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**REVIEW**
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# Music in Speech Rehabilitation for Patients with Neurological Impairments

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Music can enhance therapeutic outcomes in speech rehabilitation due to the anatomical and functional relationship between music and speech tasks. Singing and vocalization induce similar brain activities, and compensation for difficulties in speech production can be expected during these activities. Singing also requires active engagement in vocal and respiratory tasks. It is obvious that singing can be used as a pinpointed therapeutic tool for specific speech problems such as respiration, vocalization, or phonation, while also offering other emotional, motivational, and psychological benefits that are widely associated with musical activity in general. Therefore, this paper broadly reviews relevant research outcomes in association with speech and music, along with previous music therapy research involved in speech rehabilitation for patients with neurological disease. **Vascular Neurology 2009;1:33-37**

**Key Words** Music, Singing, Rehabilitation of speech, Neurologic disease.

Considering the distressing impact that damage to the brain can have upon the life of a previously healthy individual, patients with neurological impairments obviously need an intensive and effective rehabilitation process to recover their previous functionality. Patients with neurological impairments show deficiencies in various areas including physical, oral motor, and cognitive skills. In particular, speech disorders are commonly found in patients with neurologic disease, accompanying problems in language (aphasia), and speech motor control (dysarthria or apraxia of speech).[1]

Speech function is a unique means of communication, and it involves the coordination of several different subsystems: the respiratory system, the larynx, and the different parts of the vocal tract.[2] The act of singing, like speaking, requires respiration, phonation, and articulation[3]; however, singing demands more amendable coordination. In addition, not only the anatomical similarities but also the brain regions involved in both speech and singing tasks show similarities. Brain imaging studies have demonstrated left hemisphere lateralization for language perception and production.[4-6] On the other hand, music processing occurs in both hemispheres. While several musical aspects, such as melody or meter perception, and spectral processing (tone-spacing) of musical stimuli, are processed predominantly the right hemisphere,[7,8] other aspects, such as temporal processing of musical stimuli, require more involvement of the left hemisphere.[8-10] This paper broadly reviews relevant research outcomes in association with speech and music, along with previous music therapy research involved in speech rehabilitation for patients with neurologic diseases.

## Speech/Language Disorders after Neurological Impairments

Due to the complexity of motor and linguistic activities in speech production, speech impairment occurs when brain damage disrupts the neurological pathways which control these specialized motor movements. The types of communication disorders secondary to neurological impairments including stroke, Parkinson's disease or brain injury can vary according to involvement of language (aphasia), cognition, and/or speech motor control (dysarthria or apraxia of speech). These three types of disorders are common diagnoses for patients with neurological impairments who require speech rehabilitation.

Aphasia is an acquired impairment of the language system that affects all aspects of language production. Due to impairment in the language production area of the brain, the

 

most common symptom of aphasia is a difficulty in retrieving words to communicate. Extensive research regarding aphasia has focused on automatic activation with respect to Broca's aphasia. Nonfluent speech outcomes, shortened phrases, incomplete sentences, and disturbances in prosody, rhythm, and intonation of speech are characteristics of aphasia.[11] Due to the lack of attention to neuroscientific research on language functions and speech, traditional treatment for aphasia, such as speech therapy, has demonstrated mixed outcomes.[12] This could be due, in part, to misdiagnosis--commonly employed diagnostic methods misclassify up to 30% of people with aphasia.[13] Even though neuroplasticity is the theoretical foundation for brain recovery from injury, there is still a lack of understanding of the actual recovery process after the injury.

Unlike aphasia, dysarthria is a neurological motor speech impairment which can be the result of damage to the central or peripheral nervous system.[14] Dysarthric speech is characterized as slow, weak, and imprecise, with uncoordinated movements of the speech musculature. The impairment can involve respiration, phonation, resonance, and/or articulation of speech production.[14] Seven types of dysarthria have been identified based on the site of impairment. These include flaccid dysarthria, spastic dysarthria, ataxic dysarthria, hypokinetic and hyperkinetic dysarthria, unilateral upper motor neuron (UUMN) dysarthria, and mixed dysarthria.[1,15]

Flaccid dysarthria is the result of damage to the cranial or spinal nerves, so reflexive and voluntary movements are affected.[1,15] The resulting muscular weakness and reduced muscle tone influence speech range and production accuracy. Common speech problems associated with flaccid dysarthria include hypernasality, breathiness, monopitch, imprecise consonant production, and a harsh vocal quality.[1,15]

Spastic dysarthria occurs when the damage includes both direct and indirect activation pathways of the central nervous system.[1,15] Weakness and spasticity (excessive muscle tone) are common characteristics of this type of dysarthria, yielding speech impairments such as imprecise articulation, slow rate of speech, monopitch, monoloudness, and impaired prosodic features.[1,15]

