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Digital instruments and their uses in music therapy

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ABSTRACT

Technology could represent an ally in easing the formulation of a bond between music therapist and client. So far, both scholars and therapists have claimed that the implementation of technology could be paramount in transforming the client's therapeutic process, beyond representing a new and effective methodology for session analysis. This article proposes the implementation of musical technologies within the daily practice of music therapy, the latter understood as the appropriate field for the application of interactive systems technology, which track the user's movements and transform them into audiovisual and haptic feedback. The article presents an exploratory review of the use of digital instruments, based on motion tracking, in order to develop a new basis for music therapy procedures, and discusses how specific features of digital musical instruments could benefit music therapy sessions. All discussions are set within the framework of embodied cognition. We provide a discussion on how multisensory integration may be used in the treatment of clients with severe cognitive and motor difficulties. We advocate the need for an interdisciplinary approach to the practice of music therapy, and propose future lines of research concerned with the design of multimodal and empowerment-based technologies.

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KEYWORDS DMI; empowerment; sensorimotor maps; multiple trajectories; therapeutic bond

Introduction

Music therapy has traditionally favoured a holistic approach towards human beings. Music therapists take into account the physiological, psychological and physical aspects of clients. Nevertheless, while medicine has largely invested in technology, music therapy uses it only in a tangential way – rarely as part of its interventions, as reported by Hadley, Hahna, Miller, and Bonaventura (2014). Why is this so? There may be a fear of the use of technology jeopardizing the therapeutic process (Magee & Burland, 2008b) in ways that are not appropriate in the clinical setting (Hadley et al., 2014). Yet, the need for music technology within the practice of music therapy has increased in the last decade (Crowe & Rio, 2004; Magee & Burland, 2008a). Although music therapists have outlined the limitations of electronic music technologies in diverse therapeutic contexts (Lindeck, 2014; Magee & Burland, 2008b; Withehead-Pleau &

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Spall, 2014; Zigo, 2014), all agree that technology can be a powerful support tool in the course of therapy sessions by providing new insights relating to users' assessment and diagnosis. In fact, such technologies may also aid intervention, while strengthening the therapeutic bond (Partesotti, 2016) and helping the therapist connect with the clients in a different way from that enabled by acoustic instruments (Magee & Burland, 2008b), thus changing the therapist–client relationship (Nagler, 2014).

In this article, we define "technology" in terms of new interfaces for musical expression, more specifically Digital Musical Interfaces (DMIs), which are described below. DMIs are music technologies that can either take the shape of traditional instruments, or something entirely different. Characteristically, they contain a sound generation unit and a control surface, usually referred to as a gestural or performance controller (Miranda & Wanderley, 2006). These can be used by multiple performers and applied in various contexts other than music, such as art or therapy (Miranda & Wanderley, 2006, p. 1). Technology can mediate the relationship between a person's inner and external world in a different way from those used by therapists (Ihde, 1979). Not only does it allow for new possibilities, but it is "malleably extendable and/or reducible in terms of the material or technological mediations that may be embodied" (Ihde, 1979, p. 508). In 2002, the same author proposed the concept of the *technological body* to refer to the result of the interaction between the human body and technology. This concept involves the consideration of the body as something immaterial and cultural which can be extended through the use of technological instruments that, in this way, become extended embodiments. This condition appears inside an interactive environment, in which the user becomes at the same time the participant and the instrument, and engages within the environment through such an extended embodiment (Ihde, 2002).

In this article, we focus specifically on motion tracking-based DMIs, because they are both sensor-less and wireless. Indeed, their non-invasive facilitation of performance during therapy sessions may promote the kind of cause-and-effect process that we are keen on encouraging, without creating an undesirable barrier for clients or undesirable behavioural problems (Magee & Burland, 2008b). Moreover, camera-based motion tracking procedures are the most widely used systems currently (Medeiros & Wanderley, 2014). One of the reasons for their use, in conjunction with several other motion analysis techniques, is their low-cost and easy *utilization* (Medeiros & Wanderley, 2014). The term *DMI* refers to a physical or virtual surface, made up of diverse types of sensors responsible for the capture of human motion, that can produce a haptic representation. Kinetic energy is transformed into electricity by these sensors, and this makes communication possible between a human subject and the machine. There are different kinds of sensors depending on the magnitudes measured by the specific DMI, yet all enable the user to both communicate and control the space of interaction (Bongers, 2000). This is why the type of gestures involved, and the gestural acquisition per se, are paramount for the kind of feedback (i.e. the sound parameter) that technology provides for users.

