Cochlear Implants International
An Interdisciplinary Journal

ISSN: 1467-0100 (Print) 1754-7628 (Online) Journal homepage: http://www.tandfonline.com/loi/ycii20

Jumpstarting auditory learning in children with cochlear implants through music experiences

Christine Barton & Amy McConkey Robbins

To cite this article: Christine Barton & Amy McConkey Robbins (2015) Jumpstarting auditory learning in children with cochlear implants through music experiences, Cochlear Implants International, 16:sup3, S51-S62

To link to this article: http://dx.doi.org/10.1179/1467010015Z.000000000267

Published online: 11 Jan 2015.

Jumpstarting auditory learning in children with cochlear implants through music experiences

Christine Barton[1], Amy McConkey Robbins[2]

[1]Central Canal Creative Arts Therapies, Indianapolis, IN, USA, [2]Communication Consulting Services, Indianapolis, IN, USA

Musical experiences are a valuable part of the lives of children with cochlear implants (CIs). In addition to the pleasure, relationships and emotional outlet provided by music, it serves to enhance or 'jumpstart' other auditory and cognitive skills that are critical for development and learning throughout the lifespan. Musicians have been shown to be 'better listeners' than non-musicians with regard to how they perceive and process sound. A heuristic model of music therapy is reviewed, including six modulating factors that may account for the auditory advantages demonstrated by those who participate in music therapy. The integral approach to music therapy is described along with the hybrid approach to pediatric language intervention. These approaches share the characteristics of placing high value on ecologically valid therapy experiences, i.e., engaging in 'real' music and 'real' communication. Music and language intervention techniques used by the authors are presented. It has been documented that children with CIs consistently have lower music perception scores than do their peers with normal hearing (NH). On the one hand, this finding matters a great deal because it provides parameters for setting reasonable expectations and highlights the work still required to improve signal processing with the devices so that they more accurately transmit music to CI listeners. On the other hand, the finding might not matter much if we assume that music, even in its less-than-optimal state, functions for CI children, as for NH children, as a developmental jumpstarter, a language-learning tool, a cognitive enricher, a motivator, and an attention enhancer.

Keywords: Music, Cochlear Implants, Children, Language Development, Intervention, Pediatrics, Perception, Learning

Introduction

Some would argue that music and language are human inventions and institutions and, in essence, are what separate us from the rest of the species on this planet (Bruscia, 2014; Patel, 2008). Others assert that humans are predisposed to learn music and language (Gordon, 2003, Locke, 1993). Every known culture possesses its own language(s) and musical canon(s) and, whereas they differ greatly across cultures, the instincts to sing and speak are universally human (Mithin, 2006). Mothers and fathers around the globe sing to their infants in a desire to soothe, engage, and communicate emotions, setting the stage for future success in music and language learning. Most children are never directly taught to speak and sing; they acquire these abilities from listening to others and trying to imitate what they hear. In order to become fluent singers and speakers, children with normal hearing (NH) achieve a series of milestones that emerge as a result of biological readiness, environmental influence, access to sound all day, and participation in meaningful, reinforcing experiences. These milestones occur at slightly different times for each child, but the progression remains similar for both music and language: hearing and listening, singing and speaking, reading and writing. Bluestine (2000, p. 39) calls this universal learning sequence 'sound-before-sight-before-theory'. However, for a child to be successful in either the music or language domain, input stimuli must be abundant and easily accessible. This is important for all children, but particularly for those who listen via cochlear implants (CIs), because these devices deliver an incomplete and impoverished signal to the user.

Music and spoken language are multisensory experiences (auditory, visual, and kinesthetic) and are socially and culturally shaped for making meaning. With the advent of sophisticated

Correspondence to: Christine Barton Email: cgbarton@sbcglobal.net

DOI 10.1179/1467010015Z.000000000267

neuroimaging technology, scientists can now peer into the brain that is engaged in listening to or creating music. They have identified shared neural mechanisms or pathways involved in music and language processing (Limb, 2006; Patel, 2008). This fairly recent interest in the musical brain from an auditory neuroscience perspective has also revealed that individuals who are engaged in music training of some sort have structurally different brains from non-musicians. These differences result in some positive gains in non-musical areas such as memory, math, attention, cognition, emotions, and hearing in noise (Kraus and Chandrasekeran, 2010; Parbery-Clark *et al.,* 2009; Strait and Kraus, 2014; Tierney and Kraus, 2013; Trainor *et al*., 2009). As such, these changes promote an adaptive auditory system that is constantly regulating as it processes information during listening. In other words, the musical listener achieves a high level of 'auditory fitness' (Kraus and Chandrasekeran, 2010). Armed with this compelling evidence that music positively changes the brain, would not we wish for every child, *especially those with a hearing loss*, the chance to reach his or her fullest musical potential?

The importance of input for speech and music acquisition

The input characteristics of childhood auditory experiences for linguistic mastery are critical in determining how children's output is shaped (Segal and Kishon-Rabin, 2011). As clinicians focused on how children *talk*, we also observe and monitor what children listen to, recognizing the link between input and output. Therapy sessions maximize audition by taking place in a quiet environment, sitting close to the child and talking when the child is not looking at the speaker's face or mouth, using an animated voice, directing the child's attention to an object, interacting frequently and providing repetition (Cole, 1994). We also guide and coach parents to help their child utilize hearing as the primary sensory modality, integrate listening and spoken language techniques into the child's daily routine, understand developmental language progression, and help the child learn to monitor his or her own speech production (AG Bell Academy, 2007).

