Why Is Music Effective in Rehabilitation?

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Abstract. In this chapter a conceptual foundation of employing music in rehabilitation is highlighted. The basic assumption is that, when a person is involved in performing or listening to music, she has a comprehensive experience in which several mental registers are activated simultaneously. The specific effect of music is to trigger a coordinated action of motor, visuospatial and verbal mechanisms. Thanks to the synergic activation of these mechanisms, music can stimulate, support and driven the mental functions to be rehabilitated.

Keywords. Music, Music Therapy, Rehabilitation

Introduction

In what sense can music be considered a technology? In a superficial sense, music is technology because, for it to be produced and enjoyed, it needs tools. Except for singing, every musical performance is mediated by some artefact, which can be very simple and primitive – such as cut reeds, tanned and stretched animal skins, roughly moulded metal sheets – or very sophisticated, as in the case of electronic equipments that generate new kinds of sounds and new ways of interacting with sounds [1, 2]. Material devices are also required for music reproduction in all occasions except for at a live concert. In this regard, the range of traditional technologies – radio, long playing records, audiotapes – has recently been expanded (or replaced) by new technological opportunities [3, 4, 5]. But music can also be understood as a technology in a less superficial sense. Music, as a symbolic system, is a cognitive technology, an extension or prosthesis of intelligence, a form of embodiment of thought whereby mental life expresses and builds itself. In this perspective music is a tool of the mind and, as such, it allows for interesting opportunities for rehabilitation.

Attempts at using music for therapeutic goals date back to a long time [6]. A statement about psychology made by Ebbinghaus may also be true for this tradition, which often labelled as music therapy [7, 8]; it has a long past but a recent history. Indeed, a scientific approach to understanding the benefits people can get from music has developed only in the last few decades. Actually the variety of music-based methods employed with therapeutic purposes is quite wide, as is the range of different situations in which such methods are offered. In the neurorehabilitation field, the spectrum of potential patients benefitting from music therapy interventions is broad, ranging from motor deficits to speech disorders, from cognitive deterioration to

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dysfunction in emotional control, from coma conditions to hyperactivity [9, 10]. To simplify the picture, it is possible to identify three large categories in the therapeutic-rehabilitative utilisation of music:

− music is used to induce a psycho-physiological state (usually relaxation, and more generally a state of well-being), a mood (calmness, joy) or an attitude (for example, emotional disinhibition) that can either be the goal itself of the intervention or serve to introduce another intervention (for example, a training session or a psychotherapeutic session) aiming to facilitate the processes meant to be triggered in the patient. In this respect Sorrell and Sorrell [11], for example, have noticed that music improves the life quality of elderly people and is a motivational input in performing rehabilitation exercises; similar beneficial effects of music are found with patients suffering from Parkinson’s disease [12]. It has also been found that elderly people perform better in working memory tasks if they are listening to music [13];

− music is used to activate behaviours and mental operations that need to be rehabilitated. In this case music can either perform an accompanying function (for example, in combination with motor exercises or while pronouncing sentences) or be the main or exclusive task in which the patient is absorbed (for example, in the context of (re)training memory functions, the patient can be involved in an activity based on melody recognition). Along this line, just to give an example, Bannan and Montgomery-Smith [14] have shown that involving patients with Alzheimer’s dementia in choral singing enables them to improve their attention skills; a similar result has been found with brain damaged patients with the aid of technological tools [15]. Music-based activities can produce not only the recovery of a specific function such as attention, but also a more general intellectual recovery. Särkämö et al. [16] have shown that having patients listen to music on a daily basis results in a better post-stroke cognitive recovery than listening to audiobooks;

− music is used to stimulate the person to relate to other people [17]. Here, use is made of either a general communicative value of music (by listening to music one can share it with other people; by singing and/or playing with others one can perform something together) or more specific interpersonal dynamics triggered by music (for example, music enables us to express responses and experiences that we would otherwise be incapable of verbalizing.) An example of such a use of music can be activities in order to improve social interactions in patients after strokes or traumatic brain injuries [18, 19], or the attempt to communicate through sounds with patients in a minimal consciousness state or in prolonged coma [20].

