



## Enhancement of stroke recovery by music

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### Abstract

*The connection of musical sounds and the brain functions is a major challenge of modern neuroscience. It has long been proven that music has a psychological effect on human beings, including induction and modification of cognitive states, moods and emotion. Brain activity, metabolism and blood flow are closely linked. Cognitive activation leads to metabolic changes in specific cortical centres. Consequently, any change in cognitive cortical activity reflects in blood flow velocity. This is especially important in patients recovering from stroke. At present stroke is a frequent, serious, and hindering global health-care problem, and rehabilitation is a major part of patient care. Thus any improvement in blood flow through the brain during rehabilitation period is a major contribution in stroke recovery. The recent studies show that rehabilitation in well coordinated multidisciplinary stroke units proved to be more successful in the recovery of stroke patients. One of the possible attributing factors to the improvement of stroke rehabilitation could be incorporation of music listening in the therapy. Furthermore the studies show that music stimulation increases blood flow in patients suffering from acute ischemic stroke enhancing the post-stroke recovery and can therefore be a helpful tool in neurorehabilitation.*

### REVIEW ARTICLE

Human race has been living with music since ancient times. People listen to music, play music, and create music. Considering what important role it plays in human life, it is hard to believe that music is just another hobby. The interest in music starts in early childhood. It is the central core of every culture and probably goes far back to the beginning of the human species. It flourished through centuries and probably shaped our culture.

Music plays important part in animal kingdom as well. The song in some birds has a specific function of seduction and sometimes it is used to mark the territory. It is also a form of communication with other birds and is thus deeply incorporated into the structure of the avian nervous system (1). The purpose of music in humans is less clear. Human brain has more than one center for music. Listening to music activates large neural network embedded in the human brain. Most of us are able to recognize the music, melodic pieces of music, harmony within the music as well as distinguish low from high tones, and quite possibly different beats. We integrate all the parts of the music, and »create« a melody in our head by using different parts of the brain. The structuring of music very often includes our unconscious emotional perception of music and produces a complete response to the music.

Listening to music is apart of auditory and emotional as well as the motor process. Unconsciously during music listening, we activate the facial muscles as well as body muscles according to the music. The same changes occur when we just imagine the music in our head.

Imagining music is sometimes out of control. There are published cases of musical hallucinations, and in some people, certain music can initiate seizures. Surprisingly large number of people experience different colours and tastes, even smells while listening to music. Such synesthesia is more a symptom than a gift (1).

Music has a powerful effect on people. It can be calming, animating and comforting, and sometimes helpful in the organization and synchronization of work. Music has a therapeutic potential in both psychological and neurological diseases.

The connection of music and brain function is a great challenge of our time. Recent research shows that music has a psychological effect on human beings, including induction and modification of cognitive status, mood and emotion (2, 3). Brain activity, metabolism and blood flow are closely linked. Cognitive activation leads to metabolic changes in specific cortical centers, and these changes can indirectly monitored by measuring the changes of blood flow in the brain. Consequently, any change in blood flow velocity in large cerebral arteries is a reflection of changes in cognitive activity. Thus the increase in cerebral blood flow velocity increase mostly reflects the increase in cerebral metabolism induced by motor, sensory, or cognitive function activation (4, 5, 6). Appropriate method for monitoring changes in blood flow velocity is Transcranial Color Doppler (TCD) that has been used in measuring of the cerebral circulation for twenty years. Scientists nowadays use it in recent studies to assess brain dynamics during cognitive activity testing (7, 8, 9, 10).

Previous research of auditory stimulation showed that the perception and processing of musical information in healthy individuals requires activation of both cerebral hemispheres (11). Matteis and colleagues described a bilateral increase in cerebral blood flow during a music recognition tasks (11). Evers and colleagues describe the use functional TCD in assessment of brain hemodynamics during music perception in musically trained and musically uneducated individuals. They found differences in hemispheric lateralization during music auditory stimulation (12).

A stroke is the result of cerebrovascular disease and is the leading cause of disability in modern society. It is a neurological disorder that requires urgent medical treatment. Stroke is the third leading cause of death and the leading cause of disability in developed countries. In Croatia, in the last few years, stroke is the second leading cause of death and the leading cause invalidity. One-third of the stroke patients are younger than 65 years. Despite substantial progress in the management of stroke patients still about a third of stroke patients die (13). Approximately 30% of patients who survive a stroke later depend on others for help, 20% need help with walking, 15% of

patients end up in the specialized facilities. Furthermore 70% have reduced work capacity (14).