There is scant research on the musical input parents provide their child with CIs. Although clinicians pay close attention to the spoken language input to which children with CIs are exposed, most have not been trained to query parents about the quality or quantity of music present in the child's daily life. We do not know how much or even if music is incorporated into the child's daily routine in an accessible, developmentally appropriate manner. Even so, there is an accepted notion that music experiences should be a part of the lives of children with CIs (Estabrooks and Birkenshaw-Fleming, 2003; Rocca, 2006). Ling (2001, p. 103) a pioneer of the auditory–verbal method, wrote: 'When music and song are not made available to them, the experience of children who are deaf or hard of hearing is unnecessarily restricted'. These authors note the importance of coaching parents on how to best integrate music experiences alongside spoken language practice.

The nature of music experiences and the skill set achievable by children using CIs are debated. There is a gap between analytic music studies conducted in laboratories and clinical reports of children's music abilities and enjoyment in real-world settings. Limb (2006) asks us to consider the nature of music. 'Music generally constitutes a unified whole that cannot be naturally subdivided. (e.g., it is hard to listen to a melody while ignoring the rhythm.) As such, it is plausible that the division of music into smaller units may not be the best method to approach the subject of music at large'. (p. 436). Sloboda (2005, p. 101) would support the notion that music research concern itself with the use of 'real music versus impoverished music-like stimuli' because subjects may not understand certain characteristics of music if the complexity of rhythm and pitch are absent. He and other researchers are moving toward the use of ecologically valid, or real-life music, as opposed to the use of discrete musical elements such as isolated pitches minus rhythm. Trehub (2013) cautions: 'the prevalence of timbres of convenience [e.g., electronically-generated pure tones] in studies of music cognition may obscure important aspects of music processing in human listeners of all ages'.

Input matters: parallels between infant-directed speech and singing

Throughout human history, music and speech have co-existed. While debates continue between musicologists and linguists over whether music or speech came first and the evolutionary reasons for their existence, caregivers around the world intuitively understand that both are important. Infant-directed (ID) speech (motherese, musical speech) is cross-culturally universal and is among the first kind of auditory input that an infant hears (Trainor *et al.*, 1997). ID speech differs from non-ID speech in that it is typically higher in pitch, rhythmic, has more exaggerated pitch contours, long pauses, short utterances and tends to be slower and expressive (Houston and Bergeson, 2014; de L'Etoile, 2006). This type of speech is acoustically salient and serves initially to capture the infant's attention. The intrinsic auditory patterns, rhythm, grouping, and phrasing, found in ID speech prime the processing skills necessary to later decode speech (Bergeson *et al.*, 2006).

Similarly, ID singing is also a universal phenomenon and is distinct from singing that occurs when an infant is absent. In addition to the benefits of comforting and soothing, ID singing attracts the infant's attention and communicates the caregiver's emotional intent (Trainor *et al.*, 1997; Trehub and Gudmundsdottir, 2015). Corbeil *et al.* (2013) found that infants, regardless of age, attended more to a happy ID singing voice than to a neutral adult-directed speech. Fathers and older children make similar modifications in singing to babies. The fact that an infant must be present for any of these modifications to occur suggests that ID speech and singing are naturally responsive and intuitive behaviors. They are also time-sensitive. Studies suggest that, as infants gain more auditory experience, mothers change the nature of their speech to complement the newly acquired skills. For example, Bergeson *et al.*, (2006) found that mothers of infants with CIs used characteristics of ID speech when engaged with their infant. Remarkably, mothers also adjusted their speech characteristics relative to their child's *hearing* age, not *chronological* age, supporting the notion that ID speech is naturally responsive and sensitive to the child's needs.

Researchers, clinicians, and CI manufacturers are engaged in ongoing work to understand what makes music sound like music to a person with a CI. Those of us who work as listening and spoken language specialists are optimistic that the research will lead to even more sophisticated fine-structure processing, which will reduce a number of limitations that have been highlighted in current literature (Gfeller *et al.*, 2011; Jung *et al.,* 2012; Looi *et al.,* 2008; Mitani *et al.,* 2007). In the meantime, these authors subscribe to the notion that music is an important ingredient in child development and should be part of the habilitation process for children with CIs who live in a hearing world.

Music as a jumpstarter of spoken language

Device limitations aside, positive outcomes rely on rich, natural, and engaging input. As clinicians working with young children with CIs, we see the potential that music has to jumpstart the mechanisms required to process and produce spoken language, as well as other important developmental skills. The Oxford dictionary defines 'jumpstart' as: 'to give an added impetus to something that is proceeding slowly'. Using this definition, we view music as valuable, not just at the initial stages of CI use, but across the lifespan of the listener. The fact that as humans we not only *know* music, but we also *do* music as a way of connecting with and engaging each other, speaks to the power of music *in* therapy and music *as* therapy.

