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# The Possibilities of Applying Music in Logopedic Therapy. A Survey of Research

ABSTRACT

The existence of relationships between music and speech, noticed and described already by ancient thinkers, is now confirmed by the results of many empirical studies. These connections are present not only in the acoustic and auditory characteristics of music and speech but they are also observable in the similarities between the processes of their perception and expression, which makes it possible for music activity to be used in improving functions involved in speech perception and its realization.

The paper presents the current findings based on research results available in literature that concern the possibility and efficacy of use of music in the treatment of speech, hearing and voice disorders.

**Keywords:** music in logopedic therapy, relationships between music and speech, music trainings

## RELATIONSHIPS BETWEEN MUSIC AND SPEECH

Language and music are universal and specific to the human species. They are some of the most complex forms of communication that a human has at his/her disposal (Hauser, Chomsky and Fitch, 2002; Patel, 2003). Since they are multilevel, organized systems, it is possible to create countless numbers of linguistic and musical forms out of a definite repertory of elements, these forms springing up according to specific rules binding in a given musical or linguistic system. Like

in language, the existence of phonological, syntactic and semantic rules in music can be pointed out (Sloboda, 2002). The elements from which larger units are built are discrete and temporally organized into sequences of varying complexity (Patel, 2003; 2011). Their perception is categorical (Podlipniak, 2017).

The use of music in logopedic therapy is justified by the existence of similar or partially shared neurobiological mechanisms of speech and music processing (Patel, 2011). Certain principles common to music and speech that govern their perception are also observable. The emergence of these principles was possible in human phylogeny on account of the fact that music and language display similarities in the acoustic features and auditory signals that they use, and in formal organization. Both language and music, being realized in the sound sphere, use changes in pitch, duration, volume and tone of sounds. Out of the shared features of their formal organization, present in speech in prosody, the most often distinguished are the rhythm-stress structures, rhythmic pulse, pace, and temporal changes in pitch, which form melodic structures in music and intonation structures in speech (Sloboda, 2001, Patel, 2003).

The shared mechanisms of music perception and expression, described in many publications, are firmly based on the results of research on human development as a species and an individual. The existence of relationships between music and speech in phylogenetic development is shown by studies on the emergence and evolution of these forms of communication. Publications on the subject demonstrate the existence in the past of "musilanguage", primary to speech and language, from which they evolved, that evidences their common origin and indisputable relations (Brown, 2000; Mithen, 2009).

Relations between perception and expression of speech and music are also observed in studies on the development of these skills in ontogeny (Trehub, Trainor and Unyk, 1993; Doherty et al., 1999; Saffran et al., 1999; Brown, Martinez and Parsons, 2006; Patel, 2011; Wysocka, 2012). Linguistic and musical development show many similarities. They occur through imitation, during a person's socialization and his/her contact with a particular language and music in a specific cultural circle. They require the proper functioning and improving of the mechanisms of auditory perception, categorization, statistical learning, and the working and long-term memory. There is a lot to suggest that the acquisition of successive language and musical skills (analogous or similar to one another) largely takes place in a parallel way (cf. Shuter-Dyson, 1999; Brandt, Gebrian and Slevc, 2012).

Especially close relationships with high therapeutic potential can be observed between singing and speech. Singing and speech use the same vocal-auditory channel; hence the nervous mechanisms responsible for their reception and expression show many similarities. A lot of data on the subject is provided by the contemporary studies on the perception of singing and speech prosody. The often

cited experiments conducted by Diana Deutsch and associates (Deutsch, Lapidis and Henthorn, 2008; Deutsch, Henthorn and Lapidis, 2011), known as speech to song illusion, show that the same fragment of utterance can, in different circumstances, be interpreted by listeners in linguistic terms (as a phrase with a specific intonation) or as a fragment of a sung melody, the great number of repetitions being conducive to the distinction of discrete units in it that are perceived as concrete musical pitches.[1] The authors of those experiments stress that their results indicate that there are relationships between mechanisms of speech perception and music perception, and highlight the extraordinary plasticity of the nervous system, which, by involving the same connections, allows processing of the same stimulus with the same acoustic characteristics, in two ways: as linguistic or musical, depending on the conditions accompanying its presentation.