Wanderley and Depalle (2004) classify gestural controllers into four types: alternate controllers, extended instruments or hyperinstruments, instrument-like controllers and instrument-inspired controllers (Table 1). There is still a dated tradition, regarded as backward-looking, that conceives the implementation of musical technologies within the daily practice of music therapy as exceptional and somewhat alien to the purpose of traditional music therapy. The aim of this article is to review the use of musical instruments based on the motion tracking technology present in the

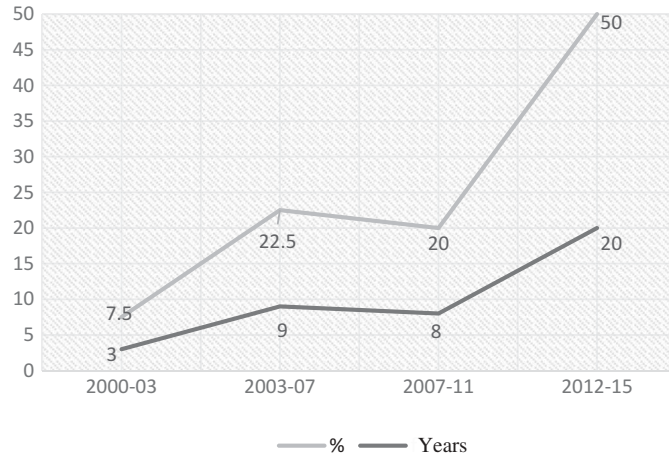

Figure 1. Analysis of research output by 4-year subperiods.

The use of technology as a therapeutic tool

As Magee and Burland (2008b), technology empowers clients and enables them to access a wider range of timbres and instruments – their study claims that music technology motivates and facilitates the client's participation while meeting cultural identity needs. In another, more recent article (2012), the same scholars underline the importance of this identity-driven process in situations where people with complex disabilities have to adapt during music therapy sessions. In this context, if music therapy aims at promoting an alternative sense of self through shared music-related experiences and interactions with others (2012), then music technology can facilitate creative expression that moves beyond the confines of clients' disabilities (Magee & Burland, 2008b). In the same article, there emerges the need for greater awareness of the technologies being developed in client-relevant healthcare areas (Magee & Burland, 2008b, p. 4) – a point stressed elsewhere by Magee (2014a, p. 84) when considering the importance of putting clients' needs first. Magee and Burland (2008b, p. 10) argued that the appropriate use of music technology can broaden the therapists' scope and improve their work as a result of the greater diversity of available tools. The therapist must have the capacity to surprise – to grab the clients' attention, motivation and interest – and the implementation of electronic music technology could lead to a more expressive way of working in general (Magee & Burland, 2008b). In this contribution, the authors consider the benefits of using music technology as: facilitating access; strengthening self-control; promoting the client's expression; motivating the client to actively participate while addressing his/her identity issues; and encouraging interdisciplinary collaboration between music therapists, while offering professionals the opportunity to deploy more resources in order to meet the client's needs (Magee & Burland, 2008b, pp. 6–10). Magee and Burland (2008a) argue that there is a high demand for the application of

Table 1. Types of gestural controllers.

Alternate controllers	Hyperinstruments	Instrument-like controllers	Instrument-inspired controllers
Differ from traditional instruments in their shape, way to use, material and built-in process (e.g. Music gloves).	Are augmented instruments with sensors or other devices. The performer can control the sounds linked to his/her movements (e.g. Hypercello).	Are designed to represent the physical and sound characteristics of an acoustic instrument, but they offer more sonorities (e.g. Moog Synthesizer).	Their final design can be substantially different – morphologically and in their control surface – from the acoustic instrument they are inspired by (e.g. Radio Baton).

Note: Gestural controllers classified by Wanderley and Depalle (2004).

literature over the last 15 years, in order to better understand their potential benefits and limitations in music therapy.

Methodology

The purpose of this article is to provide an initial approach to the implementation of motion tracking techniques in music therapy settings, against the larger backdrop of camera-based music technology. We make no claims to have exhausted the material available for analysis, since progress is continuously being made in this area. Our aim is to provide new insights for future development through studies and clinical perspectives on the implementation of motion tracking technologies. As pointed out by Berger (2016), in connection with kinesthetic activities, a whole-brain-whole-body approach is the proper way to achieve bodily self-awareness. We therefore believe that the introduction of camera-based motion tracking technologies advances the embodiment process in clients and paves the way for further outcomes.

We have conducted a qualitative analysis on a set of published literature spanning over 15 years and reaching into the recent past. Our focus lies on the period from 2000 to 2015, where we have searched for materials matching the descriptors (*music*) *technology* and *music therapy* in specialised journals[1] and other relevant publications. We originally selected 42 publications, eventually discarding 2 which did not meet the criteria for inclusion (DMIs and music therapy). Ph.D. dissertations were excluded from the sample. The majority of the 40 items under scrutiny were articles published in journals (19), followed by 11 conference papers and 10 contributions published as book chapters or sections. All were reviewed and rated according to several categories reflecting the device used, the target users, the results achieved, the limitations encountered and the identified potential. We divided the 15-year period covered by our analysis into four subsets of years (2000–2003, 2004–2007, 2008–2011, 2012–2015), for which we quantified research outputs. A line-graph shows the results of this quantifying analysis, highlighting a progressive growth and implementation of clinical research involving the use of technology in music therapy between 2000 and 2015 (Figure 1).

