**Chapter 83**

**Music Therapy and Other Music-Based Interventions**

**Laura Fusar-Poli1,**

**Grace Thompson2,**

**Miriam D. Lense3,**

**And**

**Christian Gold4**

1Department of Clinical and Experimental Medicine, Section of Psychiatry, University of Catania, Catania, Italy

2Melbourne Conservatorium of Music, The University of Melbourne, Melbourne, Australia

3Department of Otolaryngology – Head and Neck Surgery, Vanderbilt University Medical Center, Nashville, TN, USA; Vanderbilt Kennedy Center, Nashville, TN, USA

4Department of Psychology, University of Vienna, Vienna, Austria; GAMUT - The Grieg Academy Music Therapy Research Centre, NORCE Norwegian Research Centre AS, Bergen, Norway

**Corresponding author:** Dr. Laura Fusar-Poli, Department of Clinical and Experimental Medicine, Section of Psychiatry, University of Catania, Via Santa Sofia 78, 95123 Catania, Italy. E-mail: laura.fusarpoli@gmail.com

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**Abstract**

The interest in music and musical abilities of autistic children have been observed since the earliest descriptions of the condition. Music is a universal language known for millennia and music-based interventions including music therapy have found several applications in the fields of developmental psychology and mental health over the last decades. This group of complementary therapies aims to help the clients to optimize their health, using various facets of musical experience and the relationships formed through them. Several psychological theories and neurobiological models may explain the specific mechanisms through which music-based interventions work for autistic individuals. The present chapter aims to describe the sensorimotor, attentional, emotional, and social processes underpinning the potential effectiveness of music therapy in this population and to provide an overview of the most recent literature findings. At the end of the chapter, an account of the autistic giftedness and talent for music is presented.

 *Key words:* music; social interaction; emotion; entrainment; sensorimotor integration; musical talent.

**83.1 Historical Perspectives**

The earliest case descriptions of autistic children by pioneers such as Kanner (1943) included descriptions of the children’s responses to music, their interest in music, and even their musical abilities. Some children were observed to hum or sing well-known songs and tunes, and at times they would socially engage with others who shared their particular interest in music; however, at other times music seemed to fully absorb the children’s attention which made social engagement more challenging. Soon after these initial observations, researchers began to explore autistic children’s reaction to music (Sherwin, 1953, p. 831) as a potentially useful diagnostic tool, while also pointing to possible therapeutic applications.

Meanwhile, the general therapeutic benefit of music listening and participation was becoming widely recognized by medical specialists. Following the success of using music therapeutically to treat World War II veterans with mental illness, music therapy quickly developed as a professional discipline and the first training program commenced in the United States in 1944 (Davis, Gfeller, & Thaut, 2008). Soon after, music therapy training and professional associations formed in Europe, Australia, Asia, and Scandinavia. By the 1950’s, music therapists were publishing case descriptions of their work with autistic children, often described at the time as adapted music education, where rhythm activities, dancing and singing were used to support children to achieve communication and social goals (Reschke-Hernandez, 2011).

**83.2Music Therapy and Music Practitioners**

Qualified music therapists are trained and practice in a wide range of diverse cultural contexts. Nonetheless, there is a common, broad definition for music therapy stating that the music therapy “helps the client to optimize the client’s health, using various facets of music experience and the relationships formed through them as the impetus for change” (Bruscia, 2014, p. 36). The World Federation of Music Therapy is the international umbrella organization for the profession, with members including qualified individuals and national associations from eight regions in the world (World Federation of Music Therapy, 2017). Bachelor and Master’s level degree courses in music therapy typically lead to accreditation with professional associations which govern and define practice standards, competencies, and codes of ethics for their members (Kern & Tague, 2017).

While music therapists work with a wide range of clinical populations, workforce surveys show that autistic people form a significant percentage of the typical caseload (Jack et al., 2016; Kern & Tague, 2017). The majority of autistic clients receiving music therapy services are preschool and school aged children (Kern & Tague, 2017). Qualified music therapists are one of a variety of music practitioners who work with autistic people, such as music teachers, community choir leaders and band directors. Whereas music therapists have specialized training in tailoring their methods and techniques to meet individual therapeutic goals, other music practitioners can also facilitate music experiences that may have therapeutic value in the context of education and community music making.

**83.3 Theoretical Accounts**

Music therapists draw upon a wide variety of theoretical frameworks to inform their practice (Wheeler, 2015). Some professionals also combine music therapy methods with practice models and approaches from related disciplines, including the Social Communication Emotional Regulation Transactional Supports Model (Walworth, Register, & Engel, 2009), family-centered practice (Thompson, McFerran, & Gold, 2013), Social Stories (Brownell, 2002), Developmental, Individual Difference, Relationship-Based Floortime (Carpente, 2017), and Applied Behaviour Analysis Verbal Behaviour (Lim & Draper, 2011) approaches.

Music therapists and other practitioners typically base their practice on the understanding that music experiences offer a form of communication and interpersonal connection that does not rely on conventional methods of expressive language and social gestures. For example, musicians who play together and perform for audiences often describe the experience of music making as acting “like gravity, pulling the players into relationship” (Ansdell, 1995, p. 74). Musical interactions and activities are therefore expected to offer a context where diverse forms of expression and communication is possible between participants.

The theory of communicative musicality (Malloch, 2000) provides a foundational understanding of this lived phenomenon for music practitioners. This theory, grounded in video microanalysis of parent-infant interactions, describes how human beings’ earliest forms of shared attention and meaningful social exchanges rely on fundamental musical elements such as pitch, timbre, pulse and form. Further, Stern’s developmental theory proposes that infants and children develop best when they are cared for by a responsive adult who is emotionally attuned to their mood and needs (Stern, 1977; Stern 1985). Stern often highlighted the musical elements at the heart of attuned and responsive non-verbal social communication exchanges between parents and infants. He described how, in most parent-child interactions, the adult creates phrases, rhythms, undulating melodies and repeated forms with their movement and voice (Stern, 2010). Children’s cognition and communication are therefore believed to flourish within the context of early, spontaneous, plentiful and attuned affective interactions with their caregiver.

When parenting autistic children, the caregiver’s ability to accurately read the mood or needs of their child may be impacted, and therefore the rhythms of interaction may be disrupted (Ammaniti & Ferrari, 2013). These disruptions to the natural flow of social communication may limit the developmental opportunities ordinarily available to the child, and therefore non-verbal affective interactions may be relied upon for a longer period of time. Music therapists draw on these developmental theories as a rationale for providing enhanced opportunities for affective interactions via music experiences (Holck, 2004; Kim, Wigram, & Gold, 2009; Mössler et al., 2019; Thompson, 2017). The music therapist aims to motivate and support the autistic person to actively participate in social musical play as a way of supporting wider developmental benefits, while also supporting caregivers to musically and emotional attune to the child.

**83.4 Why Music-Based Interventions May Work For Autistic People**

Music perception and production experiences comprise a network of brain areas involving sensory, motor, attentional, emotional, and social processes (Patel, 2011; Wan & Schlaug, 2010). Music-based interventions for autistic individuals are frequently targeted to these processes that in turn support social communication (Janzen & Thaut, 2018; Sharda et al., 2018; Trevarthen, 2002; Wan et al., 2011). In particular, music’s involvement of predictability, reinforcement/reward, emotion regulation, and shared attention, may support social interaction processes (Lense & Camarata, 2020). It has been hypothesized that music therapy and music-based interventions may in part enable transfer between musical and non-musical skills due to shared neural resources involved in these tasks (Hardy & Lagasse, 2013; Janzen & Thaut, 2018; Wan & Schlaug, 2010). Researchers have begun to directly investigate neural and physiological mechanisms potentially underlying the connections with music in this population.

**83.4.1 Sensorimotor Integration Processes**

One potential avenue in music therapy is supporting sensorimotor integration in autistic individuals (Janzen & Thaut, 2018; Sharda et al., 2018). Both literature and self-accounts of autistic people reported that sensorimotor integration appears to be disrupted (De Jaegher, 2013; Donnellan, Hill, & Leary, 2012; Robledo, Donnellan, & Strandt-Conroy, 2012). Atypical sensory and motor processes may directly contribute to and/or reflect broader challenges in social interaction (Mössler et al., 2019; Thye, Bednarz, Herringshaw, Sartin, & Kana, 2018).

Musical rhythm and time perception involve a network of brain areas important for movement processes including basal ganglia, cerebellum, premotor cortex and supplementary motor area, parietal cortex, and prefrontal cortex (Grahn, 2012). These neural networks have been proposed to provide the substrate for music-based interventions potentially impacting altered brain connectivity in autistic individuals (Hardy & Lagasse, 2013; Janzen & Thaut, 2018). Functional neuroimaging studies involving autistic individuals reveal an overconnectivity between sensory networks, which relates to the sensory processing abnormalities and multisensory integration deficits (Chen et al., 2020). Conversely, the connectivity of frontotemporal and cortical-subcortical networks appears reduced (Hahamy, Behrmann, & Malach, 2015; Keown et al., 2013; Rudie & Dapretto, 2013).