In the first and third above mentioned cases music seems to play a non-specific role, as it aims at very general goals (to motivate the patient, to induce an appropriate state of mind, to make interpersonal contacts, to socialize, etc.) or is preparatory to or complementary with other kinds of intervention. But in the second case music seems to be appreciated for what it can specifically produce. As DeNora argued, music is not only a communication medium and it is not used by people just to produce sought-after emotional states and to escape unwelcome conditions. Music is also a tool for action and reflection. We use music to recall important people or events of our life. Music can affect individuals by changing the way their body is arranged, their behaviour, their way of experiencing, their self-perception and their way of perceiving other people and
situations. In short, music has a transformative power; it does things, changes things and allows things to happen [21]. Then, it is a matter of understanding the reasons why the specific use of music can result in the achievement of goals in the field of neurorehabilitation.

1. Music as a multi-register tool

The key idea we intend to develop here is that when someone has to do with music, both in a receptive mode (listening) and in a productive mode (performing), the person has a comprehensive experience in which several mental registers are activated simultaneously and synergically. The specific effect of music, or at least the effect we would like to emphasize here, is to trigger a coordinated action of multiple mechanisms. This peculiarity can serve as the foundation for the efficacy of sound-based rehabilitation treatments. These mechanisms can be identified along three lines, corresponding with three relevant cognitive registers available to humans: motor, iconic and verbal.

These three registers follow a recurrent distinction in psychology that has been acknowledged by different theories and has been effectively systematised in Bruner’s work. He identified three developmental stages; in each one there is a specific system of mental representation: enactive, iconic or symbolic [22]. First, the child’s motor behaviour shows definite strategies for action that make us assume that movements are guided by mental representations. These are the enactive representations, formed by operational patterns, i.e. patterns that coordinate the sequence of different acts or segments forming a movement. Iconic representations are representations which are independent from the action, even though they are bound to perception, since they are formed by images or spatial schemata. They allow the representation of states, relations, or transformations of events. To perform tasks that require abstraction one needs symbolic or verbal representations, which operate through concepts, categories and hierarchies. The tripartition suggested by Bruner between enactive, iconic and verbal-symbolic can be useful in making our point, because it helps us to identify three registers, that is, lines along which the mental processes activated by music unfold and to find in these lines some likely reasons why music-based rehabilitation interventions can be successful.

Firstly, music activates the motor mode, because it is naturally connected with the body. Music is always initiated by a body gesture (blowing, beating, etc.) Moreover, a lot of music is composed keeping in mind the actions it is supposed to accompany (dance or military march, for instance). Some people in Africa have no specific word to indicate music; there is only a term designating the presence of music and dance at the same time. In many contexts music goes with working activities: in Ghana gardeners work more swiftly when accompanied by music; in the Hebrides the activity of textile workers is accompanied by songs that change according to the movements to be performed; some songs of sailors change according to the required manoeuvres [21]. Blacking [23] emphasised and supported the notion of music as being strongly embedded in the body movements, a point corroborated by his long-lasting experience in studying African music. This author thought that the physical-motor experience makes the sounds take on a different meaning to the ones we perceive with our ears. From an ontogenetic point of view, the connection between music and movement develops very early. Moog [24] observed that 4 month olds start to respond to music
with large body movements. Philips-Silver and Trainor [25] reported that at 7 months of age the infant shows his preference for a rhythm associated with a synchronised rocking of the cradle. At 18 months of age children spontaneously perform rhythmical movements synchronised with sounds, while they are listening to music [26]. At a later age, the connection between music and movement does not require involvement of one’s own body. For example, Boone and Cunnigham [27] asked 4 and 5 year olds to make a teddy bear dance according to the emotional features of short musical segments while they were hearing them. Afterwards adults were presented the videotaped performance played by the children without the accompanying musical track and were requested to identify the emotion that the body movement intended to express. Results showed that children succeeded in moving the teddy bear so as to express the emotional meaning of the music. The detailed analysis of how children manipulated the teddy bear showed that upward movements, rotations, shifts, as well as the tempo and the force of the movements, differed significantly according to the expressive meaning of the corresponding music.