Ataxic dysarthria is related to cerebellum damage, which results in a breakdown in motor organization and control.[1,15] Generally, it demonstrates incoordination and reduced muscle tone, which lead to imprecise consonant production, distorted vowels, irregular articulatory breakdowns, impaired prosody, monopitch, monoloudness, and a harsh vocal quality. Usually, the speech of persons with ataxic dysarthria sounds slurred, as though they were intoxicated.[1,15]

Hypokinetic and hyperkinetic dysarthria result when damage occurs in the basal ganglion motor circuits.[1,15] Considering that basal ganglia regulate muscle tone, control postural adjustments during skilled movements, and enhance goal-directed movements, these two types of dysarthria show limited ranges of movement and failure to inhibit involuntary movement. In fact, Parkinson's disease is the most common etiology of hypokinetic dysarthria. While hypokinetic dysarthria involves basal ganglia only, hyperkinetic dysarthria involves both basal ganglia and portions of the extraphyramidal system. Injuries in these areas result in excessive involuntary movements. Speech problems for hypokinetic dysarthria include monopitch, monoloudness, low pitch level, breathy voice, and short rushes of speech. Speech problems for hyperkinetic dysarthria include distorted, slow and/or interrupted speech, articulatory imprecision, and a harsh vocal quality.[1,15]

UUMN dysarthria is the result of unilateral damage to the upper motor neurons that control the speech muscles. Weakness in the lower face, lips, and tongue on the opposite side from the brain hemisphere damaged is the most common symptom.[15]

Finally, mixed dysarthria, as the name indicates, includes a mixture of two or more of any dysarthria type. When more than one type of dysarthria is present, the dominant type is determined by the location of the damage.[1,15]

These different types of dysarthria cause multiple speech problems at various levels; however the primary goal of dysarthria treatment is improved intelligibility.[16] Improving speech intelligibility is directly related to the quality of communication; therefore treatments focus on restoring or compensating for the impaired speech function of the speaker.[1,17] In addition, both congenital (e.g., cerebral palsy) and acquired conditions (e.g., stroke, Parkinson's disease, or multiple sclerosis) are included in the etiology of any dysarthria.

Finally, apraxia of speech (AOS) is one of the major speech/language disorders found in neurologically impaired patients. Apraxia was described as articulatory incoordination in the absence of linguistic deficits.[15] Later, AOS as a neurogenic disorder was characterized by defective motor programming necessary for serial articulation in the absence of muscular incoordination, weakness, or tone abnormalities.[18] While several researchers have characterized AOS as an inhibition or impairment in programming of orofacial movements of the central nervous system,[19,20] others insist that AOS includes issues with the linguistic encoding system. Even though there are varying views of precise nature of AOS, the literature demonstrates common features of AOS such as higher error rates with an increase in utterance length or complexity,[1,21] abnormal rhythm,[19,20] or increased articulatory and prosodic error rates with volitional utterances.[13,19,20]

Due to the controversial definition of AOS, assessment tar-

geting AOS characteristics is also controversial.[22] In general, AOS is viewed as an effortful or erratic speech production in the absence of muscle weakness.[23]

All three speech disorders--aphasia, dysarthria, and apraxia--are common diagnoses found in speech rehabilitation for patients with neurological impairments. Any damage occurring in brain areas which control speech production generates speech disorders; however, each disorder requires multidisciplinary approaches in its rehabilitation to maximize treatment effectiveness. The close relationship between speech production and musical behaviors, including singing and vocalization, leads to a igher expectation regarding the efficacy of utilizing musical elements in speech rehabilitation. Therefore, it is necessary to analyze whether the use of music or musical elements in speech rehabilitation does in fact contribute to rehabilitation outcomes.

## Brain Activities in Speaking and Singing

The relationship between music and speech production has been investigated through brain research. Generally, a portion of the brain known as Broca's area, in the posterior part of the inferior frontal gyrus, is acknowledged to be involved in speech production, and current research findings reveal that this area is activated by various musical tasks as well, including pitch and rhythm discrimination, pitch memory, and musical syntax.[7,24-27] As many music therapists acknowledge, patients with Broca's aphasia perform better when singing the lyrics of songs than when reading those same lyrics.[28-31] This finding may be due to the change in processing for sung and spoken song lyrics.[32] The left hemisphere is more engaged in propositional speech, while the right hemisphere shows greater involvement with automatic or non-propositional speech, such as counting or singing familiar songs.[32]