Investigations of rhythmic sensorimotor behaviors in autistic individuals, particularly during social tasks, demonstrate why such behaviors may be an important target during music-based interventions. Compared to neurotypical subjects, autistic individuals show lower synchronization to others during rhythmic interaction activities (e.g., swinging a pendulum [Fitzpatrick et al., 2016]; rocking in rocking chair [Marsh et al., 2013]; rhythmic tapping of body movements, and interpersonal rhythmic clapping or drumming games [(Fitzpatrick et al., 2017a; Fitzpatrick et al., 2017b Kaur, Srinivasan, & Bhat, 2018)]. As previously mentioned, these reductions in synchronization may relate to individuals’ social skills, though the specific pattern of behavioral associations slightly differs across studies perhaps due to heterogeneity in synchronization task demands and type of social skills assessed (Fitzpatrick et al., 2017a; Fitzpatrick et al., 2017b; Kaur et al., 2018).

Recently, Mössler, Schmid, Assmus, Fusar-Poli, and Gold (2020) suggested that symptoms related to restrictive and repetitive behaviors, including sensory abnormalities and motor issues, should be addressed to a greater extent by music therapists. Music therapy – particularly improvisational music therapy -- offers unique potentials for addressing bodily expressions related to these symptom clusters. The expressive features of music (i.e., tempo, dynamics, timbre, and pitch) correspond with the dynamic forms of bodily-emotional expressions during the interaction between the client and the therapist. This notion is supported by the improvement of core symptoms after a combined dance/movement and music therapy intervention in autistic adults with severe impairments (Mateos-Moreno & Atencia-Dona, 2013). Music interventions targeting sensorimotor impairments may facilitate so-called “emotional attunement”, which is hypothesized to increase opportunities for the child to improve self-awareness, to experience shared attention, and to enhance social communication (Geretsegger et al., 2015; Mössler et al., 2019; Schumacher, Calvet, Reimer, Salmon, & Litwin, 2019).

**83.4.1Attentional Processes and Rhythmic Entrainment**

Autistic individuals exhibit a variety of attentional disruptions, including difficulties in attentional attainment, disengagement, restricted attention, and particularly joint attention, which is directly related to social development (Jones, Venema, Earl, Lowy, & Webb, 2017; Mansour, Dovi, Lane, Loveland, & Pearson, 2017). Hence, supporting attentional processes through rhythmic entrainment may be an important aim.

Music-based interventions use rhythm to prime attentional and motor processes through neural entrainment (Hardy & Lagasse, 2013; Janzen & Thaut, 2018; Thaut, McIntosh, & Hoemberg, 2015). The Dynamic Attending Theory proposes that attentional entrainment to predictable rhythmic stimuli may enable individuals to develop expectancies for when events will occur (Large & Jones, 1999). Entrainment occurs cross-modally, facilitates stimuli processing, and response production at expected times, and is modulated by attention to the task and experience (Bolger, Coull, & Schön, 2014; Escoffier, Herrmann, & Schirmer, 2015; Iversen, Repp, & Patel, 2009). A variety of studies in neurotypical individuals has revealed that regular auditory rhythmic cues facilitate detection of visual events (Bolger et al., 2014; Escoffier et al., 2015; Miller, Carlson, & McAuley, 2013), linguistic events (e.g. syllable detection [Cason, Hidalgo, Isoard, Roman, & Schön, 2015; Cason & Schön, 2012], grammaticality judgments [Chern, Tillmann, Vaughan, & Gordon, 2018]), auditory events (e.g., durational changes [McAuley & Fromboluti, 2014]), and motor responses (Bolger et al., 2014). A few studies indicate age-appropriate musical rhythm perception (e.g., Jamey et al., 2019) and production skills (Tryfon et al., 2017) in autistic individuals though other studies observe poorer or more variable rhythmic synchronization skills to an external stimulus (e.g., drum/metronome; [Franich et al., 2020; Kaur et al., 2018]). Rhythmic sung stimuli elicit more typical frontotemporal connectivity versus spoken speech in autistic children (Lai, Pantazatos, Schneider, & Hirsch, 2012; Sharda, Midha, Malik, Mukerji, & Singh, 2015). These studies support a potential role of music-based intervention in impacting neural processes related to attentional deficits in autistic individuals.

**83.4.3 Emotional processes**

An additional focus on music processing in autistic individuals is the neural, physiological and psychoneuroendocrinological correlates of emotional responses to music. Although autistic individuals show impairments in the ability to understand emotions in non-musical social communication (American Psychiatric Association, 2013), studies indicate typical recognition of emotions expressed in music in both children and adults (Allen, Davis, & Hill, 2013; Heaton, Hermelin, & Pring, 1999; Quintin, Bhatara, Poissant, Fombonne, & Levitin, 2011; Stephenson, Quintin, & South, 2016).

Autistic individuals report to use music for regulating arousal levels (Allen et al., 2009) and studies indicate typical recognition of emotions expressed in music in autistic children and adults (Allen et al., 2013; Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016). Studies of physiological responses to emotional music are mixed, however, and suggest there may be a delayed or altered developmental trajectory. Autistic children and adolescents had lower arousal levels than an age-matched neurotypical sample as measured via galvanic skin response in response to emotional instrumental music (Stephenson et al., 2016), while both autistic and neurotypical adults exhibited similar arousal levels (Allen et al., 2013).

Music impacts activity in brain regions that are involved in the initiation, generation, maintenance, termination, and modulation of emotions (Koelsch, 2009). Neural responses to happy or sad music appear to be broadly similar in both autistic and neurotypical adults revealing activation of regions involved in processing temporal, rhythmic, and pitch information (e.g., superior temporal gyrus, supplementary motor area, cerebellum [Caria, Venuti, & de Falco, 2011]) and processing emotion and reward (e.g., ventral striatum [Gebauer, Skewes, Westphael, Heaton, & Vuust, 2014]; caudate nucleus [Caria et al., 2011]). Findings of activity in the insula in response to emotional music in autistic individuals is mixed with both hypoactivation (Caria et al., 2011) and hyperactivation (Gebauer et al., 2014) reported, potentially reflecting arousal levels and cognitive processing demands in evaluating the emotional quality of the music. Activation of reward processing systems during emotional music engagement may provide an additional mechanism for music interventions and may intersect with sensorimotor connectivity as synchronized movement to music is associated with increased activity in these areas (e.g. caudate [Kokal, Engel, Kirschner, & Keysers, 2011; Trost et al., 2014]).

Future investigations could specifically examine the role of amygdalar and hippocampal functioning in response to music in autistic individuals. Studies in typically developed individuals highlight hippocampal and amygdalar activation in response to emotional music (Koelsch et al., 2013; Koelsch, 2014; Gosselin et al., 2007), which has also been reported in autistic individuals (Caria et al., 2011). Studies are inconsistent with regard to volume and activity in limbic system areas (e.g., amygdala, hippocampus) in autistic individuals compared to neurotypical controls (Aylward et al., 1999; Groen et al., 2010; Haar, Berman, Behrmann, & Dinstein, 2016; Kim et al., 2010; Munson et al., 2006; Murphy, Foss-Feig, Kenworthy, Gaillard, & Vaidya, 2012; Nicolson et al., 2006; Nordahl et al., 2012; Schumann & Amaral, 2006; Sparks et al., 2002; Eilam-Stock, Wu, Spagna, Egan, & Fan, 2016).

**83.4.4Social Processes**

Music-based interventions thus present several mechanisms through which they may foster social interaction. Music is also able to directly promote social processes. Moreover, social processes inherently involve interactions between two or more individuals. Koelsch (2014) identified seven social functions involved in musical activities, which can be memorized as “seven Cs”: social *c*ontact, social *c*ognition, *c*o-pathy (i.e., the social function of empathy), *c*ommunication, *c*oordination of actions, *c*ooperation, and social *c*ohesion of a group (Koelsch, 2014). Considering these core components and functions of music alongside the impairments encountered by autistic people in all these areas provides rationale for investigating music-based activities in this population.

Indeed, a growing body of work investigates how musical activities may impact the behavior of interaction partners such as parents or peers during play with autistic children (Boorom et al., 2020; Hernandez-Ruiz, 2020; Lense et al., 2020; Lense & Camarata, 2020; Thompson, Shananan, & Gordon, 2019). For example, musical activities naturally increase parents’ physical responsiveness of their child’s play (e.g. mirroring, imitation), which is important for supporting children’s social development (Boorom et al., 2020). Thus, music may support social interaction by impacting neural and behavioral processes of both partners in the interaction (Lense & Camarata, 2020).