Within the context outlined so far, we next approach the issue of digital musical instruments and their potential in music therapy sessions.

[1]*Nordic Journal of Music Therapy, Voices, British Journal of Music Therapy, Journal of Music Therapy, Presence, Psychology of Music.*

technology within therapy sessions, but that there is a gap concerning the assessment of these tools and the guidelines needed for their practical use.

As pointed out by Magee et al. (2011), the implementation of electronic music technologies in music therapy was established more than 20 years ago. At present, however, there is a strong need for guidance regarding their optimal uses in this setting (Magee et al., 2011). From a more recent perspective, Nagler (2014) suggests harnessing music technology for the purposes of therapeutic practice, while Magee (2014a, p. 85) recommends principles of practice in using this tool, considering that clients usually have a mixed combination of needs. Hadley et al. (2014) advocate the imperative need to implement music technology in clinical practice for the sake of clients, moving past personal assumptions and biases about it (Hadley et al., 2014), while Krüger (2007), highlights the power of technologies that enhance the clients' communication and storytelling skills. In yet another study, Hahna, Hadley, Miller, and Bonaventura (2012) undertake a review of several uses of technology in music therapy from the 1930s until today. The article states the importance of making the most of the creative input that technology can bring to the practice of music therapy.

The current article reviews and discusses the implementation of motion tracking technologies as supportive factors in the therapeutic process, both for the client and the music therapist. We review recent literature on music technology and music therapy, with a special focus on possible indications and contraindications of its use. After describing DMIs and highlighting their main features and potential benefits for music therapy sessions, we discuss the kind of interactions that motion tracking technologies may bring about in the therapeutic environment. We argue that, after the client has learned how to properly interact with motion tracking music technology, he/she reaches a *state* called Creative Empowerment (Partesotti, 2016).

In the last decade, music technology has developed rapidly. Interactive music devices have been built for several purposes including artistic performances, musical practice and therapy, among others. One innovative feature that they introduce, by comparison with acoustic musical instruments, is that they can be played by people without any training (Mulder, 2000, p. 315), thus permitting the design of specific exercises to learn and regain motor ability in diverse situations (Benveniste, Jouvelot, & Michel, 2008; Camurri et al., 2003; Kontogeorgakopoulos, Wechsler, & Keay-Bright, 2013; Rizzo & Kim, 2005). Digital musical instruments disrupt the causal relation between the performance and the sound outcome (Peñalba, Valles, Partesotti, Castanón, & Sevillano, 2015), and they change the way the user creates and experiences music, as the gestural interface is separated from the sound generation unit (Wanderley & Depalle, 2004). The fact that a digital instrument can be designed with the needs of specific individuals in mind makes it easier for anybody to be able to play it, as long as the instrument is properly designed. As stated above, musical technology can provide real-time sound control for people with limited gestures and movements, as well as new experimental sounds – "new timbres and sound worlds using electronic instruments" (Hunt, Kirk, & Neighbour, 2004, p. 50). In a case study, Krüger (2000) supports the application of music technology in the organisation and development of therapeutic sessions, describing, for example, the benefits of *hyperinstruments* (Table 1) for the therapy process. In our discussion of technological interfaces applied to music therapy, we refer to DMIs as essentially camera-based motion tracking technologies, in which users' body motions correspond to multimodal feedback: auditory, visual, or a combination thereof.

Next, we outline a few significant examples (Table 2).

Table 2. Five music technologies for therapeutic practice.

Device	Creator	Type	Feedback	Other characteristics	Application
Soundbeam	E. Williams in 1984 (Swingler, 1998)	Instrument-like controller	Sound, visual, haptic, proprioceptive	Turns the user's voice/noises into sounds effects; possibility to visualize 3D user's image through markers	DSA, children with special needs, elderly
Motion Composer	R. Wechsler (2012)	Alternate controller	Sound, proprioceptive	Six environments, no markers on the body	People with and without disabilities
SATI R	C. Mauri, A. Solanas, T. Granollers, N. Parés, J. Bagés, & M. Garcia (2009)	Alternate controller	Sound, visual	It is possible to select and track a specific part of the body, and to track a voluntary movement with a marker.	Cerebral palsy, DSA
CARE HERE	Brooks, A. L. & Hasselblad (2004)	Alternate controller	Sound, visual	Possibility to select the kind of graphic feedback	Elderly, rehabilitation, handicapped
AUDIOVISUAL Drum	Hunt, A., Kirk, R. &Neighbour, M. (2004)	Hyperinstrument	Sound, graphic projected onto the drum's surface	The sound emerges from the drum, real-time image control, possibility to map performer's energy to sound harshness and visual perspective.	Music Therapy practice

Soundbeam

Soundbeam (SB) was designed by Williams in 1984 and inspired by Thereminvox. It is a gestural controller, and more particularly an ultrasonic sensor device, that was first designed for dancers and was eventually applied to the practice of music therapy (Swingler, 1998). The device provides and combines different control parameters such as a *Transposer* setting for the modulation of scales and a *Mode* setting for note-related information (chords, dynamics, velocity, etc.). Furthermore, it offers the possibility to visualize the user's 3D image by applying up to four sensors/markers on his/her body. SB 5 has been released recently and is capable of recognising the user from a distance of up to 6 m, and converting detected micro-movements (for example, of the eyes) into music. Moreover, it is fitted with a control unit consisting of 2–4 ultrabeam sensors and four wireless switches, which the user can touch to change the sound. The user can generate and shape sound effects by using only very small movements.