The purposes of this paper are to: (1) review the ways in which music experiences enhance developmental skills in normal-hearing (NH) listeners; 2) describe the Integral Approach to Music Therapy (Bruscia, 2014) and the Hybrid Approach to Pediatric Language Intervention (Fey, 1986); and (3) present specific music and language intervention techniques used by the authors in their music-supported approach to working with children wearing CIs.

Music experiences enhance developmental skills

Strait and Kraus (2011) have reviewed research substantiating that musicians are 'better listeners' than non-musicians with regard to how they perceive and process sound. Why might this be so? Is it possible that experience with music over time actually gives musicians, and potentially children with CIs, a jumpstart on maximizing auditory function and other language-related abilities? To address these questions, we review a heuristic model of music therapy. Heuristic used in this context refers to a speculative guide that serves to point out and stimulate interest, leading to further discussion and investigation. This model encompasses five modulating factors that contribute to the positive effects of music therapy: attention, emotion, cognition, behavior, and communication (Hillecke, Nickel and Bolay, 2005), and an additional factor, perception, contributed by Koelsch (2009). A cursory review of research pertaining to each of the factors is included.

Attention: the assumption is that music as an auditory stimulus has the ability to attract attention. Music training provides a mechanism for education in the auditory domain, enhancing the ability to direct our *attentional spotlight* (Strait and Kraus, 2011). This is a critical skill, because what we hear is determined by how well we listen and by our capacity to direct our attention to the input of highest interest while monitoring our surrounding for changes that require immediate attention (Strait and Kraus, 2011). Children as young as 9-months old show listening preferences and demonstrate selective attention to sung rather than instrumental nursery rhymes (Glenn and Cunningham, 1983). Houston (2009) reported that deaf infants' attention to speech at 6 months after CI correlated significantly with their performance on a word recognition task 2 to 3 years later. These findings suggest the possibility that more attention to speech leads to better speech perception skills. The work of Houston and Bergeson (2014) prompts a number of clinically relevant considerations. First, if deaf infants' attention to speech after implantation is less than that of NH infants, how will that impact their future language development? Second, is assessing attention to speech useful for tracking spoken language development after implantation? Third, what is the role of input characteristics on infants' attention to speech?

Emotion: the assumption is that music can modulate and regulate emotion. The ability to identify and understand emotion is the very essence of communication. Unfortunately, children with CIs often have difficulty extracting the subtle emotional cues that are present in spoken language (Hopyan-Misakyan *et al.*, 2009; Wang *et al.,* 2013). Because music embodies a wide range of emotions and has the capacity to evoke moods and feelings, Hopyan *et al.* (2011) explored the notion that music could provide more salient emotional cues than spoken language for CI children. In previous studies, they determined that children with CIs enjoy and seek out music and reported that listening to music could change their mood, thus making music a naturally enjoyable way to access hearing. Hearing children are able to accurately identify expressed musical emotions by age five (Thompson, 2009) using primarily two elements of music that enable emotional encoding: tempo (beats per minute) and modality (major or minor). The findings of Hopyan *et al.* (2011) and Volkova, *et al.* (2013) revealed that children with CIs were able to extract the emotional content in music at a level significantly better than chance, relying more on tempo than major or minor mode, or melody. Strait *et al.* (2009) found that shared neural and acoustic mechanisms are involved in the perception of both speech and music and that experience with music can enhance extraction of emotion in speech. This provided biological evidence to the notion that musicians are better at perceiving expressed emotion.

Cognition: the assumption is that music and speech share neurocognitive processing mechanisms. Audition is a superior modality for processing sequentially based material (such as music). With tasks that require learning or remembering temporally ordered events, people do best when they can rely upon hearing (Collier and Logan, 2000; Glenberg and Jona, 1991). Growing evidence indicates that experience with sound may provide a sort of scaffolding for the development of general cognitive skills that depend on the representation of temporal or sequential patterns, as suggested by Conway *et al.* (2009). These authors posit that sound, compared with vision, may specifically carry higher-level patterns of information related to timing and sequencing, suggesting that hearing is the primary gateway for perceiving *sequential* patterns of input that change over time (rather than over space, as in vision). They assert that 'the development of fundamental sequence-learning mechanisms would be delayed when this type of [sequential-pattern] input is unavailable, as is the case in deafness (p. 4)'.

Behavior: the assumption is that music has the potential to condition and prompt behavior without requiring conscious will. Rhythmic entrainment, or the body's ability to automatically synchronize to a steady beat, can influence body movement patterns. The connection between music and dance is a well-known example. The act of moving while listening to music alters the metrical interpretation of the music (Phillips-Silver and Trainor, 2005). Woodruff Carr *et al.* (2014) found that preschool children who can entrain (synchronize movement) to an external beat scored higher on early language skills because of their ability to precisely encode speech syllables. In turn, this was predictive of future reading ability. Thaut and co-workers have extensively researched rhythm and its effects on neurologic processes in those with impaired motor control such as Parkinson's and stroke patients and children with cerebral palsy. Thaut's (2008) clinical intervention, rhythmic auditory stimulation, is based upon evidence that supports its utilization as part of sensorimotor, speech, and cognitive rehabilitation (Thaut and Abiru, 2010). Altenmüller and Schlaug (2015) have studied the use of melodic intonation therapy (MIT) as a means of recovering speech after a brain injury, or in nonverbal children with autism. In this intensive therapy, a patient intones words at a rate of one syllable/second by changing pitches (usually two notes separated by a minor third) and tapping out each syllable with the left hand. Long strings of information, as in phrases, are broken up into units or chunks to reduce cognitive load and facilitate efficient use of short-term memory. This method recruits undamaged parts of the brain to help the patient achieve or recover speech fluency. MIT has recently gained the attention of the American public owing to its successful application as a primary intervention in rehabilitation for U.S. Representative Gabrielle Gifford following severe brain injury.