Another potential avenue for future research into music and social processes in ASD may consider the role of oxytocin, a neuropeptide important for social behaviour and cognition (Bartz, Zaki, Bolger, & Ochsner, 2011) and which may be implicated in ASD (Vanya, Szucs, Vetro & Bartfai., 2017; Guastella et al., 2016). Oxytocin is modulated by group music activities such as group singing (Grape et al., 2003; Keeler et al., 2015). Oxytocin also interacts with reward processing mechanisms that are involved in musical engagement; these systems may contribute to connections between music, social motivation/reward, and social bonding (Savage et al., 2020).

Despite the huge efforts made during the last years, the research into the biological mechanisms underlying music perception and production in autistic individuals is still at an early stage. Future studies will need to investigate the relationships between neural, physiological, and psychoneuroendocrinological processes with specific music therapy programs and treatment targets in order to identify intervention mechanisms.

**83.5 Therapeutic Goals and Research Findings**

A workforce survey from the United States found that the most typical goals in music therapy with autistic clients centered around communication, social, and emotional domains, while a focus on academic and motor skill development were less common (Kern, Rivera, Chandler, & Humpal, 2013). With the emphasis on working with children and young people, it is clear that many music therapists generally aim to maximize developmental outcomes. The training and theoretical stance of the therapist, however, will impact the way in which they support the individual to achieve their goals. For example, music therapists trained in behavioral approaches may focus more on functional skills such as turn-taking, choice making (LaGasse, 2014) and goals related to verbal behavior (Lim & Draper, 2011). Alternatively, music therapists influenced by relational or social pragmatic approaches tend to focus more on social communication capacities (Carpente, 2017). Regardless of the music therapist’s theoretical influences, goals and objectives are typically specific, individualized and evaluated to keep track of progress.

While music therapists are person-centered in their approach to practice, there are common referral themes and aims identified in the literature. The latest Cochrane review of music therapy for ASD included 10 studies with 165 participants (Geretsegger, Elefant, Moessler, & Gold, 2014). Music therapy was superior to standard care with respect to several outcomes, particularly social interaction, non-verbal and communicative skills, initiating behavior, and social‐emotional reciprocity. Promising findings were reported also for social adaptation, joy, and quality of parent‐child relationships. Importantly, none of the included studies reported any adverse effects, however, methodological issues (e.g., small sample size, incomplete reporting of study methods, short study durations, varied outcome measures) limited the confidence in their findings (Geretsegger et al., 2014).

In July 2020 we searched CENTRAL, Ovid MEDLINE, EMBASE, LILACS, PsycINFO, CINAHL, ERIC, ASSIA, Sociological Abstracts, and Dissertation Abstracts International databases and selected all randomized controlled trials (RCTs) and controlled clinical trials (CCT), written in English and published on peer-reviewed journals without time restrictions, evaluating the effects of music therapy (i.e. music-based intervention delivered by a professional therapist) in autistic individuals. Dissertations, master and doctoral theses, andarticles written in languages other than English, were excluded from the present selection.

Study characteristics and results are summarized in Table 83.1. We identified 17 papers, with the number of participants per paper ranging between 4 and 364. It is thus evident that a large number of clinical trials have been published over the few last years. Several studies have reported significant improvements in communication and/or social interaction, which appeared the most investigated domains. Of note, the Trial of Improvisational Music Therapy for Children with Autism Spectrum Disorder (TIME-A) study, an international multicenter RCT (Bieleninik et al., 2017; Crawford et al., 2017) was the trial with the highest quality and the most rigorous methodology. Findings of this rigorously reported trial on the primary outcome were negative: Autistic children did not significantly improve in the primary outcome (the Autism Diagnostic Observation Schedule (ADOS) – Social affect domain) after 5 months of improvisational music therapy, as compared to enhanced standard care. Yet, exploratory outcomes of response rates and quality of life suggested beneficial effects of music therapy (Table 83.1). It is worth mentioning that ADOS is a diagnostic tool and is not intended to measure subtle improvements or behavioral changes (Provenzani et al., 2020), which may be subjectively perceived by clients and their families (Blauth, 2017; Gold & Bieleninik, 2018; Thompson & McFerran, 2015; Thompson et al., 2019; Turry, 2018). This highlights the need for appropriate outcome measures sensitive to change in music intervention studies (McConachie et al., 2018; Mössler et al., 2020).

One of the few studies to investigate neural changes in response to music therapy focused on school-aged autistic children who participated in 8-12 weeks of improvisational music therapy or a non-music control intervention (Sharda et al., 2018). Resting-state functional connectivity (RSFC) was assessed before and after the intervention. Compared to the non-music intervention, music therapy was associated with greater RSFC post-intervention between auditory and striatal and motor regions, and reduced RSFC between auditory and visual regions. Moreover, RSFC post-intervention was related to children’s communication skills on a parent-reported questionnaire (Sharda et al., 2018). These findings further support the notion that music therapy may directly interact with the neural networks (e.g., sensorimotor) which appear typically altered in autistic people.

While a full meta-analysis is needed, preliminary observations of these studies indicate that music therapy research has progressed over the last few years. For instance, the duration of interventions was significantly extended. While the oldest trials were based only on few music therapy sessions (e.g., Brownell, 2002 – 5 days; Buday, 1995 – two weeks), the latest studies had a duration of several weeks or months (e.g., Bharathi et al., 2019 – three months; Bieleninik et al., 2017 - 5 months; Porter et al., 2017 - 12 weeks; Rabeyron et al., 2020 - 25 weeks; Sharda et al. 2018 – 8 to 12 weeks). Additionally, more recent studies generally adopt stronger methodology, such as adequate randomization, allocation concealment, and blinding of outcome assessors.

Outcomes measures were mainly related to the severity of core symptoms, specifically communication and social interaction. Restricted and repetitive behaviors as well as other outcomes, such as quality of life, self-esteem, psychiatric comorbidities, adaptive and maladaptive behaviors were investigated only by few or single studies. Scientists, stakeholders, and autistic individuals have suggested that trials for autistic people should not be directed only to core symptoms, but also consider other meaningful outcomes, such as well-being, quality of life, and adaptive functioning (Provenzani et al., 2020; Silberman, 2017). Thus, it would be desirable that music therapists would also shift their attention to a multiplicity of goals while developing future trials and include autistic individuals as co-researchers (Locock & Boaz, 2019).

**Table 83.1.** Characteristics of randomized clinical trials (RCT) and controlled clinical trials (CCT) evaluating the effect of music therapy with autistic people.

