

Music and neurorehabilitation: Yes, we can!

In recent decades music has played an important role in the field of therapy and rehabilitation at different levels. Thus, music can be considered not only a source of pleasure or an aesthetic phenomenon, but also a possible healing intervention. To support this assertion, however, we first need to understand why music can be used as a form of therapy, in this case in the neurorehabilitation setting. The rationale behind the use of musical techniques in rehabilitation derives from the strong impact that sound has on the brain, at cortical and sub-cortical level, involving pre-motor and motor areas, the basal ganglia, the cerebellum, and also limbic and paralimbic areas (Hillecke et al., 2005; Koelsch, 2014). The literature contains evidence of the effects of music in many clinical settings, and highlights possible underlying mechanisms. Neuroimaging studies in healthy subjects and patients (Schlaug, 2015; Moudjian et al., 2017) have proved that music can improve neuroplasticity, and shown that music interventions, used in the rehabilitation field, can have significant immediate and longer-term treatment effects in different diseases such as stroke, Parkinson's disease, multiple sclerosis, dementia and cerebral palsy (Yoo et al., 2016; Bella et al., 2018; Shahraki et al., 2017; Wittwer et al., 2013; Kim et al., 2011). Therapeutic music interventions have been shown to be effective on motor functions (mainly gait and upper limb functions), cognitive functions (language, neglect, memory, attention, etc.), and on psychological components associated with neurological diseases (e.g., depression) (Sarkamo et al., 2016). Another aspect emerging from the literature concerns the differences in the practice and content of music therapy techniques within neurorehabilitation. It is possible to distinguish listening interventions from active approaches that involve the music therapist and patient directly (Raglio et al., 2015). In music listening interventions, sonorous-music stimuli have direct effects on individuals, whereas in active approaches, the therapist decides what stimuli are given during the rehabilitation intervention, and these are therefore mediated and modulated by the relationship with the patient. In these approaches sonorous stimuli can be used concurrently with rehabilitation treatment, as for example in situations where music matches movements or is used as a cognitive exercise; in other cases, music listening is proposed independently of the rehabilitation intervention, with the aim of improving a patient's wellness and reducing cognitive and psychological symptoms overlapping with neurological damage (Särkämö et al., 2008). The main music therapy techniques used in the field of neurorehabilitation are part of the Neurologic Music Therapy (NMT) approaches (Thaut et al., 2014) and they are based on structured and manualized active sonorous-music interventions in which rhythm plays a crucial role: the music therapist supports motor, cognitive and sensory rehabilitation through the use of sound-music elements that facilitate "entrainment" and synchronization processes and promote patients' recovery (Thaut et al., 2014). The process of "entrainment" connects the brain with external stimuli and can be defined as a mechanism for adapting one's own frequency to that of another system. Patients with movement disorders are also able to synchronize with external rhythmic patterns. This is possible thanks to the intrinsic periodicity of these particular music stimuli and the auditory system's ability to rapidly build temporal models and then adapt these, in a natural way, to even minimal changes. "Entrainment" can serve not only to regulate movement timing, but also to improve spatial and strength parameters. In fact, synchronization is based on the beat but also on the duration of the rhythmic pattern. This, by creating a stable model that allows to the brain to successfully prepare the movement, adapting it to the rhythm, creates the conditions for anticipatory movement planning. The use of such synchronization with a rhythmic stimulus can be extended to cognitive aspects, in particular to language rehabilitation where a specific technique (called Melodic Intonation Therapy) (Zumbansen et al., 2014), based on the musical elements of speech (melody and rhythm), is used to improve expressive language by involving a preserved function (singing) and engaging language-capable regions in the undamaged right hemisphere (Norton et al., 2009). Other techniques can be defined "music-supported therapy". In these cases, gross and fine movements of the hemiparetic upper extremity are trained through playing both melodic and rhythmic musical instruments (e.g., keyboard, drums, etc.) (Sihvonen et al., 2017). Sometimes pre-recorded music (selected taking into account movements type and speed) is also used in clinical practice to support physical exercises. These approaches do not follow specific NMT protocols, but they are based on similar principles.

Some active music therapy approaches have also shown effectiveness in the neurological field, integrating relational and rehabilitation aspects and showing significant results in both these domains (Pacchetti et al., 2000; Raglio et al., 2017).

More recently, a technique named "sonification" was also reported (Scholz et al., 2014). "Sonification" can be defined as the use of sonorous-music elements to convey movement-related information. Synthesized sounds are used in the context of movement mapping. Mainly pitch, intensity and timbre are used to represent movements and the

modulation of these parameters makes it possible to change the perception of movements. “Sonification” can improve rehabilitation of motor functions and can facilitate the integration of auditory and sensory-motor systems. This technique can also strengthen and support the damaged proprioceptive system and can make rehabilitation a more pleasant and stimulating process, potentiating the emotional and motivational aspects (Schlaug, 2009; Scholz et al., 2016). The evidence-based music therapy approach has certainly made an important contribution to research in the field of rehabilitation. However, the time is now ripe to step up the level of collaboration between all rehabilitation professionals, neuroscientists and music therapists, so as to integrate their knowledge and expertise, and also allow more robust and tailored research projects. There is a particular need to focus on methodological aspects and the development of an in-depth definition of music therapy techniques with respect to different diseases and rehabilitation aims. In short, the time has come to try and establish more clearly what aspects of music can act effectively in rehabilitation settings. Although rhythm is a key element in all rehabilitation techniques, music is a very complex phenomenon in which structures and parameters (melody, harmony, timbre, pitch, intensity, etc.) can all be modified in different ways, making it possible to steer the rehabilitation intervention toward specific effects. It is important to understand what techniques work best in different rehabilitation fields, and establish the dose/effect relationship. This needs more research, but also more systematic and continuous efforts in clinical practice, based on greater awareness and more tailored use of sound-music elements, as well as interventions conducted by trained therapists. Music interventions in rehabilitation need to be re-modulated and enriched, taking into account the scientific paradigm characterizing each particular rehabilitation treatment. In the light of these premises and considerations, it seems possible and desirable, to see manualized music interventions and relevant research programs in the field of neurorehabilitation introduced at institutional level. This could make a significant contribution to the improvement of rehabilitation processes, and have a major impact from both a clinical and a neuroscientific point of view.

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