SB facilitates the playing of music without any physical contact, and works via ultrasound pulses that are reflected back into the device as the beam is interrupted by body motion. It has been employed in the therapeutic field with subjects with severe disabilities, and its use may bring about important changes in treating autism spectrum disorder symptoms (Ellis, 2009). The company offers training sessions for music therapists, since SB uses a MIDI protocol that requires some previous knowledge.

Motion composer (MC)

Wechsler's MC is an interactive system that turns movements into sounds (Wechsler, 2012). The structure consists of an alternate type of controller that ultimately acts as a nontraditional musical instrument (Miranda & Wanderley, 2006). Like SB, it tracks users' movements and transforms them into different kinds of sounds. MC is based on six different environments that involve diverse kinds of usability by the subject. One basic difference, compared to SB, is that this technology does not require the client to touch or press any surface in order to change the interaction pattern – instead, MC depends solely upon the kind of movement that the user makes. Peñalba et al. (2015) have analysed the types of interactions that participants with and without disabilities show with this device. An interesting outcome of this study is that clients with and without disabilities provided statistically similar interactive responses. Therefore, in both groups facilitated the development of very similar skills in musical expression.

SATI b

This product was part of a 2-year project named SATI (Therapeutic Interactive Audiovisual System, by its Spanish initials) carried out by Mauri et al. (2009). Its aim was to apply an interactive technology to the treatment of individuals with moderate or severe cerebral palsy (Mauri et al., 2009). The system's architecture comprises a room and a camera sensor, used to capture the direction and amount of movement displayed by the user, as well as his/her overall level of activity. This architecture requires the application of a marker on the client's body. Additionally, it provides two other kinds of feedback, one haptic and another audiovisual and

displayed on a screen. The user's movements are converted into notes. Furthermore, the device transforms the voice, and other noises produced by the subject, into sound effects with which s/he can interact. After trialling this technology for 1 year with people with special needs, the authors (Mauri et al., 2009) suggested its potential use in the treatment of individuals with severe and multiple disabilities, such as cerebral palsy, among others.

CARE HERE

CARE HERE, a project by Lewis-Brooks and Hasselblad (2004), stands for Creating Aesthetically Resonant Environments for the Handicapped, Elderly and Rehabilitation. It came into existence in 2000, with the aim of creating a community of specialist professionals. The project consists of a user interface with a library of audiovisual contexts ready to be employed by therapists and other people. This technology is based on *an interactive virtual space* (Brooks & Hasselblad, 2004) and provides subjects with an audiovisual response. In this environment, the interaction allows the externalization of a perceived experience (Brooks, 2011). This concept has been applied so as to enhance body awareness and the perception of one's own movements, in children with neuromotor disabilities. CARE HERE is based upon the concept of *aesthetic resonation*, a process that occurs when the user receives an immediate and aesthetically pleasurable response from the technology being used, which in turn enables him/her to forget about their physical efforts and so continue moving.

Audiovisual Drum

Audiovisual Drum was built in 2004 by Hunt, Kirk and Neighbour and was designed to give the user multimodal feedback (graphical and audio) while playing an interactive instrument. Accompanying photographic images are manipulated by texture mapping, which means that they change as the drum is being played. The device was designed for individual use, but a music therapist can take part without being part of the interactive environment. It can facilitate active participation, for example, with clients having emotional problems, for whom the use of sound effects, loops and other tools could be helpful in composing and then listening back to their compositions. Its creators chose to design their technology based on a drum-like instrument because drums are acoustic instruments regularly used in music therapy sessions, and are particularly suitable for generating feelings of reward (Hunt et al., 2004). Its creators emphasized that this technology could be set up easily by a music therapist, without previous technology-based knowledge.

Analysis of possible applications of digital instruments in music therapy sessions

Aesthetic resonation and empowerment

As emphasized by Swingler (1998), in music therapy "the less the client is able to say something with sound because of a physical or cognitive disability, the heavier becomes the therapist's responsibility for empathy and interpretation" (p. 254).

One of the more severe problems within a music therapy session is the user's lack of self-expression in the process of musical creation, which seem to be directly proportional to his/her physical disabilities. In Ellis's opinion, however, technologies such as SB produce Aesthetic Resonation (Ellis, 2004; Swingler, 1998) – that is, the acquisition of total control over the technology despite any physical limitations – a finding also confirmed in other investigations (Brooks, 2011; Hunt et al., 2004). The application of these types of technologies can affect users' psychosocial performance (Krüger, 2007) and thereby promote positive outcomes in the practice of music therapy. This is particularly true of clients with cerebral palsy or Parkinson's disease (PD) (Holden, 2005) (certainly more so than in motor rehabilitation therapies), for whom social integration and skills may be enhanced (Maier, Ballester, Duarte, Duff, & Verschure, 2014). As Ellis points out, progress made by clients across a range of disabilities depends on their internal motivation – a concept bonded to that of aesthetic resonation (Swingler, 1998, p. 255).