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| Reference | Country  | Participants | Music therapy intervention(s) | Control intervention | Outcomes (measures) | Results |
| Bharathi, Venugopal, & Vellingiri, 2019 | India | *N* = 52Age: range 6 to 12 years (mean 9.5)Sex: 26 M, 26 F | Three 35-minute active group MT sessions each week for 3 months (Orff method: singing, dancing, playing musical instruments while listening to music), *N* = 26 | Three 35-minute passive group MT sessions each week for 3 months (no interaction, only music listening),*N* = 26 | Core symptoms (CARS, TSSA) | MT superior to control in social communication. |
| Bieleninik et al., 2017; Crawford et al., 2017 | Multicenter (Australia, Austria, Brazil, Israel, Italy, Norway, Korea, UK, USA) | N = 364Age: range 4 to 6.11 yearsSex: 302 M, 62 F | * 30-minute individual improvisational music therapy sessions for 5 months, 3 sessions per week, *N* = 90
* 30-minute individual improvisational music therapy sessions for 5 months, 1 session per week, *N* = 92
 | Enhanced standard care, *N* = 182 | * Core symptoms (ADOS, SRS)
* Quality of life (QoL-child, QoL-family)
* Adverse events (parent reports)
 | Primary outcome: No significant difference in symptom severity based on the ADOS social affect domain. Exploratory outcomes: Benefits of MT on response rates; benefits of high-dose MT (3x/week) on quality of life. No adverse events reported. |
| Brownell, 2002 | USA | *N* = 4Age: range 6 to 9 yearsSex: 4 M, 0 F | Structured receptive MT (songs with social stories), 5 individual daily sessions, *N* = 4 | * Structured receptive “story therapy” (reading of social stories), 5 individual daily sessions, *N* = 4
* No intervention, 5 days, *N* = 4
 | Repetitive behaviors in classroom | Reading and singing condition more effective than no intervention. Singing condition more effective than reading only in one case. |
| Buday, 1995 | USA | *N* = 10Age: range 4 to 9 yearsSex: 8 M, 2 F | Structured receptive MT (songs used to teach signs), 5 individual sessions, *N* = 10 | Rhythm therapy (rhythmic speech used to teach signs), 5 individual sessions, *N* = 10 | Sign and speech imitation in sessions (rating of a video recording) | Significant main effects for condition type (music vs. rhythm) for both the number of imitated signed and spoken words. In each case, correct imitation favored music condition training over rhythm condition training. |
| Gattino, et al., 2011 | Brazil | *N* = 24Age: range 7 to 12 years (mean 9.75 years)Sex: 24 M, 0 F | Relational music therapy (improvisation not using a structured protocol; 3 assessment sessions, 16 intervention sessions, 1 final assessment session) in addition to standard treatment, 20 thirty-minute sessions, scheduled weekly, *N* = 12 | Standard treatment (clinical routine activities including medical examinations and consultations), *N* = 12 | Core symptoms (CARS)  | No difference between treatment and control. Significant improvement in ASD only in nonverbalcommunication.  |
| Ghasemtabar et al., 2015 | Iran | *N* = 27Age: range 7 to 12 years (mean 9.1)Sex: 14 M, 13 F | MT Orff-Schulwerk 12 sessions (two sessions of 1h/week) in 45 days, delivered by two music therapists | Control group (without intervention) | Core symptoms (SSRS-P)  | Significant increase in social skills’ scores of the MT group. |
| Kim, et al., 2008, 2009 | Republic of Korea | *N* = 15 at entry; N = 10 for analysisAge: range 39 to 71 months (mean 51 months)Sex: 13 M, 2 F | Improvisational music therapy, 12 thirty-minute sessions, scheduled weekly, *N* = 10 | Play sessions with toys, 12 thirty-minute sessions, scheduled weekly, *N* = 10 | Core symptoms/Problem behaviors (PDDBI, ESCS, observation of registered tapes) | Improvisational MT was more effective at facilitating joint attention behaviors and non-verbal social communication skills in children than play. Significantly more and lengthier events of eye contact and turn-taking in improvisational music therapy than play sessions. |
| LaGasse, 2014 | USA | *N* = 17Age: range 6 to 9 years (mean 7.58)Sex: 13 M, 4 F | Music therapy group, twice a week for 50 mins, over 5 weeks, *N* =9; small groups (3-4 children/group) led by board-certified music therapist (the Transformational Design Model) | Social skills group, twice a week for 50 mins, over 5 weeks, *N* =8 | Core symptoms (SRS, ATEC, behavioral observations) | Significant differences for joint attention with peers and eye gaze towards persons. No significant differences for initiation of communication, response to communication, or social withdrawal behaviors. Significant interaction between time and group for SRS scores, with improvements for the MT but not the SSG. Scores on the ATEC did not differ over time between the MTG and SSG |
| Lim, 2010 | USA | *N* = 50Age: range 3 to 5 years (mean 4.8 years)Sex: 44 M, 6 F | Music training (“Developmental Speech and Language Training through Music”; videotaped songs with target words), 6 individual sessions within 3 days, *N* = 18 | * Speech training (videotaped spoken stories with target words), 6 individual sessions within 3 days, *N* = 183.
* No training, *N* = 14
 | Core symptoms (behavioral observation of verbal production) | Participants in both music and speech training showed improvements in verbal production. Low functioning ASD showed greater improvement after the music training.  |
| Lim & Draper, 2011 | USA | N = 22Age: range 3 to 5 years (mean 4.3 years)Sex: 17 M, 5 F | Music training ('music incorporated ABA VB'; sung instructions, songs with target words), 6 individual sessions within 2 weeks, n = 22 | - Speech training (ABA VB; spoken instructions, sentences with target words), 6 individual sessions within 2 weeks, n = 22- No training, n = 22 | Core symptoms (observation of verbal behavior) | Both music and speech trainings were effective for verbal production, with no significant differences between the two interventions. Music training better for echoic production, speech better for tact production. |
| Mateos-Moreno & Atencia-Dona, 2013 | Spain | *N* = 16Age: mean = 25 yearsSex: 15 M, 1 F | Total of 36 approx. 60-minute group sessions of combined dance/movement and music therapy (two per week), *N* = 8 | TAU - no alternative therapies apart from regular activities, *N* = 8 | Core symptoms (ECA-R) | Significant improvement in the combined dance/MT group. |
| Porter et al., 2017\* | UK | N = 47Age: mean =12.6 yearsSex: 34 M, 13 F | Alvin model of ‘Free Improvisation’ (Bruscia, 1987). 12 individual weekly session of 30 minutes, n = 24 | TAU (psychiatric counselling and/or medication), n = 23 | * Core symptoms (SSIS)
* Problem behaviors (CBCL)
* Self-esteem (Rosenberg Self-Esteem Scale)
* Depression (CES-DC)
* Family functioning (FAD)
 | Significant improvement in socio communication difficulties, and reduction of problem behaviors. |
| Rabeyron et al., 2020 | France | N = 37Age: range 4 to 7 yearsSex: 31 M, 5 F | Music therapy, 25 weekly structured 30-minute sessions (5 min opening ritual of music listening, 20 min instrumental and vocal improvisation, 5 min closing ritual of music listening) performed by a music therapist and a co-therapist (nurse or educator), *N* = 19 | Music listening, 25 weekly 30-minute sessions performed by a nurse or educator, listening to playlist of commercial music including French and foreign songs, *N* = 17 | * Core symptoms (CARS)
* Clinical Global Impression (CGI)
* Problem behaviors (ABC)
 | CGI scores decreased more for participants in the MT than in the ML condition. This clinical improvement was associated with an improvement of autistic symptoms on lethargy and stereotypy ABC subscales.  |
| Schwartzberg & Silverman, 2013 | USA | *N* = 30 for analysis Age: range 9 to 21 years (mean 15.79)Sex: 29 M, 1 F | MT structured + music-based social story sessions for 50 min, 3 consecutive days.  | Social story sessions 3 consecutive days | * Core symptoms (ASSP)
* Cognition (CC)
 | No significant difference at ASSP. Main effects for time on the CC were significant. |
| Schwartzberg & Silverman, 2016 | USA | N = 29 for analysisAge: range 9 to 21 years (mean 15.57)Sex: 26 M, 3 F | Sing short stories (music-based social story session) - Procedure: During each day of the summer camp, 50-min music sessions to all campers attending the camp. | Read aloud short stories | Cognition (CC) | Mean CC scores increased after MT treatment each day and from day one to day three for both the control and experimental groups.  |
| Sharda et al., 2018 | Canada | *N* = 51Age: range 6 to 12 years (mean 10.25 years)Sex: 43 M, 8 F | 45-minute individual weekly MT sessions, 8–12 weeks, *N*  = 26 | Play-based non-musical intervention, *N*  = 25 | * Core symptoms (CCC-2, SRS-2, PPVT-4)
* Quality of life (Beach Family QoL)
* Adaptive behaviors (VABS)
* Neuroimaging (rsfMRI: intrinsic brain connectivity of fronto-temporal brain networks)
 | Communication scores higher in the music group post-intervention. Significant differences also in QoL. Associated post-intervention resting-state brain functional connectivity greater in music vs. non-music group between auditory and subcortical regions and auditory and fronto-motor regions. Post-intervention brain connectivity was lower between auditory and visual regions in the music compared to the non-music groups, known to be over-connected in autism. Post-intervention brain connectivity in the music group related to communication improvement. |
| Thompson, McFerran & Gold, 2013 | Australia | *N* = 23Age: range 3 to 6 years (mean 3.8 years)Sex: 19 M, 4 F | Home-based, family-centered music therapy (using songs, improvisation, structured music interactions), in addition to standard care, 16 sessions, scheduled weekly, *N* = 12 | Standard care, *N* = 11 | * Core symptoms (VSEEC, SRS-PS, MBCDI-W&G)
* Parent-child relationship (PCRI)
* Child engagement in MT sessions (MTDA)
 | Family-centered MT improved social interactions in the home and community and the parent–child relationship, but not language skills or general social responsiveness. |

**Legend:** *ABA VB:* Applied Behavior Analysis Verbal Behavior; *ABC:* Aberrant Behavior Checklist; *ADOS:* Autism Diagnostic Observational Schedule; *ASSP:* Autism Social Skills Profile; *CARS:* Childhood Autism Rating Scale; *CBCL:* Child Behavior Checklist; *CC:* Comprehension checks; *CCC:* Children's Communication Checklist; *CES-DC:* Center for Epidemiological Studies Depression Scale for Children; *CGI:* Clinical Global Impression; *ECA-R:* Revised clinical scale for the evaluation of autistic behavior; *ESCS:* Early Social Communication Scales; *F:* Female; *FAD:* Family Assessment Device; *M:* Male; *MBCDI-W&G:* The MacArthur-Bates Communicative Development Inventories, Words and Gestures; *ML:* music listening; *MT:* Music therapy; *MTDA:* The Music Therapy Diagnostic Assessment – Clinician observation measure; *PCRI:* Parent–Child Relationship Inventory; *PDDBI:* Pervasive Developmental Disorder Behavior Inventory; *PPVT:* Peabody Picture Vocabulary Test; *QoL:* Quality of life; *rsfMRI:* Resting-state functional Magnetic Resonance Imaging; *SRS:* Social Responsiveness Scale; *SRS-PS:* Social Responsiveness Scale – Preschool Version for 3-Year-Olds; *SSG:* Social skills group; *SSIS:* Social Skills Improvement System; *TAU:* treatment as usual; *TSSA:* TRIAD Social Skills Assessment; *UK:* United Kingdom; *USA:* United States of America; *VABS:* Vineland Adaptive Behavior Scales; *VSSEC*: Vineland Social-Emotional Early Child-hood Scales.