Communication: the assumption is that music and communication share a number of properties, allowing humans to use music to communicate as if in a verbal dialogue. Many cultures use music to bring people together, enhance shared social and emotional states, and build community and group cohesion. Music therapists often use instrumental (no lyrics) improvisation as a way of nonverbally connecting with a communication-impaired client. The text box below highlights an example of an improvisational method employed by the authors to support linguistic and cognitive development.

> *Improvisational Music Therapy with Sam*
>
> Sam was an eight-year-old bilateral CI user with additional diagnoses of cognitive impairment and autism. He and his family were followed weekly by these authors in co-led speech and music therapy. His complex neurologic issues made it difficult for him to communicate verbally, so Signing Exact English II was his preferred mode of expressive communication. His mother stated that even before he was implanted, he was attracted to music and would sit on the piano bench while his grandmother played and sang to him. Sam sought out music at every opportunity and enjoyed musicing with the therapists. He was able to maintain a steady beat to a variety of meters, and could actually match pitches presented to him vocally by the therapists. However, because of expressive language and motor control limitations, producing song lyrics was nearly impossible.
>
> The music therapist used improvisational music experiences to engage and elicit Sam's musical abilities. He was given a pre-tuned xylophone based on a pentatonic scale (CDEGA). This meant any dissonant pitches were removed and required no particular skill set to play, other than to use two mallets. A quick demonstration of the different possibilities of playing the xylophone was demonstrated by the speech-language pathologist and imitated by Sam. Once this "musical vocabulary" was mastered, the music therapist then improvised at the piano (using the same scale) while Sam played the xylophone. This experience empowered Sam to successfully carry on a "musical conversation" complete with imitation, turn taking, and coordinated actions with the therapist.

Perception: the assumption is that music training can affect the perceptual mechanisms necessary for language comprehension (Koelsch, 2009). This is especially relevant for children with receptive and expressive language impairments. Several studies have shown that the ability to process speech prosody and syntactic abilities in NH individuals are enhanced with music training (Moreno *et al.,* 2008; Marin 2009; Strait *et al.,* 2009). CIs are designed to provide sufficient information for the user to attain high levels of speech recognition and production. However, music requires more fine structure timing and pitch cues than speech. Thus, for children using CIs, pitch discrimination and production can be difficult because of spectral limitations of the device (Hsiao and Gfeller, 2012). Some studies have shown that music training can improve pitch perception in children with CIs (Chen *et al.,* 2010; Yucel *et al.,* 2009). The ability to identify music instruments requires timbre recognition, another challenge for CI recipients. However, with training, timbre recognition can improve (Driscoll *et al.*, 2009*). Perhaps what is equally important to note is that a CI user's ability to perceive certain elements of music is not related to an appreciation or enjoyment of music* (Wright and Uchanski, 2012).

Therapeutic strategies for jumpstarting auditory learning

Integral approach to music therapy

Bruscia (2014) distinguished two primary strategies and four therapy methods that clinicians may employ within the Integral Approach to music therapy.

Two primary strategies within the integral approach

First, one can adopt outcome-oriented strategies, in which the therapist choses a measureable target response, sets pre-determined goals, leads the experience, and looks for cause–effect behaviors (e.g., uses pitch or rhythm training to improve auditory perception). Outcome-oriented strategies tend to address a client's problems and are guided by evidence-based practices. Second, one can adopt experience-oriented strategies, whereby the therapist is focused on a basic understanding of the client's needs, but is willing to let the client lead and use the music experiences as a process to reveal desired goals (e.g., engaging the client in a music process that allows them to explore feelings and thoughts as well as their relationships to music and to others).

Both outcome-oriented and experience-oriented strategies can incorporate ecologically oriented strategies, which involve selecting the optimal setting for therapy to take place (home, school, or studio), and deciding whom to involve in the sessions (parents, siblings, other professionals). Ecologically oriented strategies also help define who the client is and how best to maintain linguistic and cultural sensitivity. Understanding the differences in these strategies is important for two reasons. First, it creates a paradigm in which therapists may plan and evaluate music experiences as a part of their own orientation to music therapy practice. Second, it provides at least a partial explanation for the disparity between the conclusions reached by those who conduct music research and those who practice music therapy with CI children. Music researchers, who primarily use an outcome-oriented view of music, tend to rate musical ability in CI children as fairly low. Clinicians, who primarily use an experience-oriented view of music, tend to rate musical ability in CI children as fairly high. From each groups' orientation, both ratings are accurate.

Four methods of music therapy experiences within the integral approach

Bruscia (1998) characterized the four methods of music experiences that are typically used in therapy sessions. These are briefly reviewed below.