Secondly, music carries an iconic, i.e. a visuospatial, component. Music, at least in some circumstances, seems to translate spontaneously into images, so much so that in German the term Tonmalerei (painting with sounds) has been coined in order to indicate the possibility of depicting visual pictures through musical notes. To corroborate the fact that, besides a motor element, also an iconic dimension belongs to music, we can recall that in Non-Western musical cultures the performer’s activity is controlled by space representations rather than by sound representation. But in the Western world too music is connected with visual thought. For example, it is proven that musicians, as compared to non musicians, have greater capacities of visuospatial memory and their hippocampus – the cerebral structure connected with this kind of memory – is more developed than in the latter [28]. Practicing music develops visual memory abilities, probably because of the inherent figural nature of sounds patterns. Even people without any musical training think about music in spatial terms. In an experiment Halpern (mentioned in [29] p. 202) presented one word, by selecting it from the lyrics of a song, and subsequently another word from the same song. The task of the subjects was to compare the height of the notes corresponding to the two words. The reaction time recorded during this task increased as a function of the distance (in terms of bars) between the two words in the song. This suggests that the listeners scanned mentally an image of the melody. Hence, in music there seems to be a similar activity to the scan of visual images.

Thirdly, music carries a verbal component. Between music and verbal language there are overt analogies:

- there is a poor variation in the structural aspects of both music and verbal language among cultures;
- the skills required in music and verbal language appear early in ontogenetic development;
- music and language follow similar principles of perceptual organisation;
- music and language can be described in terms of organised time units;
- both consist of complex productions generated by few elements;
- these elements are combined according to rules;
- the rules determine hierarchical structures;
- the rules allow the generation of a potentially infinite number of combinations of elements.
These similarities concern mostly the syntactical aspects of music and have enabled authors such as Lerdhal and Jackendoff [30] to identify some general cognitive principles that are the foundations for musical listening. As happens for the syntactical structure of verbal language (understood in a Chomskian sense), music implies an unconscious construction of abstract structures that meet the dictates of a generative grammar with a set of recursive analytical rules. However, the verbal dimension of music appears not only at the level of syntactical structures, but also in terms of narrative structures. In the approach of Heinrich Schenker [31] – an author who anticipated the ideas advocated by Lerdhal and Jackendoff – the diatonic triad is the Ursatz, i.e. the basic structure, in which (i) the tonic represents the initial balance, (ii) the dominant introduces tension and (iii) the return to the tonic re-establishes the balance. One can find a correspondence between this harmonic pattern and the grammar of stories, some of which imply a transition from (i) the initial situation to (ii) the appearance of troubles/hindrances/problems to end (iii) with the resolution of the conflict/struggle/quest/tension.

Finally, the verbal dimension of music appears at the phonetic-prosodic level, when one attempts to render the inflections of the spoken language through musical sounds, and at the pragmatic level, when the dynamic of roles, entrances and alternations of the interlocutors in the development of the discourse is at play.

Music activates in the listener and the performer some mental processes in all three registers (motor, iconic and verbal) and in this synchronised activation of several registers we can find the reasons of its therapeutic-rehabilitative efficacy. Now we have to develop further this point.

2. Levels and correspondences

Within each register – motor, iconic and verbal – different levels can be identified. The motor register articulates at the level of neurovegetative responses triggered by sounds (for example, variations of the heart and breathing rates), at the level of gestural responses (as it is shown by the tendency to accompany music by tapping the feet or drumming the fingers, etc.) and at a level of more complex patterns of action (for example, those implied in the art of dancing).

In the iconic register visual synaesthesia develops; in fact, visual experiences may be elicited by sounds (sounds are heard as dark, shining, etc.). Furthermore, the visual features of music appear in the topological relations that sounds remind (for instance, music can be assimilated to continuous or broken lines or it can inspire a sense of closure or opening, etc.). Finally, music takes shape in visuospatial isodynamisms (it suggests upward or downward jumps, approaching or departing trajectories, etc.).

The verbal register is involved at a basic level through the usage of onomatopoeic devices (the musical sounds imitate natural or artificial sounds) and at a more sophisticated level through the prosodic intonations (accelerations and decelerations, as with rhythm and intensity, hinting at the "tone" – solemn, whining, peremptory, friendly, etc. – with which the musical discourse is pronounced) to construct a discursive structure (distribution of parts, entrances and relative turns, repartition of "topics" introduced in the discourse, etc.).