Researchers of the evolution of speech and music emphasize that singing and speech were interrelated in the phylogeny of the human species (Brown, 2000; Masataka, 2007). These relationships are also observable in different, especially early stages of human ontogenetic development, in which singing is a natural form of communication between the child and his/her parents/carers, especially mother, that is used parallel to or alternatively with speech (Trehub, Unyk and Trainor, 1993; Shenfield, Trehub and Nakata, 2003; Creighton et al., 2013). The interpenetrating features of speech and singing are present in the child-directed speech (Papoušek, Papoušek and Symmes, 1991; Trainor, Austin and Desjardins, 2000; Arnold and Jusczyk, 2002). Singing to a child and the use of high contrasts of phonetic features in the child-directed speech resembling song characteristics supports his/her emotional, communicative and linguistic development (Cevasco, 2008; Brandt, Gebrian and Slevc, 2012; Estes, Graf i Hurley, 2013; Fancourt and Perkins, 2018).

The processes of learning speech and music proceed in a similar way. It has been shown that during speech development, the child unconsciously uses a statistical strategy for detecting sound sequences in the speech of those around him/her (Romberg and Saffran 2010). This is also a similar case with learning music (McMullen, Saffran, 2004), the auditory and particularly music structures being regarded by some researchers (Conway and Christiansen, 2005; Brandt, Gebrian and Slevc, 2012) as the most receptive to sequential learning. They therefore hypothesize *(auditory scaffolding hypothesis*) that these structures can be a kind of *auditory scaffolding* utilized to stimulate general cognitive abilities related to learning and processing time patterns and sequences. They help maintain the time

[1] The effect of speech to song illusion can be experienced by the reader through listening to the vocal material placed by Diana Deutsch on the site: http://deutsch.ucsd.edu/psychology/pages.php?i=212, which also contains the exact description of the experiments referred to in the present article.

order and the order of elements in a sequence due to stimulating and maintaining the activity of temporal-frontal connections in the brain (Conway, Pisoni and Kronenberger, 2009).

A large number of data on the relationships between musical and language skills are provided by the results of examinations of persons with speech and language disorders. In dyslectic patients, the following were found: very low results in music perception tests (after: Anvari et al. 2002), disorders in the quick temporal processing of the spectral structure of speech and music (Merzenich et al., 1996; Overy, 2000), disorders in the perception of changes in basic frequency (Leppänen et al., 2010), and changes in the amplitude of sounds and rhythmic structures (Goswami et al., 2002; Huss et al., 2011).

Another group of persons in whom a high decrease in the level of musical skills is reported are children with SLI. They were also found to have a decreased sensitivity to sound duration, disorders in rapid temporal processing, in sequential auditory processing, and in perception of changes in the amplitude of music and speech sounds (Benasich and Tallal, 2002; Corriveau, Pasquini and Goswami, 2007; Jentschke et al., 2008).

Lower music perception ability as compared to hearing persons is also found in patients with the impaired hearing organ (Olszewski et al., 2005; Hsiao, 2008; See et al., 2013; Wysocka and Mackiewicz, 2017). Deficits in this area are caused by hearing loss itself but also by the specific structure of hearing aids that are limited in processing the frequency characteristics (including spectral) of sounds (Peng, Tomblin and Turner, 2008), extremely important in music perception because it is on this characteristics that the perception of the pitch and tone of music sounds depends.

## MUSIC IN LOGOPEDIC THERAPY – THEORETICAL ASSUMPTIONS

The high potential in the use of music in logopedic therapy stems from the fact that music and speech share many acoustic and structural features, but, first of all, from similarities in the neurobiological mechanisms of their perception and realization. Music perception and expression trigger the activity of not only the cervical cortex but also the brain areas (cortical and subcortical) that control attention and motor functions, and the areas involved in emotional behavior (Stephan, Lega and Penhune, 2018; Wallmark, Deblieck and Iacoboni, 2018). The proof of the high involvement of emotions in the perception of music is the fact that even very small changes in musical parameters (e.g. in tonality) involve the limbic loop and trigger emotional response (Chapin et al. 2010; Gorzelańczyk et al. 2017).