Re-creative method – the child is engaged in singing or playing pre-composed songs, music, activities, or games. This method is useful for children who need structure to develop certain skills and behaviors. Examples include, singing nursery rhymes and songs, lullabies, finger plays (*Itsy Bitsy Spider*), musical games, and using pre-composed songs and changing the lyrics to fit the needs of the child.

Improvisational method – the child sings or plays music 'in the moment' creating melodies and rhythms as they are involved in the process of 'musicing' (Aigen, 2005). This method is useful for children with limited language abilities to appropriately express emotions and ideas. Examples include, providing or allowing the client to choose an instrument for improvisation while the therapist provides accompaniment and musical structure as the client plays. The therapist or client may choose a non-musical theme to guide the improvisation (birthday party, playground) or even an emotional state (happy, sad, angry, fearful).

Receptive method – the child is engaged in active listening to a song, sound or piece of music and responding verbally, silently or through movement. This method is useful for working on specific levels of auditory functioning (Erber, 1982) such as pairing a movement to a particular instrument. If the therapist plays a drum (out of sight), the child steps forward; if the therapist plays a cymbal, the child steps backward, gradually adding more instruments and paired actions. Or, the therapist plays a slide whistle (out of sight), and the child moves his body up and down according to the direction of the whistle. Music listening can also facilitate imaging. For example, the therapist may play a recorded piece of instrumental music and guide the child through a story (going to the beach, a birthday party, visiting grandma). After the process, the child can relate the images he or she experienced.

Compositional method – the child and therapist write a song or piece of music or make a video or audio recording. This method is useful for helping a child document thoughts, feelings and ideas. Examples include: documenting a client's thoughts and feelings in song, making a Music Experience Book (Barton, 2011), or a SoundStory (Barton, 2013).

The four methods of music experiences described above may be used to address goals that are experience-oriented (focusing on active listening and musicing) or outcome-oriented (focusing on discrete differences between features of sound/ear training; Patel, 2012). The authors' music-supported approach places primary emphasis on experience-oriented strategies, in large part because of the developmental nature and skills of the young child. It places secondary but strategic focus on outcome-oriented strategies. That both these strategies can be incorporated into one practice is a hallmark of the integral approach (Bruscia, 2014) and relies upon the clinician's ability to select targets for intervention that are individualized to a CI child's needs. Note, also, that relationships formed between child and therapist, child and self, child and music, and clinician and family are paramount to the therapeutic process and its success.

Hybrid approach to pediatric language intervention

One sees historic parallels to the music distinctions reviewed above when considering models of intervention in the speech/language domain (Duchan, 2004). Fey (1986) places various language interventions along a naturalness continuum, suggesting that the most 'natural' interventions are those that are true to real-life communication experiences. Fey suggests that, all things being equal, the more natural approach is preferred, due to the likelihood of skills generalizing to other environments. He cautions, however, that naturalness may come at the expense of the intensity of practice that is achievable in a less-natural, drill-based activity, which is analogous to an outcome-oriented strategy in music therapy. Fey reminds clinicians that naturalness is a positive aspect in therapy to the extent that it helps a child reach identified goals and succeeds in fostering better speed, durability and generalizability of skills. He has endorsed a 'hybrid' approach to pediatric language intervention, suggesting that we balance structured drills with motivating linguistic interactions. Hybrid approaches are attempts by the clinician to develop intervention activities that are highly natural and, at the same time, provide the clinician with opportunities to make use of procedures that will maximize the three factors noted above, speed, durability and generalizability of learning. Three characteristics of a hybrid therapy session mentioned by Fey are

(1) Clinician will have at least one, and typically, several specific goals;
(2) Clinician will select activities and materials that appear to be highly conducive to the spontaneous use of utterances containing the targets;
(3) Clinician will modify her own language not just to reflect the communicative needs of the child but also to emphasize the use of the child's target forms.

This is very similar to the integral approach to music therapy (Bruscia, 2014). We engage in repeated practice with some basic skills that are building blocks of music, but we balance this with ample naturalistic interactions where the child is actually 'doing music'.

Music-supported listening and spoken language intervention for children with CIs

As clinicians, we use music and music experiences throughout the therapy sessions. Because NH caregivers and siblings are an integral part of a 1-hour weekly session, they help reinforce and generalize targeted therapy goals during the remaining 100+ hours they are not in therapy. Music is a family affair and a natural part of everyday life. It is our role as therapists to work with family members to ensure that the characteristics and quality of their musical input is engaging and attention-getting for their child with a CI. The aim is to jumpstart the mechanism by which the child becomes a competent consumer of auditory experiences. Nordoff and Robbins (1971) write

> A therapy which has as a goal the freeing and development of the individual within universal human principles is more effective than one that aims merely to normalize. Universal values transcend the limited values of any one nationality or culture, Universal values can live in music. This is why music can become so important in the lives of exceptional children (p. 56).

The importance of musicing and the auditory–oral feedback loop

In our sessions, we are committed to the practice of 'musicing', a term that has been used since the seventeenth century. Elliott (1995) used this term to emphasize the human component involved in the process of making music. It implies an active participation in music rather than passive observing of it. It indicates the use of real rather than artificially manipulated music input, both through instruments and voice. Aigen (2005, p. 67) writes, 'The judgment that musicing is occurring implies that there is intelligence, intention and consciousness present, although these qualities may not be verbally expressed'. Active musicing occurs during both perception and production music experiences, much as language learning occurs during both receptive and expressive tasks. Musicing contributes to the formation and refinement of an input–output auditory feedback loop. Aigen (2005) delineates some of the values central to musicing as: Requires an understanding of silence; requires listening; incorporates the individual within the communal; cultivates a respect for craft; and creates connection. It is not difficult to recognize how applicable these values are to the priorities we set for communicative competence in children with CIs.