\*The study published by Porter et al. (2017) included participants with a wide range of psychiatric and neurodevelopmental disorders. In Table 83.1, only the data regarding autistic participants were reported.

**53.6 Musical Giftedness**Special talents are more common in autistic people than in other groups: Literature has suggested that one third of autistic adults show superior skills in one or more areas, such as memory, visuo-spatial abilities, calculation, drawing, and music (Happé, 2018). Leo Kanner himself described several examples of extraordinary musical memory. Indeed, six of his 11 clinical vignettes included descriptions of music-related behaviors that seemed extraordinary compared with the developmental level. Particularly remarkable was the case of a child who was able to discriminate between 18 symphonies and name their composers by 18 months (Kanner, 1943).

The link between ASD and high-performance skills may be explained by the theory of the weak central coherence: Normally the brain forms concepts that impart automatic judgment and confer intuition but tends to hide details from conscious awareness (Happé, 1999). This process results in seeing the whole more than the parts. Conversely, the autistic mind, being more concrete and appreciating the parts more than the whole, may access details that are not normally considered (Boso, D’Angelo, & Barale, 2013). In the organization of cerebral functioning, weak central coherence seems to represent a distinct cognitive style rather than a deficit (Happé, 1999; Happé & Frith, 2006).

The first study to identify superior performances on musical task in autistic people was carried out by Applebaum, Egel, Koegel, and Imhoff (1979). They observed that reproduction of atonal melodies (i.e. melodies which are apparently not based on traditional Western tonalities) was superior in the group of autistic participants compared with typically developing children who had higher levels of musical experience (Applebaum et al., 1979). Subsequently, Heaton, Hermelin, and Pring (1998) tested the hypothesis that absolute pitch, consistently observed in musical savants (Miller, 2014), could also be highly prevalent in autistic individuals. Motivated by Zatorre and Beckett's (1989) suggestion that absolute pitch might reflect the ability to retrieve an arbitrary association between a pitch and a verbal label, autistic children along with age and intelligence-matched peers were presented with music tones and animal pictures for paired learning. The findings from the study showed superior recall for the tone/animal pairings in autistic children (Heaton et al., 1998). It was also noted that retrieval scores correlated with scores on the block design test from the Wechsler Intelligence Scales, a test considered to be a marker for weak central coherence (Shah & Frith, 1993). It was therefore suggested that a local bias at the perceptual level was implicated in absolute pitch in autistic individuals (Happé, 1999).

While research into music cognition in ASD was originally motivated by an interest in musical savants, findings from studies testing children who do not meet criteria for savant skills suggest that some individuals possess considerable musical potential. Several cases are reported in literature. For instance, Heaton, Pring, and Hermelin (1999) described the case of Dominic, a musically untrained autistic adolescent, who had absolute pitch and performed at the ceiling on a battery of music analysis tasks. This boy had access to several musical instruments, but participating in structured music lessons proved highly challenging (Heaton et al., 1999). Brenton et al. (2008) presented the case of a 4-year-old autistic boy who was discovered to possess absolute pitch during music therapy sessions. He and his mother would play musical games in which he could identify and sing the tonal pitch without external reference notes; his mother, who was a professional violinist, could not (Brenton et al., 2008). Boso et al. (2013) described the exceptional talent of a 17-year-old congenitally blind and autistic pianist, whose musical transposition skills were definitely superior to his typically developed, sighted peers (Boso, et al., 2013).

Music therapy interventions may provide opportunities to develop these musical skills and to harness music strengths for non-musical goals, as well as provide insight into musical processing in autistic people.

**83.6 Conclusions**

Music-based interventions appear promising for autistic people, with growing theoretical and empirical rationale for their potential in combination with standard care. Moreover, a large amount of evidence has reported that the integration of music-based intervention with standard care appeared to be highly acceptable and clinically attractive. Even with several clinical trials published over the last years, research is still at the beginning of the journey. Further studies conducted with a rigorous methodology and adopting outcome measures as appropriate to their treatment targets (which may include areas of functioning beyond core ASD symptoms), should be implemented by researchers. Given the variability in types of music interventions, studies should carefully consider the proposed mechanisms of action of their intervention approach and design and measure intervention components accordingly. Functional neuroimaging, physiology, and psychoneuroendocrinology evaluations may represent a bond between music therapists and neuroscientists, to better explore the mechanisms underlying musical processing in autistic people.

Music-based interventions offer a distinct way “to create rich opportunities for creative expression that are respectful of the strengths, interests and personhood” of autistic individuals (Thompson, 2018, p. 50). Clinicians, music therapists, and researchers should start listening and decoding the autistic musical language.

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**References**

Allen, R., Davis, R., & Hill, E. (2013). The effects of autism and alexithymia on physiological and verbal responsiveness to music. *Journal of Autism and Developmental Disorders, 43*(2), 432-444.

Allen, R., Hill, E., & Heaton, P. (2009). The subjective experience of music in autism spectrum disorder. *Annals of the New York Academy of Sciences*, *1169*, 326–331.

American Psychiatric Association (2013). Diagnostic and statistical manual of mental disorders (5th ed.) (pp. 50 - 59). Arlington, VA: American Psychiatric Publisher.

Ammaniti, M., & Ferrari, P. (2013). Vitality affects in Daniel Stern's thinking—A psychological and neurobiological perspective. *Infant Mental Health Journal, 34*(5), 367-375.

Ansdell, G. (1995). *Music for life: Aspects of creative music therapy with adult clients* (Vol. 1). London, UK: Jessica Kingsley Publishers.

Applebaum, E., Egel, A. L., Koegel, R. L., & Imhoff, B. (1979). Measuring musical abilities of autistic children. *Journal of Autism and Developmental Disorders, 9*(3), 279-285.

Aylward, E. H., Minshew, N. J., Goldstein, G., Honeycutt, N. A., Augustine, A. M., Yates, K. O., . . . Pearlson, G. D. (1999). MRI volumes of amygdala and hippocampus in non-mentally retarded autistic adolescents and adults. *Neurology, 53*(9), 2145-2150.

Bartz, J. A., Zaki, J., Bolger, N., & Ochsner, K. N. (2011). Social effects of oxytocin in humans: context and person matter. *Trends in Cognitive Sciences, 15*(7), 301-309.

Bharathi, G., Venugopal, A., & Vellingiri, B. (2019). Music therapy as a therapeutic tool in improving the social skills of autistic children. *Egyptian Journal of Neurology Psychiatry and Neurosurgery, 55*(1), 44.

Bieleninik, L., Geretsegger, M., Mössler, K., Assmus, J., Thompson, G., Gattino, G., ... Time-A Study Team (2017). Effects of improvisational music therapy vs. enhanced standard care on symptom severity among children with Autism Spectrum Disorder: The TIME-A randomized clinical trial. *JAMA-Journal of the American Medical Association, 318*(6), 525-535.

Blauth, L. K. (2017) Improving mental health in families with autistic children: Benefits of using video feedback in parent counselling sessions offered alongside music therapy. *Health Psychology Reports, 5*(2), 138-150.

Bolger, D., Coull, J. T., & Schön, D. (2014). Metrical rhythm implicitly orients attention in time as indexed by improved target detection and left inferior parietal activation. *Journal of Cognitive Neuroscience, 26*(3), 593-605.

Boorom, O., Muñoz, V., Xin, R., Watson, M., & Lense, M. D. (2020). Parental responsiveness during musical and non-musical engagement in preschoolers with ASD. *Research in Autism Spectrum Disorders*, *78*, 101641.

Boso, M., D’Angelo, E., & Barale, F. (2013). Neurophysiological correlates of musical giftedness in autism spectrum disorders. *Music & Medicine, 5*(4), 223-227.

Boso, M., Forth, J., Bordin, A., Faggioli, R., D'Angelo, E., Politi, P., … Heaton, P. (2013). Transposition ability in a young musician with autism and blindness: Testing cognitive models of autism. *Psychomusicology: Music, Mind, and Brain, 23*(2), 109-116.

Brenton, J. N., Devries, S. P., Barton, C., Minnich, H., & Sokol, D. K. (2008). Absolute pitch in a four-year-old boy with autism. *Pediatric Neurology*, 39(2), 137-138.