Many devices, on the other hand, can gather multimodal information and utilise this for user feedback. Berger (2002) highlights that sensory integration during therapy sessions can help develop both cognitive and emotional adaptive responses in the client (Berger, 2002, p. 173). Music and visual feedback can also enhance creative expression with a therapeutic purpose, giving clients the opportunity to empower themselves while composing music and painting. Moreover, the term *aesthetic resonation*, in reference to CARE HERE and SB, explains how, during engagement with a feedback loop within an audiovisual control system, the client overcomes their physical limits in favour of a creative commitment. In another case study, involving the use of the e-mocomu technology (e-motion, colour and music) – an alternate controller with which sounds and colours are regulated by the spatial movements of users – data were retrieved regarding self-perceived outcomes for 17 participants (Partesotti, 2016, 2015). The data showed an increase in both their self-reported performance and self-confidence. In other words, a process of empowerment occurred within an interactive environment, involving music and visual feedback, which may well fit into music therapy sessions as well. In a preliminary study on the CARE HERE project, Camurri et al. (2003) applied aesthetically resonant environments in which subjects received audiovisual feedback to the treatment of PD patients, and found a clear improvement of 27% in their physical performance. Clients could paint in real-time through their spatial motions (Camurri et al., 2003, p. 14) and, as the authors claimed, obtained benefits in terms of motivation and physical accomplishment. As we pointed out in a former research paper, "some characteristics of colours connected to music (such as hue and saturation) can reflect emotional states; thus, the colour preferences (including the absence of colours) may be used to evaluate emotional states in subjects with particular psychological disorders and needs" (Partesotti & Tavares, 2014, p. 904).

Expressive and aesthetic freedom

Ellis (2004) also reminds us of the limitations of the standard musical interaction that can happen during a music therapy session, at the expense of the resulting soundscape and the interplay between client and music therapist. This can happen because the therapist often makes decisions about which type of music is composed or otherwise utilised in the sessions – decisions that are subjective in nature. Regarding this point, Dreier (1994) discusses how the therapist could potentially

cause a therapeutic failure in the determination process of the client through their influence upon the client's process. A successful therapeutic session should therefore be determined only by a collaborative relation between the music-based therapy and the clients themselves, on the basis of mutual empowerment (Dreier, 1994). Indeed, without the deployment of external technologies, the session is susceptible to engaging a standard musical vocabulary, based on the therapist's command of traditional musical language, and this could restrict the client's freedom of expression and repertoire. Underlying this view is the belief that a hierarchical relationship does not benefit the client, and that it is rather preferable to establish a mutual collaboration in order to shape an empowering interaction with the user, instead of a relationship based on dependence (Rolvsjord, 2004). Hence, the interactive technology applied in the field of music therapy can open up a wide range of possibilities for the therapist and, above all, for the client.

Furthermore, we should consider that a large number of clients participating in music therapy sessions lack basic musical knowledge. This has not typically presented a problem for the various methodological applications of more traditional music therapy, whose curricula contemplate the issue and teach future practitioners to compensate for the client's lack of formal training. However, technological applications in this kind of setting can foster a direct dialogue between user and therapist, overcoming the client's possible absence of expression (due to initial frustration caused by a lack of formal musical ability), and thereby improving the therapeutic environment (Rolvsjord, 2004). Interactive music devices can facilitate musical expression, since they are relatively easy to use and do not require previously acquired academic musical skills. This does not mean that such technology can be used with any patient, however. With this said, the kind of interactive music devices that we are discussing here are largely client-friendly, intuitive and easy to use (Knight & LaGasse, 2012). The user experiences an immediate feeling of control through his/her body, even with very few movements or actions. In other words, the environment provided by interactive music devices is immersive, empowering, and promotes kinetic interaction and the user's body awareness. As several authors suggest (Brooks, 2011; DeNora, 2000; Partesotti, 2016), this has some implications within the field of music therapy. For example, the client does not need to have previous knowledge of how to play a traditional musical instrument, or theoretical expertise in order to properly perform. This helps the user to overcome difficulties of expression.