The important role of the auditory–oral feedback loop is well established in deaf children who are learning spoken language through listening (Pollack, 1985). A similar input–output loop exists when children are acquiring music skills. In both domains, our goal is to replicate in CI children what develops in NH children. Children with NH learn to talk, not only by hearing the speech of others but also by having an ongoing, finely tuned feedback mechanism that allows them to hear their own vocal productions, beginning with early cooing and babbling. This mechanism also gives NH children intrinsic reinforcement when they hear their own musical productions such as elongated vowel segments produced on varying pitches, musical babble sequences and later, attempts to replicate the melody of a song. Hearing accurate representations of their own singing allows NH children to modify their output in increasingly sophisticated ways. Such experience-dependent modifications continue throughout the lifespan (Kraus and Anderson, 2014).

The situation with children born profoundly deaf is different. From birth until they receive CIs, they have no access to the sounds they produce, either speech or musical in nature. Once they receive CIs, their access is vastly improved, yet still imperfect. Because we recognize the imperfect properties of a CI signal, the auditory–oral loop becomes a prime focus in therapy. In the auditory–verbal method, clinicians provide feedback about children's vocal productions, and encourage them to monitor their speech as they hear their own voice and to spontaneously correct errors. For spoken language, the establishment of a finely tuned auditory–oral loop in children with CIs takes place as a combined result of many factors, some of which are: auditory access to meaningful stimuli, intrinsic reinforcement, external feedback, opportunities to modify productions and repeated practice.

Our experience with CI children suggests that such an input–output loop for music is also available but its development is often limited. The most frequently cited reasons for this are the signal processing constraints of the CI, although we have not found this to be consistent with our clinical work. As already noted, prelingually deafened children have nothing against which to compare their musical percepts and those who become engaged in rich musical experiences are motivated by and find pleasure in music. What other factors, then, contribute to a poorly developed input–output loop for music in some CI children? Examining the factors above, we would cite *meaningful stimuli* and *opportunities to refine productions* as prime reasons, given that many music activities for CI children use isolated, extracted stimuli that are devoid of musical meaning. These activities often are limited to perception tasks, with no production or 'output' component, meaning children have no opportunities to hear their own productions, analyze them and modify them – practices essential for the refinement of the input–output loop. At the risk of over-simplification, these authors contend that a well-developed input–output loop for music in CI children goes hand-in-hand with experiences that are rich with opportunities for musicing.

Incorporating music into the therapy session

Music is auditory, visual, kinesthetic, cognitive, cultural, and emotional. Children experience music in a different way from their 'grown-up' counterparts (Schwartz, 2008). Children sing while they play, move when they listen and seek out others to share the experience. They make up spontaneous songs which incorporate all aspects of their lives and imaginations. In advocating for using music within therapy, it is important to note that these authors are not suggesting music teaching, but rather supporting the musical nature inherent in every child; the 'music child' (Nordoff and Robbins, 2007). This concept includes receptive, expressive and communicative abilities fundamental to the development of the child and his or her willingness to form and sustain relationships. The therapist's role is to guide the parents or caregivers to provide quality music experiences (receptive, re-creative, improvisational, and compositional) for their child. Table 1 contains an overview of the authors' music-supported intervention approach.

Infants and toddlers

The voice is the most important instrument a human possesses (Barton and Robbins, 2007). It is critical to sing, sing, and sing some more. Initially, some parents may be hesitant about singing with their child, but the expectation is that they will sing during sessions and continue to carry the music into other aspects of the infant's life. Practice builds confidence. Important strategies and interventions include:

- Use the ID singing approach by employing a slower tempo and a higher-pitched voice. The therapist

Table 1 A music-supported approach to listening and spoken language intervention for children with CIs

Assumptions	Music experiences	Rationale
There should be a balance between outcome-oriented and experience-oriented strategies	Pitch/rhythm training (same-different, high-low) Creating/playing/singing/moving	Integrated approach to music therapy (Bruscia, 2014); Hybrid approach to pediatric language intervention (Fey, 1986)
Children need to be active participants in music experiences	Frequently engage children in authentic music experiences; Re-creative, improvisatory, receptive, compositional (Bruscia, 1998)	Concept of 'musicing' as active engagement with the therapist (Aigen, 2005)
Music supports listening and spoken language learning	Nursery rhymes/chants/finger play/songs/musical games Beat synchronization	Speech and music share common elements: Pitch, timbre, and timing (Kraus and Chandrasekeran, 2010) Both share neural processing structures in the brain (Patel, 2008)
Didactic musical training may be a strategic part of the integral approach	Individualize focused instruction for each child to target pitch perception/production and timbre recognition.	Studies indicate improvement after repeated trials of musical training (Chen *et al.*, 2010; Yucel *et al.*, 2009)
Provide opportunities for child to *create*, not just *perceive* music	Clinician naturally interweaves production and listening experiences	Integration of perception and production tasks is an efficient practice in spoken language intervention (Robbins, 2009)
Music activities may enhance and regulate emotional state and provide indexical identification clues	Listening to and creating music with clear emotional intent: happy, sad, angry, sleepy Sing songs in different voices: high/low	Relationship exists between music perception and recognition of emotional states (Hopyan *et al.*, 2011), indexical features (Barton and Robbins, 2007)
The child needs opportunities to engage in music experiences with family/interdisciplinary team members	Family is encouraged to share music of their own culture. Family follows through with music experiences to support progress and assist with generalization	Consistent with ecologically oriented strategies (Bruscia, 2014); hybrid approach (Fey, 1986)
Music engages multiple senses	Movement with and without props, attending concerts, drawing while listening to music	Children rely on more than just audition when involved in music. Appealing to many senses strengthens the appeal and supports each child's primary learning style (Schwartz, 2008)