What relationship exists between the different registers? The registers are interdependent and synchronised. They are activated by the same musical input and mirror the same characteristics of this input, yet with a different emphasis (for example,
an aspect of the piece will be better reflected or expressed in the motor register, another in the verbal one). What is processed within a given register is correlated to and presents some analogies with what happens in another register. Let us attempt to use a concrete example to describe the isomorphism between different registers. If we imagine a stretch of gravel path, on its surface some stones will protrude more than others and some depressions will form. Let us imagine pressing a piece of cardboard into the ground. Some features of the gravel path – its protrusions and depressions, etc. – will be found on the piece of cardboard. Where on the ground there was a sharp stone, on the card there will be a narrow and high protuberance. In some way, the characteristics of the ground have been “retranscribed” in the shape the card has taken. There are some correspondences between the two surfaces, even though each one is “made” of different things (in this example, stones for the former and cellulose mixture for the latter). If we imagine we pour some coloured paint on the modelled card after it has been pressed into the ground, the paint will run down along the protrusions of the card and thicken in its depressions, colouring protrusions and hollows with different intensity. If we flatten the card now, we can still detect the original roughness of the ground that has been impressed on it in terms of protrusions and hollows, because the different intensity of the paint has “transcribed” the three-dimensional undulations of the paper. With a different medium (the paint pigment) the characteristics of the ground have been maintained, since we still find the same set of relationships made of hollows and protrusions that are on the ground. We have three different planes and three different materials – stones, paper and coloured pigment. Although in a different manner, all of them represent the same system of relations, since the same “print” has been impressed in these different materials. A «transcription» is therefore a projection, on a certain cognitive register, of characteristics emphasized in a different register. The «transcriptions», i.e. the correspondences that are formed between the various registers (motor, iconic and verbal), contribute to transform the mental processing of music into a consistent complex of acts which generates an overall strong impression.

The ability to grasp the correspondences between different registers appears quite early. According to Stern [32], infants show an ability to connect the content of heterogeneous senses (sight, hearing, touch). For example, infants capture the relation between the rhythm of a repeated noise and a similar rhythm of a caress and they associate these rhythms with the switching on and off of a light occurring at the same pace. At 3 weeks after birth infants grasp the relationship between a time pattern reaching their hearing and a similar visible time pattern. When the mother tries to quieten her baby by singing or pronouncing some words with rhythmical and prosodic inflections and she accompanies her voice with a movement of her hands caressing the child’s body in a manner synchronised with the pace of her voice, the baby perceives the correspondence between the two experiences (auditory and tactile). Musical cognition is a multimodal form of knowledge which, through the simultaneous triggering of several registers, produces a global experience. It is now time to consider each one of these registers and their consequent potentials in terms of rehabilitation.

3. The motor register

On a first level of the motor register we find how music triggers neurovegetative reactions not casually and affects the biological rhythm of the individual. Within a general tendency to synchronise the internal bio-physiological oscillations with the
external rhythms which are heard, we can notice that the musical rhythm induces variations in the cardio-vascular and respiratory rates that, in turn, affect other physiological changes. It has been confirmed that lullabies decrease the heart beat and the respiratory rate, which synchronise with music [33]. It is not only rhythm that has these effects; the emotional quality of music also changes the cardio-respiratory rate [34].

On a different level of the motor register, it is proven that people grasp the expressive tension-release dynamisms in music [35]. When subjects were asked to push a device depending on the tension perceived in the musical piece they were listening to, the authors noticed that moments of tension and relaxation alternated. Furthermore, high tension was detected in correspondence with sections of fortissimo, when the melody was ascending, the density of notes increased, places of dissonance occurred, rhythmical and harmonic complexity increased, musical segments were repeated, as well as during the pauses and in the parts in which some musical ideas were developed.

Similar responses can be found at the level of muscular reactions determining the expression of the face. Usually people respond with subliminal changes of their facial expression while they are listening to music [34, 36]. These responses can be more specifically related to the type of music [33] – music with negative emotional meaning tends to produce a greater corrugating muscular activity, while music with positive emotional meaning brings about zygomatic activity. These associations between music and motor responses appear early: 3-4 year olds know how to match musical pieces and facial expressions congruently with the emotional character of the music [34].

On a more sophisticated level, it has been shown that music generates in the listener motor responses that allow the person to mirror the gestures performed by the interpreter [35]. These claims are supported by experiments showing that people are able to associate to music the corresponding gestures and actions. For instance, only by watching the videotape of a musical performance without any sound track, people can rate successfully the expressive intent inherent in the piece [36, 37]. Such a skill emerges also by observing people making sound-producing gestures in the air without manipulating any concrete instrument [38]. Similar findings were reported by considering ballet performances: hearing only the music or seeing only the body movements produced similar judgments about the beginnings and the ends of the internal sections of the performance, as well as about the tension and the emotions conveyed by the stimuli [39]. Visual experience of a musical performance provides listeners not only with information about the context where it takes place and the alleged personal features of the musician, but also a variety of cues which can emphasize the expressive intention of the executor [40, 41]. The gestures of the performer help decode also some structural aspects of music. In an experiment [42] a singer performed intervals of various ranges and was videotaped. Subsequently two samples were presented with only the sound track or only the soundless filmed sequence. In both conditions the judges adequately identified the range of the different intervals. In the video condition visual cues, such as the facial expression and gestures of the singer, were enough to assess the size of the performed melodic interval.