Mortality rate within 30 days of stroke onset is around 15% for cerebral infarction and approximately 80% of cerebral hemorrhage. It is in decline in the last four decades, almost entirely as a result of decreased morbidity rate of cerebral infarction largely due the reduction of the risk factors caused by the changes in the lifestyle. The incidence of stroke in developed countries has decreased and mortality was reduced also due to better management of patients with stroke. Unfortunately, in the countries of Central and Eastern Europe as well as in developing countries, the incidence of stroke and mortality still increases (13, 14, 15).

Ischemic stroke occurs rapidly and causes a loss of function of the affected brain regions. Surrounding a focal ischemic brain tissue there is a surrounding area of hypoperfusion called ischemic penumbra, which describes the area where the irreversible ischemic changes have not yet occurred. Depending on the sufficiency and the ability of the collateral circulation as well as therapeutic measures the neurons in the periphocal penumbra can either recover (improvement of symptoms) or irreversible deteriorate which can be seen as further worsening of symptoms. Clinical features and neurological signs indicate the localization and size of lesions, and the prognosis of the disease (13).

The recovery of neurological deficit is the most efficient in the first hours up to the first three months after the stroke occurrence. Therefore that is the optimal time to implement rehabilitation. Early rehabilitation is crucial in the treatment of stroke patient. Patients after ischaemic stroke often have severe impairments and functional limitations of movement and perception. Early physical therapy greatly improves functional recovery and reduces the number of patients dependent on professional help (13, 17). The main goals of rehabilitation after stroke are prevention of limb contractures and embolism, the optimal treatment of specific medical problems and providing psychological assistance and support to patients and their families.

Nowadays, there is strong scientific evidence in favor of the plasticity of the human brain in healthy and the brain stroke damaged brain (18). There are studies that suggest that the ability of the damaged brain plasticity is higher than in the healthy individuals (19). Developmental proteins that are not usually found in cells of the developed brain reemerge few hours after focal brain damage. These proteins are involved in the changes in the extracellular matrix, the structure of glial cells, neuronal growth, apoptosis, angiogenesis, and cell differentiation (18, 20).

Rehabilitation should start as early as possible, even in the comatose patients, preferably within a few hours or days of the stroke onset. It includes changing the position of the patient's body, proper positioning and performing passive movements in the full range of motion in healthy as well as paralyzed limbs several times a day. The intensity

of the rehabilitation program depends on the patients' neurological state, and the degree of their physical disability. In an unconscious patient, passive rehabilitation is carried out in order to prevent a contracture of the limbs, peri-arthritis and the pain in the joints as well as to facilitate the patient's period of movement re-establishment. Passive rehabilitation largely prevents the occurrence of pressure ulcers and pneumonia as well. After two or three days, the majority of the conscious patients, can spend the whole day in the wheelchair instead of the bed (13, 17).

If stroke is causing the destruction of the brain centers involved in speech and language thus causing speech disturbances or paresis of linguistic muscles, the speech therapy should begin at the same time as physical therapy. Language and speech therapy also raises the confidence of the patient and thus further contributes greatly in the rehabilitation of the patients (17).

The team that participates in the implementation of rehabilitation in stroke patients should be multidisciplinary. It should include neurologists, experienced nurses, physiotherapists specifically trained in the rehabilitation of stroke patients, speech therapist, a neuropsychologist, and a social worker. Active participation of the patients and their families, educated staff and the early beginning of the therapy as well as the right intensity of the therapy are the most important factors in successful neurorehabilitation (13).

Active rehabilitation should be continued for as long as the patient's condition requires, as part of a long-term rehabilitation program. Such programs include a series of physiotherapy treatment at least twice a year. This way the physical state of the patient achieved in the active rehabilitation program can be permanently maintained. If there is deterioration in neurological status, the patient can restart the active rehabilitation program (13).

Many novelties are introduced in the physical therapy methods, among others the role of music is researched more than ever and very significant and optimistic results were established. Music with its rhythm especially helps recovery of walking, what was presented by researchers at Colorado State University who stimulated stroke patients with rhythmic melody and after three weeks they were able to walk more steadily and had better balance than the patients without rhythmic stimulation (21).

The changes of blood flow velocity in patients with compromised brain circulation during auditory stimulation were monitored by „near-infrared“ spectroscopy. The study showed that during rehabilitation of stroke patients there was an increase in both, cerebral blood volume and cerebral oxygen volume in patients with hemiplegia while they were listening to music (22).