should provide many appropriate models and coach the parents as they sing with their child.

- Use song throughout the infant's typical day: waking up, putting technology on, diaper changes, getting dressed, snacks and mealtimes, playtime and bedtime. Incorporate songs from the child's cultural and family traditions. This is especially important for families who use a home language different from the one the child is exposed to in therapy. Take a simple tune, such as *London Bridge is Falling Down,* and change the words to personalize it or use it for a specific purpose (called a piggyback song). For example,
  - o Now it is time to say good-bye, say good-bye, say good bye.
  - o Now it is time to say good-bye, good-bye Sarah.
- Move, sway, bounce, pat, and rock the baby while singing or listening to recorded music. This helps reinforce the connection between music and movement which is important for beat synchronization to occur in the future.
- Teach nursery rhymes and finger play songs (*Itsy Bitsy Spider, Wheels on the Bus*). In addition to their rhythmic appeal, once the child learns the song, he or she can request it by making one of the gestures. For example, if a child puts his hands together and wiggles his fingers, the therapist/parent will say, 'Oh, you want to sing the *Itsy Bitsy Spider*'. Or if the clinician/parent begins to sing a familiar song out of the child's repertoire and the child accompanies with the proper hand motions, it suggests that the child is able to identify that song through audition
- Resist the temptation to play 'background' music continually, as it clutters the sound environment and encourages an infant to ignore it.
- Emphasize the importance of silence. Like speech, we need pauses to help encourage understanding of concepts like phrasing.

Preschool children

At this stage, the child is very interested in the social opportunities that music making affords. Strategies include:

- Continue singing throughout the day and offer a supply of simple-to-play, but pleasant sounding rhythm instruments that the child can access on her own.
- Turn repetitive phrases used throughout the day into simple songs by adding rhythm and melody: 'Open the door, put your coat on, clean up, where is kitty?'
- Sing familiar songs in different voices (like a lion, a mouse, a mommy, baby, or daddy). Children think this is comical, but in actuality, it teaches them to listen for the 'indexical features' of speech, or the ability to recognize voices based on certain vocal characteristics.
- Use music games to reinforce listening by targeting one of the four levels of auditory function (Erber, 1982). *Detection,* the ability to hear sound or no sound and demonstrate it by a head turn or pointing; *Discrimination,* the ability to recognize difference and similarity between auditory stimuli (cymbal vs. drum); *Identification,* the ability to demonstrate knowledge of what sound is heard (pointing to a picture, or verbally expressing); and *Comprehension,* the ability to make meaning out of the sounds that are heard (hearing a certain sound means it's time to clean up toys). For example, a clinician focused on the Discrimination level might use two very different sounding instruments, (a drum and cymbal) say, 'listen' and play one of the instruments out of the child's sight, then either play the same instrument again, or play the second and ask the child to indicate whether the two sounds were the same or different. If the child is successful at this level, the clinician may modify the task to be one of Identification, wherein the child must specify the sound heard by either pointing to a picture, saying the name, or producing the sound the instrument makes ('boom, boom' for a drum and 'crash' for a cymbal). Children often request this 'No Peeking!' game.
- Use music to reinforce action and relational concepts such as up/down; fast/slow; round and round/ and go/stop.
- Call attention to the steady beat/pulse in music and have the child imitate the therapist/parent by patting knees or playing rhythm sticks.

Primary elementary children

At this stage, school is an important part of the lives of children. They are required to follow multi-step directions and take responsibility for their materials (FM systems, CIs, backpacks, notebooks, lunch, etc.) They must become advocates for themselves when the listening environment is less than optimal. Some children may still lag behind their NH peers in expressive language development. Strategies include:

- Put directives to a simple tune or rhythm. For example, if asking the children to sit on the floor say, *criss-cross applesauce, criss-cross applesauce, criss-cross applesauce, pepperoni pizza!* When passing out or collecting instruments, a rhythmic chant is a quick way to create order, *You TAKE two sticks and you PASS the rest, uh-huh!* (children hit their sticks two times when saying, *uh-huh.*) Or *put your STICKS in the bag and PASS the rest*.
- Continue to work on beat synchronization. Weikart (1987) has researched stages of aural, visual and tactile/kinesthetic decoding in children and notes there are five stages a child must pass through to be deemed *beat competent.* They include: single bilateral symmetrical movement (patting both knees of the body at the same time); single alternating movements (pat one knee and then the other); asymmetrical movements (pat a knee and a foot simultaneously); single asymmetrical tracking movements (alternate patting a knee with one hand and a foot with the other); sequenced bilateral symmetrical movements (pat the knees two times, then the feet two times). These stages are done first in a nonlocomotor way

and then in a locomotor way. A piece of lively, instrumental folk music with a strong steady beat is an enticing way to practice beat synchronization. Using rhythm sticks, or just patting the body, change the movement pattern every 16 beats and when the children are comfortable with that, change every eight beats. Resist the temptation to use more than one word per motions. i.e., knees, feet, etc. saying the word 'watch' on beat 15 or 7 serves as a verbal prompt that the movement is going to change.