Emotional engagement

Empirical studies have outlined the effectiveness of virtual reality for the functional recovery of people after stroke, with rehabilitation gaming systems and virtual reality rehabilitation system highlighting new possibilities for treatment (Da Silva Cameirão, Bermúdez I Badia, Duarte, & Verschure, 2011; Luque-Moreno et al., 2016). In a study on virtual reality games, Collins (2011) states that gesture-based interaction with sound and music may strengthen emotional engagement. The author argues that, in a virtual reality landscape, there is "a cognitive multimodal mapping between visual, motor and auditory representations that is closely integrated to our own feelings of empathy, even with virtual characters" (Collins, 2011, p. 40). The fact that three modalities of perception are acting together gives us a feeling of reality, presence and

attachment, and contributes towards enhancing emotional engagement. Our perception is connected to our embodied experience, which means that without gestures and movements there is a loss of emotional articulation. In an interactive reality landscape, however, this perception is augmented, and can be directly tied to our emotional experience because it is not inhibited by the lack of body movements. Additionally, technology provides an unbiased and reliable instrument for a posteriori analysis of clients' emotional experience.

In the resultant enactive environment, proprioception, which supports the self-awareness of body gestures (Laskowski, Newcomer-Aney, & Smith, 1997), provides the opportunity to find new affordances while at the same time furnishing the user with the feeling of *creative empowerment* (Partesotti, 2016). This term, which will be discussed further below, is grounded in the philosophy of empowerment, which emphasizes the process of growth in individuals or groups. It refers to a multilayered process, described by Zimmerman (2000), with three main dimensions: psychological, organizational, and socio-political (community-based). Empowerment promotes personal knowledge and the development of individual skills, as well as enabling people to reach personal goals.

In music therapy, the more instruments we can offer in a session, the more opportunities we have to find the appropriate preference of the client, with respect to self-expression. The same concept should be applied when using a music technology that can, therefore, become an effective tool for expression. Furthermore, DMIs can offer the user, in real-time, more than one musical instrument for interactive purposes, owing to flexibility of the mapping between gesture and sound. Moreover, for the client, technology can become an element of cultural affiliation, since clients belong to diverse cultures. As Rolvsjord and DeNora (2004, 2000) suggest, the application of technology in music therapy can support the process of equality and mutuality between the therapist and the client, while offering a diverse tool and a larger repertoire (2000) within the sessions.

Limitations and possibilities

Many of the technologies reviewed here are already being surpassed by advancements in the field of human-computer interaction. Some of them still require the use of markers on the clients, or include a control unit that is difficult to use and not particularly intuitive. In others, the interaction requires the client to touch a surface, or must be engaged in by the individual without the support of a therapist. In the digital era, however, there is no need for invasive technologies during the session. In fact, the current research landscape suggests a turning point in interactive relations within therapeutic practice. Users with restricted mobility and no previous knowledge of the kinds of technologies discussed above may easily interact with them during a therapy session, after the music therapist sets up and prepares it for a proper interaction.

When motor problems are triggered by the stretch reflex, the use of music technologies may be contraindicated, as Magee (2014a), and the duration of their use should be restricted, in order to avoid overstimulation. Another contraindication pointed out by the author, in connection with treating clients with motor problems, could be the lack of a *point of rest* (Magee, 2014a, p. 88) – a physical position in which the client can opt to stop or to not interact with the music technology.

Needless to say, the above-mentioned parameters have to be set using the technology's mapping, which determines the kind of feedback that the user receives during the interaction. The mapping represents the first step in the design of any DMI technology, and is indeed a key process because it affects the psychological and emotional response of the client (Hunt, Wanderley, & Paradis, 2002). This process must be examined by the music therapist since, if the skills required are beyond the client's capabilities, this could lead to a break in the therapeutic relationship (Withehead-Pleau & Spall, 2014). Since some users may feel afraid or hesitant to use music technology, the therapist must balance its drawbacks and benefits in order to meet clients' needs and goals. Some users, in fact, may also experience inequality while using DMIs, because of the power dynamics which its implementation can generate across genders within the therapy setting (Magee & Wimberly, 2014). This is why it is critical to avoid the feeling of disempowerment that could result from perceptions of gender identity (Burland & Magee, 2012), by monitoring the behaviour of clients. Moreover, the duration that DMIs may be used for within the session may be limited by the user's age. As the American Association of Pediatrics (American Association of Pediatrics [AAP], 2016) suggests, in children younger than 18 months only video-chatting should be used, while between the ages of 18–24 months the recommendation is to use only high-quality programming, if demanded by parents. In turn, children aged 2–5 years should get only 1 h a day of high-quality programming, while from 6 years onwards it is advisable to set limits to the use of technology.