Brownell, M. D. (2002). Musically adapted social stories to modify behaviors in students with autism: Four case studies. *Journal of Music Therapy, 39*(2), 117-144.

Bruscia, K. E. (1987). *Improvisational models of music therapy.* Springfield, IL: C.C. Thomas.

Bruscia, K. E. (2014). *Defining music therapy* (3rd ed.). University Park, IL: Barcelona Publishers.

Buday, E. M. (1995). The effects of signed and spoken words taught with music on sign and speech imitation by hildren with autism. *Journal of Music Therapy, 32*(3), 189-202.

Caria, A., Venuti, P., & de Falco, S. (2011). Functional and dysfunctional brain circuits underlying emotional processing of music in autism spectrum disorders. *Cerebral Cortex, 21*(12), 2838-2849.

Carpente, J. A. (2017). Investigating the effectiveness of a Developmental, Individual difference, Relationship-based (DIR) improvisational music therapy program on social communication for children with autism spectrum disorder. *Music Therapy Perspectives, 35*(2), 160-174.

Cason, N., Hidalgo, C., Isoard, F., Roman, S., & Schön, D. (2015). Rhythmic priming enhances speech production abilities: Evidence from prelingually deaf children. *Neuropsychology, 29*(1), 102.

Cason, N., & Schön, D. (2012). Rhythmic priming enhances the phonological processing of speech. *Neuropsychologia, 50*(11), 2652-2658.

Chen, B., Linke, A., Olson, L., Ibarra, C., Reynolds, S., Müller, R. A., … Fishman, I. (2020). Greater functional connectivity between sensory networks is related to symptom severity in toddlers with autism spectrum disorder. *Journal of Child Psychology and Psychiatry*. doi:10.1111/jcpp.13268

Chern, A., Tillmann, B., Vaughan, C., & Gordon, R. L. (2018). New evidence of a rhythmic priming effect that enhances grammaticality judgments in children. *Journal of Experimental Child Psychology, 173*, 371-379.

Crawford, M. J., Gold, C., Odell-Miller, H., Thana, L., Faber, S., Assmus, J., … TIME-A Study Team (2017). International multicentre randomised controlled trial of improvisational music therapy for children with autism spectrum disorder: TIME-A study. *Health Technology Assessment, 21*(59), 1-40.

Davis, W. B., Gfeller, K. E., & Thaut, M. H. (2008). *An introduction to music therapy: Theory and practice.* Silver Spring, MD: American Music Therapy Association.

De Jaegher, H. (2013). Embodiment and sense-making in autism. *Frontiers in Integrative Neuroscience, 7*, 15.

Donnellan, A. M., Hill, D. A., & Leary, M. R. (2012). Rethinking autism: Implications of sensory and movement differences for understanding and support. *Frontiers in Integrative Neuroscience, 6*, 124.

Eilam-Stock, T., Wu, T., Spagna, A., Egan, L. J., & Fan, J. (2016). Neuroanatomical alterations in high-functioning adults with autism spectrum disorder. *Frontiers in Neuroscience, 10*, 237.

Escoffier, N., Herrmann, C. S., & Schirmer, A. (2015). Auditory rhythms entrain visual processes in the human brain: Evidence from evoked oscillations and event-related potentials. *Neuroimage, 111*, 267-276.

Fitzpatrick, P., Frazier, J. A., Cochran, D. M., Mitchell, T., Coleman, C., & Schmidt, R. (2016). Impairments of social motor synchrony evident in autism spectrum disorder. *Frontiers in Psychology, 7*, 1323.

Fitzpatrick, P., Romero, V., Amaral, J. L., Duncan, A., Barnard, H., Richardson, M. J., & Schmidt, R. (2017a). Evaluating the importance of social motor synchronization and motor skill for understanding autism. *Autism Research, 10*(10), 1687-1699.

Fitzpatrick, P., Romero, V., Amaral, J. L., Duncan, A., Barnard, H., Richardson, M. J., & Schmidt, R. (2017b). Social motor synchronization: Insights for understanding social behavior in autism. *Journal of Autism and Developmental Disorders, 47*(7), 2092-2107.

Franich, K., Wong, H. Y., Alan, C. L., & To, C. K. (2020). Temporal coordination and prosodic structure in autism spectrum disorder: Timing across speech and non-speech motor domains. *Journal of Autism and Developmental Disorders*, 1-21. doi: 10.1007/s10803-020-04758-z

Gattino, G. S., Riesgo, R. d. S., Longo, D., Leite, J. C. L., & Faccini, L. S. (2011). Effects of relational music therapy on communication of children with autism: A randomized controlled study. *Nordic Journal of Music Therapy, 20*(2), 142-154.

Gebauer, L., Skewes, J., Westphael, G., Heaton, P., & Vuust, P. (2014). Intact brain processing of musical emotions in autism spectrum disorder, but more cognitive load and arousal in happy vs. sad music. *Frontiers in Neuroscience, 8*, 192.

Geretsegger, M., Elefant, C., Moessler, K. A., & Gold, C. (2014). Music therapy for people with autism spectrum disorder. *Cochrane Database of Systematic Reviews* (6). doi:10.1002/14651858.CD004381.pub3

Geretsegger, M., Holck, U., Carpente, J. A., Elefant, C., Kim, J., & Gold, C. (2015). Common characteristics of improvisational approaches in music therapy for children with autism spectrum disorder: Developing treatment guidelines. *Journal of Music Therapy, 52*(2), 258-281.

Ghasemtabar, S. N., Hosseini, M., Fayyaz, I., Arab, S., Naghashian, H., & Poudineh, Z. (2015). Music therapy: An effective approach in improving social skills of children with autism. *Advanced Biomedical Research, 4*(1), 157.

Gold, C., & Bieleninik, L. (2018). Response to effects of improvisational music therapy vs. enhanced standard care on symptom severity among children with autism spectrum disorder: The TIME-A randomized clinical trial Authors' response. *Nordic Journal of Music Therapy*, *27*(1), 90-92.

Gosselin, N., Peretz, I., Johnsen, E., & Adolphs, R. (2007). Amygdala damage impairs emotion recognition from music. *Neuropsychologia*, 45(2), 236-244.

Grahn, J. A. (2012). Neural mechanisms of rhythm perception: Current findings and future perspectives. *Topics in Cognitive Science, 4*(4), 585-606.

Grape, C., Sandgren, M., Hansson, L. O., Ericson, M., and Theorell, T. (2003). Does singing promote well-being? An empirical study of professional and amateur singers during a singing lesson. *Integrative Psychological & Behavioral Science*, 38, 65–74.

Groen, W., Teluij, M., Buitelaar, J., & Tendolkar, I. (2010). Amygdala and hippocampus enlargement during adolescence in autism. *Journal of the American Academy of Child & Adolescent* Psychiatry, 49(6), 552-560.

Guastella, A. J., & Hickie, I. B. (2016). Oxytocin treatment, circuitry, and autism: A critical review of the literature placing oxytocin into the autism context. *Biological Psychiatry*, 79(3), 234-242.

Haar, S., Berman, S., Behrmann, M., & Dinstein, I. (2016). Anatomical abnormalities in autism? *Cerebral Cortex, 26*(4), 1440-1452.

Hahamy, A., Behrmann, M., & Malach, R. (2015). The idiosyncratic brain: distortion of spontaneous connectivity patterns in autism spectrum disorder. *Nature Neuroscience, 18*(2), 302-309.

Happé, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3*(6), 216-222.

Happé, F. (2018). Why are savant skills and special talents associated with autism? *World Psychiatry, 17*(3), 280-281.

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36*(1), 5-25.

Hardy, M. W., & Lagasse, A. B. (2013). Rhythm, movement, and autism: Using rhythmic rehabilitation research as a model for autism. *Frontiers in Integrative Neuroscience, 7*, 19.

Heaton, P., Hermelin, B., & Pring, L. (1998). Autism and pitch processing: A precursor for savant musical ability? *Music Perception, 15*(3), 291-305.

Heaton, P., Hermelin, B., & Pring, L. (1999). Can children with autistic spectrum disorders perceive affect in music? An experimental investigation. *Psychological Medicine, 29*(6), 1405-1410.

Heaton, P., Pring, L., & Hermelin, B. (1999). A pseudo-savant: A case of exceptional musical splinter skills. *Neurocase, 5*(6), 503-509.

Hernandez-Ruiz, E. (2020). Feasibility of parent coaching of music interventions for children with autism spectrum disorder. *Music Therapy Perspectives*, *38*(2), 195-204.

Holck, U. (2004). Interaction themes in music therapy: Definition and delimitation. *Nordic Journal of Music Therapy, 13*(1), 3-19.