In the study performed Antić and colleges, functional transcranial Doppler was used to monitor the changes in blood flow velocities in the middle cerebral arteries in stroke patients during auditory stimulation. The study shows that the blood flow through both middle cerebral arteries while listening to music was statistically greater

than the blood flow during the periods of inactivity thus proving that music affects the brain in terms of increasing the blood flow through both middle cerebral arteries. The results of the study showed that music is an effective auditory stimulus in patients with acute stroke patients. In 78.85% of the patients the study proved a significant difference in increasing mean blood flow velocities in the middle cerebral arteries as a reaction to the music comparing to the baseline blood flow. Findings correlate with the results of the study of Saitou and colleges that reported that listening to music during the rehabilitation of patients after stroke has an effect on brain activation and produces changes in cerebral hemodynamics, which is measurable by infrared spectroscopy (22, 23).

Comparing patients with minor stroke and those with severe stroke while listening to relaxing music, the study of Antić and colleges found that patients with minor stroke had significantly shorter reaction time to the music than patients with more severe symptoms of stroke. There was no statistically significant difference in the amplitude of the reaction between the two groups (23).

It is well known that the perfusion of the brain plays a major role in its recovery after damage therefore right timing is important in rehabilitation, as is the intensity with which rehabilitation is carried out. It is important to start as early as possible and provide optimal perfusion through the brain. Increasing perfusion of the brain in the early stages could reduce the consequence of the stroke. Considering the stroke to be a pathological process that affects one or more arteries in the brain leading to abnormal blood supply to vital brain regions, improvement in the hemodynamics and the blood supply of the affected area of the brain during the rehabilitation and recovery of stroke patients improves fast healing and better brain function, thus significantly contributing to the treatment (23).

Sarkamo in his work suggests that everyday music listening is of great benefit to patients after ischaemic stroke as an auxiliary method in the health care especially if at that point the other methods of neurorehabilitation are not applicable. This allows individualized, simple effective and financially advantageous manner of cognitive and emotional recovery of patients. Sarkamo and colleges have received positive results and showed a better recovery of patients after stroke with the use of musical stimulation (24). In their research they also studied the long-term effects of daily music and speech listening on auditory sensory memory after middle cerebral artery stroke and showed behavioural improvement of verbal memory and focused attention induced by music listening demonstrating that merely listening to music and speech after neural damage can induce long-term plastic changes in early sensory processing, which, in turn, may facilitate the recovery of higher cognitive functions (25). In their latest research Sarkamo presented findings about the short- and long-term effects of music listening on the recovery of cognitive function in stroke patients and the underlying neural mechanisms of these music effects. Their results indicate that listening to pleasant music can

have a short-term facilitating effect on visual awareness in patients with visual neglect, which is associated with functional coupling between emotional and attentional brain regions. Second, daily music listening can improve auditory and verbal memory, focused attention, and mood as well as induce structural grey matter changes in the early post stroke stage. In their paper they discussed the psychological and neural mechanisms potentially underlying the rehabilitating effect of music after stroke (26).

In their research Schneider and colleges performed a study and evaluated a music-supported training program designed to induce an auditory-sensorimotor co-representation of movements. The study showed that patients improvement significantly after treatment with respect to speed, precision and smoothness of movements as shown by 3D movement analysis and clinical motor tests. Furthermore, compared to the control subjects, their motor control in everyday activities improved significantly thus suggesting this innovative therapeutic strategy is an effective approach for the motor skill neurorehabilitation of stroke patients (27).

It has been reported for more than 100 years that patients with severe nonfluent aphasia are better at singing lyrics than they are at speaking the same words. Since the area for singing is mostly spared in stroke patients with dysphasia, singing is of the great help in regaining speech abilities. The studies have shown that patients with stroke who have listened to the music during physical therapy had better results than the group without musical background during rehabilitation. Research conducted by Schlaug has shown that both components of melodic intonation therapy (the intonation of words and simple phrases using a melodic contour that follows the prosody of speech and the rhythmic tapping of the left hand that accompanies the production of each syllable and serves as a catalyst for fluency) are capable of engaging fronto-temporal regions in the right hemisphere, thereby making melodic intonation therapy particularly well suited for patients with large left hemisphere lesions who also suffer from nonfluent aphasia (28).

Stroke patients also suffered of depression in a less degree and they were emotionally more stable and more communicative than control subjects (29, 30).

Music therapy doesn't consist only in listening to the music. Playing the instrument uses many aspects of the brain and body, it stimulates and synchronizes motor skills (27, 31).

The incredible therapeutic power of music is unlimited. The influence of music on healing processes was investigated by many scientists –medical and musical experts and the clear connection based on clinical studies between music and better recovery after stroke is shown. Particular benefit was shown in muscle and movement control, speech recovery, cognition and mood. Music activates many brain structures, increases cerebral circulation and stimulates the brain. For these reasons, the music would be a powerful tool in the service of the neurological rehabilitation of patients after ischaemic stroke.

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