The effectiveness of music activities in improving the functions that determine speech expression and perception stems from the existence of partially

shared neural mechanisms responsible for processing music and speech (Brown, Martinez and Parsons 2006; Patel, 2011). These mechanisms are described by the OPERA hypothesis (the acronym of words: overlap, precision, emotion, repetition, attention) formulated in reference to sound pitch perception (Patel, 2011). In accordance with the first assumption of the hypothesis (overlap) the same neural groups participate in processing the acoustic features of music and speech sounds. The perception of music therefore enhances the activity of structures involved in speech processing, which can function more effectively. The second assumption (precision) is connected with the fact that music perception requires a high processing precision because even small differences in sound parameters are important in its perception. A smaller precision in processing speech sounds is connected with the possibility of using many sources of information while receiving them (sounds): not only the acoustic features of a sound but also phonetic, semantic or even syntactic or pragmatic contexts that enable the accurate identification of even acoustically distorted signals. According to the third assumption (emotion), music activity triggers positive emotions that in turn stimulate the process of speech perception. The fourth assumption (repetition) stems from the observation that also repetition, characteristic of music-making and leading to better mastering of associated skills, triggers positive emotions as a result of felt satisfaction with having learned a musical piece. Both emotions and repetition activities are conducive to a greater activity of nervous structures, including those involved in speech perception. It is triggered and sustained by the high level of attention, also necessary in music-making activities.

Seeking the explanation for the positive impact of the processing of rhythmic structures in music on speaking activity, two additional assumptions were added to the foregoing ones (Fujii and Wan, 2014). The first concerns the acknowledgment of the partially shared structures for perceiving rhythm in music and speech in the neural networks, the other refers to the existence of the mechanism of stimulating the speech pulse through the musical pulse. This mechanism functions owing in part to the shared nerve pathways for speech and music perception but also owing to the fact that the perception of musical rhythm triggers motor reactions activated under its influence also in speech expression. These reactions controlled by the musical pulse organize articulatory movements in time and make them fluent.

The adoption of the above-described assumptions prompts a conclusion that musical training can have a positive effect on speech development or improvement through the enhancement of the activity of the nervous system at the subcortical and cortical levels, and through the activation of its structures that are involved in speaking. The foregoing assumptions are confirmed by the results of empirical studies (Kotz, Schwartze and Schmidt-Kassow, 2009; Kraus and Chandrasekaran, 2010).

## CONCRETE APPLICATIONS – THERAPEUTIC TRAINING

Music activities may positively impact on the development or improvement of many functions that determine speech acquisition, which is why they are applied to stimulate the development of speech and to treat its disorders. Music trainings are utilized to shape and restore auditory perception skills, both in stimulating speech and in the therapy of persons with hearing and speech disorders (Kowalska, 1989; Schön et al. 2004; Strait and Krauss, 2011). Music-making activity contributes to improving the ability to detect pitch changes in speech signals (Schön et al. 2004; Magne et al., 2006). It stimulates the development of verbal memory and phonological skills (Saffran et al. 1999; Anvari et al. 2002). Music activities combined with exercise also improve psychomotor processes essential for speech acquisition, (Kilińska-Ewertowska, 1977; Wan and Schlaug, 2010; Bogdanowicz, 2014).

According to the results of the latest studies, rhythm and pulse are the most important of all musical components that may impact on the improvement of linguistic functions[2] (Stahl et al., 2011; Fujii and Wan, 2014). It has been demonstrated that interconnected neural structures are responsible for the rhythmic processing of music and speech motor skills (Kotz, Schwartze i Schmidt-Kassow, 2009; Kraus and Chandrasekaran, 2010), with the active participation of the basal ganglia in this process – the leading ones in the analysis of the time sequences of sensory and motor events (Kotz and Schmidt-Kassow, 2015). Consequently, the musical rhythm and pulse can impact on the motor activity of speech organs, stimulating them for motion and organizing it in time.