Iversen, J., Repp, B., & Patel, A. (2009). Top-down control of rhythm perception modulates early auditory responses. *Annals of the New York Academy of Sciences, 1169*(1), 58-73.

Jack, N., Thompson, G., Hogan, B., Tamplin, J., Eager, R., & Arns, B. (2016). My profession, my voice: Results of the Australian Music Therapy Association's 2016 workforce census. *Retrieved from the Australian Music Therapy Association website:* http://www*.austmta.org.au/brochure/a mta-workforce-census*.

Jamey, K., Foster, N. E. V., Sharda, M., Tuerk, C., Nadig, A., & Hyde, K. L. (2019). Evidence for intact melodic and rhythmic perception in children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 64, 1–12.

Janzen, T. B., & Thaut, M. H. (2018). Rethinking the role of music in the neurodevelopment of autism spectrum disorder. *Music & Science, 1*, 2059204318769639.

Jones, E. J., Venema, K., Earl, R. K., Lowy, R., & Webb, S. J. (2017). Infant social attention: An endophenotype of ASD‐related traits? *Journal of Child Psychology and Psychiatry, 58*(3), 270-281.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child, 2*(3), 217-250.

Kaur, M., Srinivasan, S. M., & Bhat, A. N. (2018). Comparing motor performance, praxis, coordination, and interpersonal synchrony between children with and without Autism Spectrum Disorder (ASD). *Research in Developmental Disabilities, 72*, 79-95.

Keeler, J. R., Roth, E. A., Neuser, B. L., Spitsbergen, J. M., Waters, D. J., and Vianney, J. M. (2015). The neurochemistry and social flow of singing: Bonding and oxytocin. *Frotniers in Human Neuroscience* 9, 518.

Keown, C. L., Shih, P., Nair, A., Peterson, N., Mulvey, M. E., & Müller, R.-A. (2013). Local functional overconnectivity in posterior brain regions is associated with symptom severity in autism spectrum disorders. *Cell Reports, 5*(3), 567-572.

Kern, P., Rivera, N. R., Chandler, A., & Humpal, M. (2013). Music therapy services for individuals with autism spectrum disorder: A survey of clinical practices and training needs. *Journal of Music Therapy, 50*(4), 274-303.

Kern, P., & Tague, D. B. (2017). Music therapy practice status and trends worldwide: An international survey study. *The Journal of Music Therapy, 54*(3), 255-286.

Kim, J., Wigram, T., & Gold, C. (2008). The effects of improvisational music therapy on joint attention behaviors in autistic children: A randomized controlled study. *Journal of Autism and Developmental Disorders, 38*(9), 1758-1766.

Kim, J., Wigram, T., & Gold, C. (2009). Emotional, motivational and interpersonal responsiveness of children with autism in improvisational music therapy. *Autism, 13*(4), 389-409.

Kim, J. E., Lyoo, I. K., Estes, A. M., Renshaw, P. F., Shaw, D. W., Friedman, S. D., … Dager, S. R. (2010). Laterobasal amygdalar enlargement in 6-to 7-year-old children with autism spectrum disorder. *Archives of General Psychiatry, 67*(11), 1187-1197.

Koelsch, S. (2009). A neuroscientiﬁc perspective on music therapy. *Annals of the New York Academy of Sciences, 1169*, 374-384.

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience, 15*(3), 170-180.

Koelsch, S., Skouras, S., Fritz, T., Herrera, P., Bonhage, C., Küssner, M. B., & Jacobs, A. M. (2013). The roles of superficial amygdala and auditory cortex in music-evoked fear and joy. *Neuroimage, 81*, 49-60.

Kokal, I., Engel, A., Kirschner, S., & Keysers, C. (2011). Synchronized drumming enhances activity in the caudate and facilitates prosocial commitment-if the rhythm comes easily. *Plos One, 6*(11), e27272.

LaGasse, A. B. (2014). Effects of a music therapy group intervention on enhancing social skills in children with autism. *Journal of Music Therapy, 51*(3), 250-275.

Lai, G., Pantazatos, S. P., Schneider, H., & Hirsch, J. (2012). Neural systems for speech and song in autism. *Brain, 135*, 961-975.

Large, E. W., & Jones, M. R. (1999). The dynamics of attending: How people track time-varying events. *Psychological Review, 106*(1), 119.

Lense, M. D., & Camarata, S. (2020). PRESS-play: Musical engagement as a motivating platform for social interaction and social play in young children with ASD. *Music & Science*, *3*, 2059204320933080.

Lense, M. D., Beck, S., Liu, C., Pfeiffer, R., Diaz, N., Lynch, M., ... & Fisher, M. H. (2020). Parents, peers, and musical play: Integrated parent-child music class program supports community participation and well-being for families of children with and without autism spectrum disorder. *Frontiers in Psychology*, 11, 2775.

Lim, H., & Draper, E. (2011). The effects of music therapy incorporated with applied behavior analysis verbal behavior approach for children with autism spectrum disorders. *Journal of Music Therapy, 48*(4), 532-550.

Lim, H. A. (2010). Effect of "Developmental speech and language training through music" on speech production in children with autism spectrum disorders. *Journal of Music Therapy, 47*(1), 2-26.

Locock, L., & Boaz, A. (2019). Drawing straight lines along blurred boundaries: Qualitative research, patient and public involvement in medical research, co-production and co-design. *Evidence & Policy: A Journal of Research, Debate and Practice, 15*(3), 409-421.

Malloch, S. N. (2000). Mothers and infants and communicative musicality. *Musicae Scientiae, 2*(2; SPI), 29-58.

Mansour, R., Dovi, A. T., Lane, D. M., Loveland, K. A., & Pearson, D. A. (2017). ADHD severity as it relates to comorbid psychiatric symptomatology in children with autism spectrum disorders (ASD). *Research in Developmental Disabilities, 60*, 52-64.

Marsh, K. L., Isenhower, R. W., Richardson, M. J., Helt, M., Verbalis, A. D., Schmidt, R. C., & Fein, D. (2013). Autism and social disconnection in interpersonal rocking. *Frontiers in Integrative Neuroscience, 7*, 4.

Mateos-Moreno, D., & Atencia-Dona, L. (2013). Effect of a combined dance/movement and music therapy on young adults diagnosed with severe autism. *Arts in Psychotherapy, 40*(5), 465-472.

McAuley, J. D., & Fromboluti, E. K. (2014). Attentional entrainment and perceived event duration. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1658), 20130401.

McConachie, H., Livingstone, N., Morris, C., Beresford, B., Le Couteur, A. Gringras, P…. Parr, J. R. (2018). Parents suggest which indicators of progress and outcomes should be measured in young children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 48*(4), 1041–1051.

Miller, J. E., Carlson, L. A., & McAuley, J. D. (2013). When what you hear influences when you see: Listening to an auditory rhythm influences the temporal allocation of visual attention. *Psychological science, 24*(1), 11-18.

Miller, L. K. (2014). *Musical savants: Exceptional skill in the mentally retarded*. New York, NY: Psychology Press.

Mössler, K., Gold, C., Assmus, J., Schumacher, K., Calvet, C., Reimer, S., … Schmid, W. (2019). The therapeutic relationship as predictor of change in music therapy with young children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 49*(7), 2795-2809.

Mössler, K., Schmid, W., Assmus, J., Fusar-Poli, L., & Gold, C. (2020). Attunement in music therapy for young children with autism: Revisiting qualities of relationship as mechanisms of change. *Journal of Autism and Developmental Disorders*, *50*, 3921–3934.

Munson, J., Dawson, G., Abbott, R., Faja, S., Webb, S. J., Friedman, S. D., … Dager, S. R. (2006). Amygdalar volume and behavioral development in autism. *Archives of General Psychiatry, 63*(6), 686-693.

Murphy, E. R., Foss-Feig, J., Kenworthy, L., Gaillard, W. D., & Vaidya, C. J. (2012). Atypical functional connectivity of the amygdala in childhood autism spectrum disorders during spontaneous attention to eye-gaze. *Autism Research and Treatment, 2012*, 652408.

Nicolson, R., DeVito, T. J., Vidal, C. N., Sui, Y., Hayashi, K. M., Drost, D. J., … Thompson, P. M. (2006). Detection and mapping of hippocampal abnormalities in autism. *Psychiatry Research, 148*(1), 11-21.

Nordahl, C. W., Scholz, R., Yang, X., Buonocore, M. H., Simon, T., Rogers, S., & Amaral, D. G. (2012). Increased rate of amygdala growth in children aged 2 to 4 years with autism spectrum disorders: A longitudinal study. *Archives of General Psychiatry, 69*(1), 53-61.

Patel, A. D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology, 2*, 142.

Piven, J., Bailey, J., Ranson, B. J., & Arndt, S. (1998). No difference in hippocampus volume detected on magnetic resonance imaging in autistic individuals. *Journal of Autism and Developmental Disorders, 28*(2), 105-110.