The possibilities of using the link between music and body reactions for rehabilitation purposes are broad. For example, as far as physiological responses to sounds are concerned, Antic et al. [43] investigated the effect of music in a sample of patients with acute ischemic stroke. In almost 80% of participants an increase in the mean blood flow velocity in the middle cerebral artery was recorded as a consequence of listening to music for 30 minutes. Elderly people affected by dementia benefitted
from music treatments by showing lower systolic blood pressure and better maintenance of their physical and mental state than controls did [44]. With regards to muscle responses, Carrick, Oggero and Pagnacco [45] observed, through computer dynamic posturography, how people reacted to music by measuring body stability; they found positive changes, due to music, in stability scores in individuals with balance abnormalities, so suggesting that music can be a way to prevent fall and/or vertigo and to rehabilitate persons showing postural disorders. Music has been applied in gait training addressed to people with brain injuries: results showed improvements in gait efficiency, supported also by electromyographic measurements [10]. In an even more evident way, if music is utilised to provide the patient with an auditory pattern as a basis for organising movement, the synchronisation between sounds and gestures resulting from it can be applied to teach brain-damaged patients to perform the appropriate movements required to dress autonomously [46].

Technology enables us to expand the natural link between music and movement or to recover it when physical disabilities have impaired it. For example, Tam et al. [47] devised a computer system, called Movement-To-Music, which allows children with impaired movements to play and create music, resulting in broader horizons and increased quality of life. Patients with spinal chord injuries were trained to create and play music by means of an electronic music program: this tool led them to exercise upper extremities which were connected to a synthesiser through a computer [48]. Motor skills impaired by stroke can be rehabilitated thanks to an equipment constituted by electronic drum pads (to train gross motor skills) and a MIDI-piano (to train fine motor skills) designed to activate auditory-motor representations in the patient’s mind [49]. Stroke patients were induced to use such tools to reproduce a musical pattern with the impaired arm. Better outcomes were recorded in these patients as compared to the effects produced by traditional rehabilitation. Equipment enabled to produce MIDI sounds can be activated and controlled by muscular contractions, as well as by biosignals such as electrocardiogram or electroencephalogram: in this way even people with severe motor impairments can produce music and receive feedback [10]. Other similar devices are Sound Beam and Wave Rider [10]. In all cases in which music contributes to restore motor functions [50], music can be conceived as an anticipatory and continuous temporal template which facilitates the execution of the movement which has to be rehabilitated, thanks to auditory-motor synchronisation.

4. The iconic register

On a first level of the iconic register, visual representations triggered by music appear as diffused chromatic sensations. Through synaesthetic mechanisms, sounds elicit experiences afferent to non-acoustic sensory modes. In some cases synaesthesiae impose themselves on the person without her being able to stop perceiving images when she listens to sounds. In other cases it is just a special sharpness in detecting synaesthetic associations; in yet other cases (the majority) one perceives implicitly synaesthetic assonances that become the focus of the thought only if one tries to analyse them.

On a different level the images suggested by music convey topological relations. First of all, on a perceptive level, it becomes clear how the flow of musical notes is inscribed in a sound environment with basic spatial coordinates, being vectorially oriented from left to right. The Spatial-Musical Association of Response Codes
The SMARC effect, recently documented [51, 52], is supposedly evidence for it. The SMARC effect is a form of stimulus-response compatibility effect: the person is facing a screen where some signals appear; they can appear unpredictably either on the left or the right sides of the screen. The task is to push a button as soon as one perceives the appearance of the signal. If the positioning of the signal and the button to be pushed are compatible (for example, the signal appears on the left side of the screen and the button is at the left side of the person, so that she uses her left hand to push it), the response will be quicker than it would be in a situation of incompatibility (the signal appears on the left and the button for the answer is on the right). If the stimuli are musical notes, and the subjects are asked to determine whether, compared to a standard note, the following one is higher or lower, the SMARC effect occurs. If the button corresponding to the answer «lower» is on the left and the button corresponding to the answer «higher» is on the right, the response is quicker as compared to what happens if the buttons are switched. This happens because in the first condition there is compatibility between the stimulus characteristic (pitch) and the position of the button. The musical notes are therefore mentally represented in a space vectorially oriented from left to right, so that low pitches tend to be psychologically “located” on the left and high pitches on the right.