The techniques based on the music pulse and rhythm are used in the therapy of aphasic (Stahl et al., 2011), dysarthric (Cohen and Masse, 1993), SLI (Przybylski et al., 2013), dyslectic (Flaugnacco et al., 2015), autistic (Wan et al., 2011), and stuttering (Andrews et al., 1982) patients as well as those with impaired hearing (Hidalgo, Falk and Schön, 2017). The assumption underlying their application is that the music pulse may trigger and stabilize the pulse in speech (cf. Fujii and Wan, 2014). As the results of empirical research show, this assumption is indeed realized in speech perception and expression (Schön and Tillmann, 2015). Moreover, rhythmic exercises improve syntactic skills (Przybylski et al., 2013) and reading abilities (Schön and Tillmann, 2015).

[2] Interesting therapeutic implications concerning the structure of relationships between the rhythmic structure of music and speech, and the impact of the rhythmic pulse on the speech pulse also result from the theory of coupled oscillators and the neural oscillation models of speech signal processing (Pöppel 1997, Giraud, Poeppel, 2012, Jones 2016), according to which, by maintaining a specific duration of stimuli, it is possible to support the process of auditory processing of speech signals (in respect of auditory control and self-control) and the perception grouping process.

Music is also used in the therapy of persons with impaired hearing in order to shape individual auditory functions necessary for the perception of speech signals. In many trainings, emphasis is laid on molding the perception (difficult for such patients) of musical pitch and timbre discrimination (Gfeller, 2016), as a result of which an improvement occurs in the perception of intonation and stress – the prosodic phenomena for the perception of which the pitch discrimination is absolutely necessary (Yucel, Sennaroglu and Belgin, 2009).

Out of different music-making activities, singing is regarded as the most effective and with many possibilities of application in logopedic therapy. This belief is the result of many similarities existing between song and speech at the acoustic level. It is also reinforced by research results showing that the speaking functions, particularly those of prosody expression and singing, involve similar or the same brain structures (Brown, Martinez and Parsons, 2006). Singing and speaking are realized owing to the activity of the same parts of the speech apparatus, hence singing is often employed to improve respiratory, phonatory, articulatory and resonatory functions and to coordinate them. Furthermore, out of all music-making activities, singing engages the auditory feedback loop the most completely (Kleber et al., 2010), which is used in logopedic therapy to improve auditory self-control. Singing is far more demanding on the speech and hearing organs than speech is. In order to produce a melody it is necessary to produce and control concrete vocal and articulatory parameters connected with a specific pitch, its temporal changes, and with the rhythmic and accentual structure. This activity requires heightened auditory, phonatory and articulatory control and intense auditory-motor coordination (Wan et al., 2010; Zarate, 2013). Owing to the similar activity of the nervous system during singing and speaking (cf. Patel, 2011; Fujii and Wan, 2014), it is possible to transfer therapeutic effects achieved in vocal exercises onto the activities involved in speaking.

Singing is used in order to improve the motor planning of articulatory and phonatory movements and their realization. This enables the improvement of processing auditory and somatosensory information, which underlies motor planning, based on the previous experiences and also underlies controlling the execution of movement and error correction (Guenther and Vladusich, 2012). These objectives accompany the therapy of different speech disorders, including dysarthria or aphasia. In the therapy of dysarthria, vocal exercises lead to improving the phonatory function of vocal folds and improving vocal parameters (greater vocal volume, longer phonation duration, a greater pitch range in intonation contours) thus making it possible to achieve a fuller realization of prosodic features of utterances, and better speech intelligibility (Cohen, 1994; Natke, Donath and Kalveram, 2003, Di Benedetto et al. 2008; Tanner, Rammage and Liu, 2016).

In the therapy of persons with speech apraxia, both congenital and acquired, the main emphasis is laid on improving articulatory functions. However, as shown

by research results, the use of rhythmized singing also leads to the improvement of suprasegmental realizations (Roper, 2003; Kim and Tomaino, 2008).

In the treatment of patients with motor aphasia, a widely used therapy is the Melodic Intonation Therapy (MIT), which uses song and rhythmic structures produced by hand movements combined with singing and then by speaking with appropriate phrase intonation. Its effectiveness in restoring speech expression is confirmed by the treatment results in patients, conducted at different stages of the disease (Van der Meulen, Van de Sandt-Koenderman and Ribbers, 2012). Some reports on the research into the impact of this therapy on the cerebral organization of speech even mention the MIT-induced reactivation of speech circuits in the left hemisphere (Bellin et al., 1996, Schlaug, Marchina, Norton, 2009).

