the music therapy group ($p = 0.01$); there were no significant differences between the groups; music therapy improved behavioural symptoms ($p < 0.0001$, $d = 1.04$), functional ability ($p < 0.0001$, $d = 0.79$), and empathetic behaviour ($p < 0.0001$, $d = 0.61$) compared with the control treatment.
Patients' mood, cognition, behavioural disturbances, and stress experienced by their nurses	8 h in 4 weeks	There were no significant differences between the groups.
Cognition and anxiety; 51 behavioural disturbances	18 h in 12 weeks 6 h in 4 weeks	The music group improved performance in attention ($p = 0.001$, $d = 0.76$) and verbal episodic memory tasks (immediate $p = 0.001$, $d = 0.76$; delayed $p = 0.001$, $d = 0.73$), but not in anxiety; music reduced the behavioural disturbances showed by significant group difference ($p < 0.05$, $d = 0.63$).
Anxiety	6 h in 6 weeks	Anxiety decreased in the music group ($p = 0.004$, $d = 0.06$).

Continue

	Studies (n)	Participants (n)	Music therapist involved	Blinding
Music therapy (playing and listening) *vs* standard care	1	100	Yes	No
Music therapy (listening and playing) *vs* reading	1	47	Yes	Single
Music therapy *vs* resting and reading	1	30	Yes	Single
Parkinson's disease				
Music listening, rhythmic clapping, or stomping *vs* standard care	1	18	Yes	Single
Favourite music synchronised to gait *vs* regular activities	1	22	No	Single
Tango, waltz, or foxtrot dancing *vs* standard care	1	48	No	Single
Tango and waltz or foxtrot *vs* Tai Chi or standard care	1	61	No	No
Tango *vs* physical exercise	1	19	No	Single

Primary outcome	Overall duration of intervention	Main results
Agitation	6 h in 6 weeks	There was no significant difference between the groups.
Mood and quality of life	32 h in 16 weeks	There were no significant differences between the groups.
Anxiety and mood	5 h in 16 weeks	Music therapy decreased anxiety ($p < 0.001$, $d = 2.42$) and depression ($p = 0.002$, $d = 1.05$). These effects persisted up to 2 months after stopping the intervention.
Motor performance, cognition, and quality of life	12 h in 6 weeks	Music therapy improved mobility ($p = 0.006$), UPDRS III ($p = 0.003$), text recall ($p = 0.036$), item naming ($p = 0.033$), performance in Stroop test ($p = 0.007$), and quality of life ($p = 0.031$).
Walking parameters	19.5 h in 13 weeks	Walking to music improved velocity ($p = 0.002$, $d = 2.64$), stride time ($p = 0.019$, $d = 1.76$), cadence ($p = 0.007$, $d = 2.16$), and UPDRS III ($p = 0.002$, $d = 0.50$).
Functional motor control	20 h in 13 weeks	Tango group improved in balance ($p = 0.001$, $d = 2.98$), 6-min walking ($p = 0.001$, $d = 2.50$), and backward stride length ($p = 0.001$, $d = 2.19$); waltz or foxtrot group improved in balance ($p = 0.001$, $d = 3.17$), 6-min walking ($p = 0.001$, $d = 2.24$), and backward stride length ($p = 0.018$, $d = 1.96$).
Health-related quality of life	20 h in 13 weeks	Tango improved mobility ($p = 0.03$, $d = 2.50$), social support ($p = 0.05$, $d = 2.97$), and quality of life ($p<0{\cdot}01$, $d = 2.09$).
Functional mobility	20 h in 13 weeks	Tango group improved balance ($p = 0.01$, $d = 2.18$).

Continue

	Studies (n)	Participants (n)	Music therapist involved	Blinding
Multiple sclerosis				
Keyboard playing *vs* mute keyboard playing	1	19	No	No
RAS *vs* standard care	1	10	Yes	No
Epilepsy				
Nightly exposure of Mozart Sonata K. 448 *vs* no intervention	1	73	No	Single

Moreover, an accurate standardization of music exercises will be needed.[2]

In consequences, the musicologist should be familiar with research activity using the principles of verification and control of the applied methodologies also of innovative choices in relation to patients and the operating techniques used, identifying the specific contribution of music therapy beyond simple effects related to sound exposure.

Finally, further studies are needed, including those involving larger sample sizes, stratified by a single cognitive deficit through a specific

Primary outcome	Overall duration of intervention	Main results
Hand function	7.5 h in	The music group improved in the functional use of the hand significantly
	2 weeks	more showed by time × group interaction ($p = 0.003$, $d = 0.60$).
Gait parameters	2 weeks	RAS significantly decreased double-support time (left: $p = 0.018$, $d = 1.61$; right: $p = 0.025$, $d = 1.46$).
Seizure occurrence	Every night for 1 year	Seizure frequency in the music group decreased significantly during the treatment phase (17%, $p = 0.014$) and 1 year after treatment (16%, $p = 0.027$).

neuropsychological assessment.
It could be useful to identify new intervention strategies and implement rehabilitation programs in relationship to the different, predispositions, and preferences of each patient. Also, it would be very interesting to investigate changes in brain connectivity through fMRI studies, before and after musical interventions, taking into account the role of neuroplasticity and reserve (brain and cognitive). These strategies could be applied in the early stages of different neurological disease in order to slow down and control the degenerative process, providing a strong evidence for music intervention clinical utility.

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