The iconic power of music is grasped very early. According to research by Spelke [53, 54], 3 and 4 month olds are capable of detecting when sound rhythm and visual rhythm are coordinated and when they are uncoordinated. In these experiments infants were shown a visual scene in which a puppet representing an animal was making jumps. A sound was produced either when the jumping puppet was landing or a little later. The children preferred to watch the visual scene in which jumps and sounds were coordinated rather than the uncoordinated scene (their preference was assessed according to the frequency and duration of ocular fixations). A preference was shown also when the time interval between the puppet landing and the sound, although out of phase (delayed sound), was constant. Other studies showed that 6-8 month olds are able to grasp numerical correspondences between sounds and images. For example, given the choice to look at a scene in which two objects appeared or a scene with three objects, if the infants heard two sounds, they rather watched the two-object scene; while they turned their gaze to the three-object scene if there were three sounds. The skills highlighted by Wagner et al. [55] in 6 to 14 month olds are even more surprising. The children seem to be able to associate characteristics of sounds (such as pitch) and characteristics of sound sequences (ascending or descending sequences, sequences of continuous or intermittent sounds) with analogous characteristics of lines. The children prefer to watch a low line, a small circle and a dark circle in concomitance with low pitch, a high line, a big circle and a clear circle in correspondence with a high pitch; just as they prefer to turn their gaze to an ascending arrow if they are listening to an ascending melodic line and a descending arrow if the melody is descending, or a continuous line if the sound sequence is continuous and a broken line if the sound sequence is intermittent.

Older children – as documented by Walker [56] – know how to make even more complex associations, such as matching weak and strong, low and high, long and short notes respectively with long and short lines, light and dark lines, low and high lines, empty and full symbols. Fairly early on children understand that certain characteristics of sound stimuli can be represented graphically with a variety of devices [57].

What role could the visuospatial components play in listening to music? In some psychological models [58, 59] these components seem to fulfil a function only in the
preliminary and/or conclusive stages of the process of listening to music. In the former case, for example, it is emphasized how some of the organisation principles of the visual field (law of proximity, similarity, continuity, etc.) are true also for the organisation of sound events: picture-like principles would intervene in the segregation of the musical flow and in the formation of basic sound clusters. In the latter case, general patterns of emotional response triggered by listening to music would maintain characteristics of the iconic type (sense of raising/sinking, opening/closing, etc.). However, it seems that the figural aspects of musical language can be assigned a role not only in these “peripheral” moments – respectively “incoming” (perceptual organisation) and “outgoing” (emotional response) – of the process of listening, but also in the “central” moment of formation of meaning of the musical piece.

The visual resonances and spatial analogies activated by music are often used within rehabilitative interventions to induce the patient into a state that favours the recovery of his remaining cognitive and emotional resources. To this end, a method called Guided Imagery and Music (GIM) has been increasingly applied. It intentionally elicits visual imagery in the mind of the person starting from sound stimuli. Having proven that music therapy can be successfully applied in cardiac rehabilitation [60], there was the attempt to empower such a technique by associating visual imagery to musical stimulation. Thus, it has been devised Music-Assisted Relaxation and Imagery, a variant of GIM which has been proven to be more effective in cardiac rehabilitation than traditional music therapy [61].

Finally, the iconic register activated by music can be used in rehabilitation with other goals. For example, music can be used to facilitate recalling visual scenes from the past. In fact, it has been shown that music can enhance the production of autobiographical memories in Alzheimer patients [62].

5. The verbal register

A first level where one can detect correspondences between music and verbal language is the structural-syntactic level. In both cases it is a matter of putting discrete elements (notes in the former, words in the latter) in sequence by respecting some formal rules. It does not surprise, then, that aphasic people with difficulty in understanding the syntactic aspects of language also show difficulty in grasping syntactical aspects of music related to harmonic relations [36]. From a rehabilitative point of view these parallels hint at the fact that trainings focused on the processing of sequential aspects of music can be beneficial for recovering syntactic abilities in the linguistic context. The sequential nature of music makes it fit to be used in other sectors as well, such as the Parkinson’s disease. Satoh and Kuzuhara [63] asked mild and moderate Parkinson’s disease patients to walk while mentally singing. This allowed them to overcome gait disturbances, as shown by the fine-grained analysis of their videotaped behaviour.