Singing is also used to treat stuttering persons. Some research results suggest that in stuttering persons there are functional disorders within the basal ganglia (Wu et al., 1995; Lebrun, 1998), which, as has been said above, are involved in processing the rhythmic structure and sequences, both in speech and music, at the auditory and motor levels (Kotz, Schmidt-Kassow, 2015). Consequently, the use of clearly rhythmized singing that imposes a specific rhythmic structure in the cases of disorders in generating and controlling the internal structure, produced by the nervous system, leads to the coordination of and making fluent the movements of speech organs (Alm, 2004). The accentuated musical rhythmic structure - listened to, performed in singing and speech together with all kinds of movement - is applied in the therapy of children with developmental dyslexia (Bogdanowicz, 2014). This therapy improves their phonological skills and the ability to read (Flaugnacco et al., 2015, Habib et al., 2016).

Therapeutic music trainings are also present in the treatment of persons with impaired hearing and lead to the improvement of their auditory functions, including the discrimination of phonetic features and improvement of auditory working memory (Rochette, Moussard and Bigand, 2014). The singing used in the trainings also serves to develop the skills of reception and expression of speech prosody (Kowalska, 1989; Walencik-Topiłko i Wysocka, 2015).

Singing is also used in the treatment of persons with voice disorders. Vocal therapeutic trainings improve breathing, phonation, and timbre, and facilitate voice production by decreasing or increasing the tonus within the larynx (in accordance with the patient's needs). They reduce hoarseness, vocal aspiration, and hard vocal attack. Their result is also an improvement in vocal volume and greater freedom in using its pitch (Chen et al., 2007, Boone et al., 2010).

It should be stressed that singing can also perform an important interactive function. This assumption is used for example in the treatment of autistic persons, in which the vocal activity, usually a patient-therapist interaction, serves to initiate and maintain interaction, stimulate the intention to communicate as well as speech expression (Hoelzley, 1993).

## RECAPITULATION

The existence of many relationships, confirmed by empirical research results, between music and speech encourages the use of music activities in the therapy of speech, hearing and voice disorders. These relationships mainly concern their acoustic and structural properties, mechanisms of processing them, as well as the involvement of specific cognitive functions and motor activities in the process of their perception and expression.

Consequently, music, and particularly singing, serves in all kinds of therapeutic training to shape or improve different functions that determine speech acquisition and its use in communication. As shown by the research results referred to in this paper, the activities of patients participating in therapies in which music is utilized impact on the improvement of their auditory perception, phonological awareness, auditory self-control of speech sounds, somatosensory control within the articulatory organs and larynx, prosodic skills, the ability to read and produce sequences of perceptual and motor events, as well as on the motor, psychomotor and coordination functions. Music activities triggering the high activity of the brain structures involved in the process of music and speech processing are used as a factor that stimulates speaking activities. They can also help create rules of interaction and stimulate participation in it.

To conclude, it might be worth to mention the question that in many music trainings, in order to improve or develop auditory perception, and, consequently, language skills, only the activity of listening to music is used whereas motor expression, which is a reaction to it, tends to be omitted. Research results show that auditory stimulation alone does not necessarily need to result in the development of language skills or the reading ability (McArthur, 2009). The key element of improvement appears to be the motor activity of the persons taking part in the training. It should be underlined that in light of the research results presented above, the perception itself of music is not a purely perceptual action. It has been found that during perception, especially when it comes to the rhythmic organization of music, the motor structures in the brain are active (Fujii and Wan, 2014). Therefore, the use of motor activity that increases the function of these structures, associated with playing instruments or other activities, is highly desirable, not only in the cases when the therapy objectives encompass the improvement of motor functions (gross or fine, including articulatory, motor skills) but also when it is necessary to take measures to improve the perception and temporal memory of the organization of stimuli as well as the processing of sequences at the auditory, visual and motor level.

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