Considering the multisensory parameters offered by DMIs, it could be inferred that they might be distracting (Hunt et al., 2004), or may even overstimulate the client if not properly controlled. This may occur in clients with marked symptoms of epilepsy, in which the use of DMIs may be contraindicated or should at best be used under strict control. In another study (Magee & Burland, 2008b), it is pointed out that, in treating clients with behavioural disorders such as Autism Spectrum Disorder (ASD), wires and plugs may represent a barrier, so that in such cases it might be better to employ a sensor-less technology to promote the cause-and-effect process. As for clients with special cognitive needs, it is important that any music technology should provide a somatosensory experience (visual, auditory, tactile), just as acoustic instruments do (Magee, 2014a), in order to properly facilitate the desired cause-and-effect awareness. Unless this causal relationship is clear to the client, non-contact interfaces are contraindicated (Magee, 2014a). Additionally, the music therapist may avoid using music technology with clients who experience self-esteem problems (Magee, 2014a), in order to prevent their potential frustration and anxiety. Another limitation highlighted in the study by Magee and Burland (2008b) is the high cost of Digital Musical Interfaces (DMIs), which is why we propose the use of low-cost camera-based motion tracking technologies to overcome this problem. In short, despite some specific limitations and important contraindications, music technology may be more effective compared to conventional approaches, and many clients find it more appealing, if not fascinating. In Table 3 we present some of the limitations and benefits of such technological resources, as pointed out by music therapists in their clinical work. Both should be carefully considered when implementing such resources in therapy sessions, and should be contextualized according to the client's limitations, needs, and goals.

Table 3. Some general limitations and benefits to carefully consider while implementing music technology.

	Contraindications	Benefits
Stimulation	High technology sophistication could lead to an overstimulation of the user (Magee & Burland, 2008b)	
Expressivity		Work in a more expressive way for non-functional outcomes (Magee & Burland, 2008b)
Empowerment	Sense of disempowerment (Magee & Wimberly, 2014)	
Attention	Visual element can distract (Hunt, Kirck & Neighbour, 2004)	Attractive, client is fascinated by technology devices (Krout, 2014)
Clients	Not for all clientele (Hadley et al., 2014)	Helpful in strengthening the connection with the younger age group (Magee & Burland, 2008b)
Aesthetic	Aesthetic differences with traditional acoustic instruments (Magee & Burland, 2008b)	
Identity		Meets cultural identities needs (Magee & Burland, 2008b) Promotes the client's access to alternative identities (Burland & Magee, 2012) Supports self and identity construction (Magee & Burland, 2008b; Burland & Magee, 2012)
Inclusion	Causes one to feel unequal in gender terms because of unintentional power dynamics being introduced (Burland & Magee, 2012)	Promotes inclusion and sense of belonging in a creative group process (Weissberger, 2014)
Anxiety	Creates additional anxiety, stress and frustration (Withehead-Pleau & Spall, 2014; Magee., 2014a)	
Facilitation		Makes several processes faster (Weissberger, 2014)
Feedback	Loss of physical experience of the acoustic instrument, as there are aesthetic differences (Magee & Burland, 2008b; Zigo, 2014)	
Implementation in session	Lack of training on how to incorporate tools within the session (Hadley et al., 2014)	Enhances therapist flexibility and adaptability in response to very challenging clinical situations (Magee & Burland, 2008b) Promotes the client's cause-and-effect awareness (Magee., 2014a)
Technological issues	If not properly working, it could disrupt the flow of the session (Withehead-Pleau & Spall, 2014, Magee & Burland, 2008b) The repetitive use of switch sensors may be unrewarding (Magee., 2014a)	The use of switch support communication, environmental control and mobility (Magee., 2014a)

Discussion

One of the main changes brought about by an interactive system (as facilitated by a DMI) is the more central role of the client. Since clients can participate as both listener and performer simultaneously, they have the opportunity to gain "multiple perspectives over a given experience" (Benford & Giannachi, 2011, p. 7). This means that users have more opportunities to enjoy the environment, interact with space, and express themselves. This happens because a DMI-based interactive system offers *Multiple Trajectories* (Partesotti, 2016; Partesotti, Manzolli, & Peñalba, 2017). This Gibsonian concept refers to the diverse affordances, both potential and specific, offered to the client by the interactive space and linked to the Sensorimotor Maps (Partesotti, 2016). A DMI-based interactive system leads to a codetermination process whereby the client's capacities are enhanced and empowered. The codetermination process involves the Multiple Trajectories that are based on the Sensorimotor Maps (Partesotti, 2016).

A musical stimulus is "also an actual tool for cognition, a meaningful event that affords a variety of self-regulative, interactive, and sensorimotor processes depending on the agent-music interaction's degree of complexity" (Schiavio & Altenmüller, 2015, p. 9). Therefore, in dealing with DMI technologies and their applications in music therapy, we should also bear in mind the so-called philosophy of the body. Within the embodied cognition paradigm, in fact, the common denominator is the role played by the body in experiencing and perceiving both the inner and the exterior world in an enactive continuum. In this context, technology has to be considered, as we argued before, an extension of the body – a malleable tool that can be used by clients with restricted mobility or cognitive problems to stimulate their self-expression, creative composition and motor rehabilitation. These concepts are relevant in connection with music therapy sessions: DMIs may enhance the body's potential for movement by offering Multiple Trajectories to users, who can thus use their body movements to afford a new pathway to express, compose, and communicate with the therapist. This process is based on the concept of feedback (Badia et al., 2009), which is in turn associated with the creative opportunity to achieve self-expression that accompanies the feeling of control available to the user. This feeling of control that we call Creative Empowerment enables a continuous, cyclical interaction between user and technology, and is determined by the exploration of the environments, and the mapping designed a priori on the basis of the client's needs A user immersed in a DMI-based interactive system can express him/herself in a self-determinative way that strengthens his/her experiences of resilience, while producing qualitative benefits from a therapeutic perspective. As Rolvsjord (2004) points out: "Therapeutic effort [...] involves recognition and acknowledgement of resources and potentials as well as development and learning of skills and competences which will promote self-determination and participation" ("A Resource-Oriented Approach", para. 5). Hence, the concept of empowerment might be related to technology when the latter is used to facilitate a creative and resource-oriented therapy – one focused on the client's capabilities and potential. Thus, the concept of Creative Empowerment is based on the feeling of control and self-expression that the client experiences with DMI technology. In this sense, and insofar as it emphasizes the process of gaining control over the interactive tool, it shares common points with notions like aesthetic resonation (Ellis, 2004; Brooks, 2004). In fact, musical technology-based empowerment results from a feeling of control and self-