Furthermore, brain imaging and lesion studies have demonstrated the engagement of a bihemispheric brain network in music processing. Among several musical elements, melody or meter perception and spectral processing of musical stimuli have been shown to occur in the right hemisphere.[7,8,33] On the other hand, temporal processing of musical stimuli has been shown to take place mostly in the left hemisphere.[7,8,33]

Along with music processing, motor control aspects of speaking and singing are also being investigated using advanced technologies such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Several brain areas are reported to be involved in vocalization, including the supplementary motor area (SMA), the sensorimotor area, the premotor area, Broca's area, Wernicke's area, the auditory area, and the insula.[34-37] Vocalization involves both hemispheres almost symmetrically,[34,38] and singing engages the right motor cortex, the insula, and the inferior-frontal lobe of the right hemisphere.[39] It is obvious that singing and vocalization induce similar brain activities, and compensation for difficulties in speech production can be expected during these activities.

Along with the complementary neuromotor aspects, singing also requires active engagement in vocal and respiratory tasks. Even though both music and speech are regarded as forms of expression, music is often referred to as a nonverbal means of communication.[40] Singing is definitely a more varied form of communication in that it includes a wider variety of pitches, rhythms and form patterns than nonmusical speech.

Overall, several therapeutic aspects of singing can be induced based on the above review. Considering that singing and nonmusical speech share common anatomical structures and connected neural networking, singing can be used as a pinpointed therapeutic tool for specific speech problems such as respiration, vocalization, or phonation, while also offering other emotional, motivational, and psychological benefits that are widely associated with musical activity in general.

## Music Therapy Research for Speech and Voice Problems Following Neurologic Diseases

Music is a viable enhancement for speech training following stroke or other neurologic diseases since speech and singing share elements of rhythm and melody.[30] Based on these elements, singing and speech have been incorporated into a speech therapy technique called "melodic intonation therapy (MIT)". To improve speech production through MIT, singing is used to enhance expressive communication skills, particularly for stroke patients with Broca's aphasia.[41] The researchers concluded that the technique had stimulated the nondominant right hemisphere of the brain, even though the dominant left hemisphere was damaged, thus facilitating patients' language reproduction during expressive communication. Several studies were confirmed that undisturbed verbal output during singing when speech alone shows dysfunction.[31,42] The efficacy of MIT technique was intensively examined since this study was published.[30,43,44] Improvement of speech parameters were also tested using singing and rhythm instruction during speech production.[45,46]

Over the past few years, a number of speech training techniques for neurologically impaired patients have been developed at the Center for Biomedical Research in Music.[47,48] Applying those techniques to music therapy sessions for patients with neurological impairment, however, requires in-depth knowledge and extensive experience regarding neuro-

logic diagnoses.

With the emergence of neurologic music therapy (NMT) techniques, two studies have been conducted regarding the effectiveness of music on speech and physical rehabilitation for patients with neurologic diseases. In particular, utilizing music for speech problems due to Parkinson's disease has been investigated by two researchers.[49,50]

Other studies of music therapy techniques in the rehabilitation of patients with neurological diagnoses have established the efficacy of music applications in physical rehabilitation. These studies generally include the rehabilitation of ambulation and/or limb movements in persons who have suffered strokes or who have Parkinson's disease. The basis of the success of music applications in these studies is rhythm, which is identified as an essential therapeutic tool for the rehabilitation of motor patterns. As an auditory stimulation, rhythmic cues have been investigated by Thaut and his colleagues.[48,51] According to these researchers, rhythm entrains motor control, which synchronizes motor movements with auditory rhythmic cues. These cues occur in the brain at subliminal levels of perception; therefore, rhythmic auditory cueing can facilitate the rehabilitation of motor movements without involving cognitive processing.

Most research in association with NMT techniques has been focused on rehabilitation of motor dysfunctions including gait or arm movements for patients with neurologic disorders. It is obvious that more clinical research regarding the use of music in speech rehabilitation is required in the music therapy profession.

## Summary

Developing music therapy protocols and techniques in speech rehabilitation has a great benefit for neurologically impaired patients because of the shared common physiological structures involved in speaking and singing. Many investigators have conducted research to examine the brain functions during speech and musical processing including motor aspects (singing) and cognitive aspects (perception of musical elements). Most research outcomes show the interrelationship of brain function and anatomical function between speech tasks and music tasks.

Despite the potential for a greater expectation of therapeutic outcomes in the use of music in speech rehabilitation based on previous research findings, music therapy literature shows that there are a small number of research articles which have focused on the use of music in speech rehabilitation for neurologically impaired patients. Though a volume of studies exist that provide theoretical frameworks of musical stimulation for speech rehabilitation; the effectiveness of music therapy in persons who have neurologic diseases requires more evidence. Increasing the number of experimental studies is urgently required to entrench the need for music therapy services in speech rehabilitation.

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