On a different level, the verbal dimension of music appears to be related to how speech is organised. According to Schaffer [64] music can convey a narrative. The structure of a musical piece describes an implicit event; the way in which the piece is performed gives shape to this event, enriching it with emotional connotations. The gestures of musical expressiveness would then correspond with the emotional gestures of the implicit main character of the story who participates in or witnesses that event. In other words, the interpretation made by the performer has the function of helping define the character of the protagonist in the narrative script, which is implicitly
contained in the musical structure. The musical elements define the implicit event, i.e. the structure that has a decisive and primary role in determining the range of gestures suitable for that musical piece. The performer, like a storyteller, has to be loyal to the structure of the story and, at the same time, has the freedom to modulate the emotions of the characters. In other words, the performer has the task to create the character so as to add deep meaning to the literal surface of the musical piece. According to Schaffer, the details of a musical expression are more fully understood if regarded as corresponding to the gestures of an implicit main character. In this respect, we can recall the observation made by Sloboda [26] that people recognize better a melody if, as they are listening to it, they label it with concrete titles that hint at its dramatisation. This is a potential way of using music that Noy [65] designated «narrative path», which leads the listener to identify with the experience of the composer, feeling his emotions as if reliving his narrative.

Following Shaffer’s suggestion, how can we identify the narrative dimension in the structure of music itself? Like in a story, the plot unfolds through promises, creation of preconditions, anticipations, escalation, dramatic turn of events, sudden resolutions, etc., and similar variations of the arousal levels are produced by the unfolding of the musical discourse. The emotional "course" of music would be parallel to that of a story that could overlap it.

As it is easy to imagine, the narrative characteristic of music can be exploited particularly in the therapeutic context to activate dynamisms in terms of affect and emotion processing. It seems that the understanding of the emotional meaning of music has its own distinct counterpart in the brain. In this regard, Peretz [66] referred an interesting dissociation in a patient with damage to the auditory cortex. He was still able to enjoy music emotionally, but not to make simple auditory discriminations. Notably, the patient knew how to distinguish sad and cheerful melodies, he was sensitive to speed manipulations of the music and to the distinction between major and minor modes in order to differentiate sad and cheerful music, but he was not able to make any distinction between familiar and unfamiliar melodies (for example, he could not recognize that a piece he listened to was the Adagio in G minor by Albinoni; he said that this music «made him feel sad like the Adagio by Albinoni») and did not realise the errors in the pitch of the notes purposely introduced in the musical pieces he was asked to listen to, just as he could not discriminate between consonant and dissonant music. In this patient the analysis of music was intact as far as the emotional aspects were concerned, but not with regard to the syntactic ones.

Do such data lead us to believe that an emotional evaluation of music does not require cortical mediation? According to Peretz [66], this is not the conclusion to be drawn, because in the above described case a specific cortical structure could be damaged. It is well-known that at a cortical level it is possible to identify neurobiological structures which can be related to the discrimination of the emotional meaning of music. The frontal left cortical activity is higher when the subject listens to cheerful music (and when there are variations of mode and time in the direction of joy), while the right one is higher with sad or frightening music (and with its respective variations). It is also proven that the left ear (which projects to the right hemisphere) is superior when one judges music as unpleasant (i.e. atonal), while the right ear is superior in case of pleasant (tonal) music, therefore suggesting a specialisation of the left hemisphere in perceiving positive emotions and the right one for negative emotions. This inter-hemisphere asymmetry does not appear when the persons need to judge the same music not from an emotional standpoint (i.e. as pleasant or unpleasant), but in
terms of right or wrong. To sum up, an emotional appreciation of music would be supported by a specific neural path that requires cortical mediation. A two-stage model could be proposed: musical stimuli are first processed by the superior temporal gyrus (where their perceptive organisation would occur) and then by the emotional systems in the paralimbic structures and in the frontal areas (according to the meaning of the emotion).