Porter, S., McConnell, T., McLaughlin, K., Lynn, F., Cardwell, C., Braiden, H.-J., … Music in Mind Study Group (2017). Music therapy for children and adolescents with behavioural and emotional problems: A randomised controlled trial. *Journal of Child Psychology and Psychiatry, 58*(5), 586-594.

Provenzani, U., Fusar-Poli, L., Brondino, N., Damiani, S., Vercesi, M., Meyer, N., … Politi, P. (2020). What are we targeting when we treat autism spectrum disorder? A systematic review of 406 clinical trials. *Autism, 24*(2), 274-284.

Quintin, E.-M., Bhatara, A., Poissant, H., Fombonne, E., & Levitin, D. J. (2011). Emotion perception in music in high-functioning adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 41*(9), 1240-1255.

Rabeyron, T., Del Canto, J.-P. R., Carasco, E., Bisson, V., Bodeau, N., Vrait, F.-X., … Bonnot, O. (2020). A randomized controlled trial of 25 sessions comparing music therapy and music listening for children with autism spectrum disorder. *Psychiatry Research, 293*, 113377.

Reschke-Hernandez, A. E. (2011). History of music therapy treatment interventions for children with autism. *Journal of Music Therapy, 48*(2), 169-207.

Robledo, J., Donnellan, A. M., & Strandt-Conroy, K. (2012). An exploration of sensory and movement differences from the perspective of individuals with autism. *Frontiers in Integrative Neuroscience, 6*, 107.

Rojas, D. C., Peterson, E., Winterrowd, E., Reite, M. L., Rogers, S. J., & Tregellas, J. R. (2006). Regional gray matter volumetric changes in autism associated with social and repetitive behavior symptoms. *BMC Psychiatry, 6*, 56.

Rudie, J. D., & Dapretto, M. (2013). Convergent evidence of brain overconnectivity in children with autism? *Cell Reports, 5*(3), 565-566.

Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., & Fitch, W. T. (2020). Music as a coevolved system for social bonding. *Behavioral and Brain Sciences*, 1-42. doi: 10.1017/S0140525X20000333

Schumacher, K., Calvet, C., Reimer, S., Salmon, S., & Litwin, G. (2019). *The AQR tool-Assessment of the quality of relationship. Based on developmental psychology.* (*Trans. G. Litwin & S. Salmon).* Wiesbaden, Deutschland: Reichert Verlag.

Schumann, C. M., & Amaral, D. G. (2006). Stereological analysis of amygdala neuron number in autism. *Journal of Neuroscience, 26*(29), 7674-7679.

Schwartzberg, E. T., & Silverman, M. J. (2013). Effects of music-based social stories on comprehension and generalization of social skills in children with autism spectrum disorders: A randomized effectiveness study. *Arts in Psychotherapy, 40*(3), 331-337.

Schwartzberg, E. T., & Silverman, M. J. (2016). Effects of a music-based short story on short- and long-term reading comprehension of individuals with autism spectrum disorder: A cluster randomized study. *Arts in Psychotherapy, 48*, 54-61.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry, 34*(8), 1351-1364.

Sharda, M., Midha, R., Malik, S., Mukerji, S., & Singh, N. C. (2015). Fronto‐temporal connectivity is preserved during sung but not spoken word listening, across the autism spectrum. *Autism Research, 8*(2), 174-186.

Sharda, M., Tuerk, C., Chowdhury, R., Jamey, K., Foster, N., Custo-Blanch, M., … Hyde, K. (2018). Music improves social communication and auditory-motor connectivity in children with autism. *Translational Psychiatry, 8*, 231.

Sherwin, A. C. (1953). Reactions to music of autistic (schizophrenic) children. *The American Journal of Psychiatry, 109*(11), 823-831.

Silberman, S. (2017). *Neurotribes: The legacy of autism and how to think smarter about people who think differently.* London, United Kingdom: Atlantic Books.

Sparks, B., Friedman, S., Shaw, D., Aylward, E. H., Echelard, D., Artru, A., …. Dawson, G. (2002). Brain structural abnormalities in young children with autism spectrum disorder. *Neurology, 59*(2), 184-192.

Stephenson, K., Quintin, E., & South, M. (2016). Age-related differences in response to music-evoked emotion among children and adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 46*(4), 1142-1151.

Stern, D. N. (1977). *The first relationship: Infant and mother*. London, UK: Billing & Sons Ltd.

Stern, D. N. (1985). *The interpersonal world of the infant*. New York, New York: Basic Books Inc.

Stern, D. N. (2010). *Forms of vitality*. Oxford, UK: Oxford University Press.

Thaut, M. H., McIntosh, G. C., & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. *Frontiers in Psychology, 5*, 1185.

Thaut, M. H. (2014). Assessment and the transformational design model (TDM). In M. H. Tauth & V. Hoemberg (Eds.), *Handbook of Neurologic Music Therapy, (pp. 60-68)*. Oxford, UK: Oxford University Press.

Thompson, G. (2017). Long-term perspectives of family quality of life following music therapy with young children on the autism spectrum: a phenomenological study. *Journal of Music Therapy, 54*(4), 432-459.

Thompson, G. (2018). Dramatic role play within improvisational music therapy: Joey’s story. In A. Oldfield & M. Carr (Eds.), *Collaborations within and between dramatherapy and music therapy,* (pp. 31-51). London, UK: Jessica Kingsley Publishers

Thompson, G. A., & Elefant, C. (2019). "But I want to talk to you!" Perspectives on music therapy practice with highly verbal children on the autism spectrum. *Nordic Journal of Music Therapy, 28*(4), 347-359.

Thompson, G., & McFerran, K. S. (2015). "We've got a special connection": Qualitative analysis of descriptions of change in the parent-child relationship by mothers of young children with autism spectrum disorder. *Nordic Journal of Music Therapy, 24*(1), 3-26.

Thompson, G., McFerran, K., & Gold, C. (2013). Family-centred music therapy to promote social engagement in young children with severe autism spectrum disorder: A randomised controlled study. *Child: Care, Health & Development, 40*(6), 840-852.

Thompson, G. A., Shanahan, E. C., & Gordon, I. (2019). The role of music-based parent-child play activities in supporting social engagement with children on the autism spectrum: A content analysis of parent interviews. *Nordic Journal of Music Therapy*, *28*(2), 108-130.

Thye, M. D., Bednarz, H. M., Herringshaw, A. J., Sartin, E. B., & Kana, R. K. (2018). The impact of atypical sensory processing on social impairments in autism spectrum disorder. *Developmental Cognitive Neuroscience, 29*, 151-167.

Trevarthen, C. (2002). Autism, sympathy of motives and music therapy. *Enfance, 54*(1), 86-99.

Trost, W., Frühholz, S., Schön, D., Labbé, C., Pichon, S., Grandjean, D., & Vuilleumier, P. (2014). Getting the beat: Entrainment of brain activity by musical rhythm and pleasantness. *Neuroimage, 103*, 55-64.

Tryfon, A., Foster, N. E., Ouimet, T., Doyle-Thomas, K., Anagnostou, E., Sharda, M., & Hyde, K. L. (2017). Auditory-motor rhythm synchronization in children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 35, 51–61.

Turry, A. (2018). Response to effects of improvisational music therapy vs. enhanced standard care on symptom severity among children with autism spectrum disorder: The TIME-A randomized clinical trial. *Nordic Journal of Music Therapy*, 27(1), 87-89.

Vanya, M., Szucs, S., Vetro, A., & Bartfai, G. (2017). The potential role of oxytocin and perinatal factors in the pathogenesis of autism spectrum disorders - review of the literature. *Psychiatry Research, 247*, 288-290.

Walworth, D. D., Register, D., & Engel, J. N. (2009). Using the SCERTS model assessment tool to identify music therapy goals for clients with autism spectrum disorder. *Journal of Music Therapy, 46*(3), 204-216.

Wan, C. Y., Bazen, L., Baars, R., Libenson, A., Zipse, L., Zuk, J., … Schlaug, G. (2011). Auditory-motor mapping training as an intervention to facilitate speech output in non-verbal children with autism: A proof of concept study. *Plos One, 6*(9), e25505.

Wan, C. Y., & Schlaug, G. (2010). Neural pathways for language in autism: The potential for music-based treatments. *Future Neurology, 5*(6), 797-805.

Wheeler, B. L. (2015). *Music therapy handbook*. New York, NY: Guilford Publications.

World Federation of Music Therapy. (2017). Regional information. Retrieved from http://www.wfmt.info/resource-centers/publication-center/regional-information/

Zatorre, R. J., & Beckett, C. (1989). Multiple coding strategies in the retention of musical tones by possessors of absolute pitch. *Memory & Cognition, 17*(5), 582-589.