determination in the client, gained through the exercise of creative expression: a process which is in turn made possible with the help of a therapist taking part in the music therapy sessions.

In this article, we have reported examples of interactive technologies that could be used, ideally by at least two users at the same time: the music therapist and the client. Various forms of interactive technologies might be considered in order to develop the right instrument for each client. Since one of the main concerns of a therapist is the retrieval and analysis of their clients' performance data, we suggest the use and implementation of interactive technologies in music therapy settings.

Conclusion

Such technologies can provide the right parameters after each session, in line with the music therapist's aims, to help the professional analyse any improvements made. These parameters are part of the mapping strategies anticipated in the technology's design, and should be decided upon with the programmer beforehand. Alternatively, it should be possible to set in advance the parameters for each person, allowing the technology to be tailored to the type of disability experienced by the client. However, we have cautioned that music technology implemented in therapeutic contexts shows clear limitations that must be considered carefully. The limitations mainly concern issues related to the operating technology, necessitating a good understanding of the technological tool being used, and of the interactions that can be generated during the sessions, which may pose training requirements for the therapist. Additionally, the music therapist should keep in mind that the empowerment process does not necessarily occur inherently from the implementation of music technology. In discussions about gender and technology, authors like Magee and Wimberly (2014) warn about the risk of clients sensing inequality as a result of the different relationships and interactions that occur between men and women regarding music technology in the therapeutic setting (2014).

Nonetheless, though the use of low-cost technology for interactive reality media is still relatively scarce, the potential benefits of this kind of technology, for both the client and the professional, are numerous. Summarily, such benefits may include:

(a) A multimodal environment that can stimulate sensory modalities fundamental in the treatment of ASD, among other conditions (Berger, 2002).
(b) A safe environment, from both a psychological and physical perspective (Partesotti, 2016).
(c) A customized programme tailored to the requirements of each client and agreed upon beforehand with the professional (Partesotti, 2016; Peñalba, 2015).
(d) Creation of expressive musical material and the attainment of a level of self-consciousness through the use of Creative Empowerment. The latter is made possible while the client receives feedback (i.e. audio and video) from the technology and interacts with it, thus exploring new Sensorimotor Maps in order to creatively express him/herself and ultimately gain awareness of personal emotions (Partesotti, 2016).

(e) Creation and exploration of Multiple Trajectories through Sensorimotor Maps that allow the user to reach a high level of Creative Empowerment (Partesotti, 2016). This use of Sensorimotor Maps facilitates the client's motor training and rehabilitation.
(f) The availability of a tool which enables the client to easily communicate with the therapist and the group, so that the therapeutic bond is strengthened at an earlier stage (Partesotti, 2016).
(g) Sensory integration for cognitive and emotional expression (Berger, 2002).

The presence of music technology in our daily life urges us to reconsider the relationship between the client and the music therapist (Nagler, 2014). This relationship relies on the different ways of experiencing the therapeutic process through DMI-based interactive systems at a phenomenological level, and it also generates an aesthetic discourse regarding the ways in which the use of technology is conceived and safely implemented in music therapy sessions. Since the introduction of DMIs is still a recent development in the field of music therapy, more research should be carried out on this topic. This article argues that DMIs could represent an effective tool in the practice of music therapy, both for the client and for the music therapist.

The examples described in this article demonstrate the potential benefits of DMIs, and support a need for further research into, and design of, multimodal, empowering technologies, in addition to opening up an interdisciplinary dialogue that is bound to ultimately benefit clients of music therapy. Such a dialogue underscores the importance of the music therapist's appropriate training in music technology, at both a theoretical and a practical level, as well as their awareness of the limitations and advantages involved in such a technology. Furthermore, it should engage the participation of musicians, sound designers, media artists and engineers in the design of a more pleasant, portable, affordable and storable technology (Bevilacqua et al., 2016; Magee, 2014b; Miranda et al., 2011). This is the kind of open conversation between music therapy and technology that is urgently needed in order to optimise the music therapist's performance and enhance the client's self-expression.

Conflict of interests

No potential conflict of interest was reported by the authors.

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