Finally, music and verbal language share some prosodic inflections. It seems that our nervous system has developed specialised structures and processes to deal with the prosodic aspects of language [66]. The superiority of the right ear (and consequently the left hemisphere) for processing the content of words and the superiority of the left ear (and therefore the right hemisphere) for the perception of the emotional tone of voice have been demonstrated. Hence, brain damages compromise selectively the identification of emotional connotations of the voice as well as the grasping of prosodic variations in exclamations, questions and assertive sentences.

It is not accidental that children prefer songs addressed to them rather than songs addressed to adults; children know how to seize the prosodic inflections of the former and perceive them as adapted to an interaction with them. It is a fact that in all cultures children are the receivers of songs addressed to them by the adults and that in many cultures these songs are specific for children. Experiments conducted by Trehub and Trainor [67] showed that, when adults sing for a child, they make higher and slower sounds, in a more loving tone, introducing longer pauses between phrases as compared to when they sing for other listeners. Furthermore, adults seem to use two definite singing styles with children: a lullaby-like mode when they want to quieten and let the child fall asleep and a playful mode aiming to activate the child and draw his attention on interesting aspects of the environment.

The continuum existing between the spoken and singing languages gives reasons for the prosodic correspondences between texts and sounds in vocal music. But it is less obvious to explain the prosodic aspects in instrumental music. Such aspects are grounded on the fact that common traits of music and the human expression of an emotion can be found in the characteristics of the voice. A voice expressing sadness and a music conveying sadness share some features, such as low pitch, small range of pitch variations, low intensity, trailing sound flow, slowness, pauses, progressively flat trend of the pitch and the rhythm, etc. Instrumental music tries to mirror these features by means of non-vocal sounds.

The analogies between prosody of verbal language and prosody of music account for the use of singing in rehabilitating the fluency of spoken language. For example, music is beneficial in the treatment of acquired dysarthria following traumatic brain injury or strokes. The intelligibility and the naturalness of speech of dysarthritic patients improved as a consequence of set of sessions where they performed, beside motor respiratory exercises, rhythmic and melodic articulatory tasks based on intonation and singing [68]. Singing is a way to rehabilitate also aphasia. It has been proven that patients suffering from severe forms of non-flowing aphasia benefit from the Melodic Intonation Therapy [69, 70], a rehabilitation technique based on the imitation of singing [36]. Musical techniques can be applied also to improve the vocal quality, the coordination, rhythm and timing of speech and pragmatic use of language in children with acquired brain lesions [71].

Also dyslexic people can be trained through music. Besson et al. [72] found that musical activities were successful in improving pitch processing in speech, an ability that is fundamental in second language learning and that is impaired in dyslexic
children, so suggesting that music can be employed as a remediation in dyslexia to improve people’s impaired reading skills. This is in agreement with the observation according to which dyslexic children show some difficulty in the timing in music and, if they attend music classes, they improve their reading skills [36].

6. Conclusions

As we have tried to argue, if music is a tool that triggers representations and processes in different mental registers (motor, iconic and verbal) – given that sounds carry affordances, forces, vectors which drive the performance of specific actions, images and ways of speaking and that what occurs in the various registers is reciprocally synchronised – both the power of music as a spontaneous elicitor of emotions and as a natural tool of communication and the deliberate utilisation of music for rehabilitative purposes are justified.

Music is constitutively motor, iconic and linguistic, since gestures, images and words are not extrinsic elements to it. Motor, visuospatial and verbal elements are already present in the innermost nature of music. The registers that music activates (movements, figures, words) do not "attach" to music from the outside; they are embricated and are deeply embedded in music. It is because of this very imbrication that we can argue that music acts as a vicarious function in the rehabilitation context. When the processes of motor planning are impaired, music can provide the sequential and rhythmical patterns required to perform actions that need to be relearned, and this is possible because these patterns are embedded in music itself. When memory processes fail in recalling the past, music helps the memory emerge because it suggests colours, shapes, spatial movements that can be found in visual scenes. If it is the organisation of verbal language that is impaired, music can assist it, because it contains discursive patterns. In other words, music, thanks to its multimodal nature, offers “scaffolding” on which one can learn to perform movements, carry out cognitive operations or articulate verbal expressions that need to be rehabilitated.

Recently, the theoretical concepts justifying the interventions in the field of music therapy have been clarified and reliable evidence of achievable results have started to be collected. The new technologies can expand possible music-based interventions, but we have a long way to go yet to understand better the potential of music in rehabilitation.

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