- Continue to use music as a way to strengthen timbre recognition. Expand on auditory *identification* by adding many more instruments, and even some that are similar sounding (shaker and scraper, triangle and cymbal) to the 'No Peeking!' game.

Older elementary children

At this age, many children with CIs will be involved in either general education music classes or private music lessons. As clinicians with expertise in working with these students, we can become important resources for the music instructors. Pitch and rhythm training are important aspects of any music curriculum. As indicated previously, children with CIs are less accurate than NH peers in matching pitches and singing in tune, so teaching methods and some objectives may need to be modified (Hsiao and Gfeller, 2011). At the same time, children start to have preferences for popular music from movies, television, and other forms of media. This can have a positive effect on building relationships with NH friends. Other strategies include:

- Using music to convey information of a non-musical nature. Understanding that music's appealing nature allows for multiple repetitions, it is useful in cases where memorization is needed. Children in grade school in the USA are typically required to know the 50 state capitols, a task made much easier by learning a song that contains this information. Similarly, addition or multiplication facts can be sung to a catchy tune and rhythm to help the child master them. Memorizing complicated historical information such as the preamble to the United States constitution becomes a much easier feat when children learn to sing, rather than just say, this passage.
- Using music to build social opportunities and experience. For several years, three friends, all with hearing loss, met with the music therapist weekly to establish a little music group. They chose a name, *The Lucky Sevens* (changed to *The Crazy Eights* when they all turned eight), established a repertoire of several songs and then performed for school and civic functions. Another client, in her pre-teens, spent hours with her NH friends choreographing dance moves to popular music and then performing them for family and school friends.
- Using music composition to capture a child's feelings or experiences. A composition can serve as a finished product to be shared with family and friends. There are several ways to accomplish this
  - o Write and record a song. Some children write songs at home and bring them to the therapy session for the therapist to assist with lyrics, melody and music notation. Other times, the therapist will help the child select a topic or theme for a composition (loss of a pet, hearing devices devoured by a pet, a week at camp). Because the songwriting process will require more than one session to complete, the therapist will monitor the child's behavior and watch for signs that the process is positive and, if not, shelve the creation until a later date. Parents can be helpful partners throughout the process. Once the song is written, an audio or video recording can capture the creation.
  - o Create a *SoundStory* (Barton, 2013). It is possible to write a story based on an event and tell it through musical or environmental sounds alone. For example, the experience of being in a rainstorm has a sequence which therapist and child create (clouds roll in, wind picks up, thunder rumbles, gentle rain, downpour, more thunder, rain lessens, then stops). Then, instruments/sounds are selected to represent the rainstorm, which are then played in sequence and recorded. Upon playback, the listener is able to follow the story through audio alone.
  - o Create a *Music Experience Book* (*MEB*; Barton, 2011). MEBs provide a unique way for parents and their child to develop a personalized resource that will have lasting appeal. The child, parents, and therapist explore a theme for the MEB, such as a vacation, a family event, or even a therapy session. Once the theme has been chosen, parents assist the child in gathering visual and tangible objects to be included in the project. For example, one 8-year-old child wanted to make an MEB about a typical music therapy session. Parents took photos of the child engaged in playing instruments, moving to music and singing. The child then added a narrative to each of the photos. The therapist recorded the narrative and created a PowerPoint with the child's narrative embedded. It was then shared with family and friends.
- Pitch and rhythm training. If a therapist is comfortable working in this area, pitch perception concepts such as same/different, high/low, higher than/lower than may be addressed. Pitch direction (moving up the scale or down) and pitch production concepts such as vocally matching pitches and intervals can be utilized. Rhythmic training can begin with imitation of simple four beat patterns, extending to eight beats. It is useful to add syllables to reinforce duration. For example using 'bee bee bee bee' for four quarter notes and 'spider, spider, spider, spider' for eighth notes. Many elementary music educators use the Kodaly method of saying *ta* (quarter note) and *ti–ti* (eighth notes). Rhythmic notation may be useful in reinforcing the auditory patterns. If a therapist has little or no experience in this realm, then acting as a

resource for music teachers working with the implanted child can still be a valuable contribution.

Conclusions

Music sustains us from the 'cradle to the grave'. It is there when we celebrate the good life and there to sustain us when we falter. It gives us comfort when words fail. We know this intuitively. What research is now telling us is *why* we know this. The studies highlighted in this article, as well as others examining the role of music across the lifespan and particularly in later life, offer explanations for why music is important not only for auditory well-being, but to our physical and emotional health (Alain *et al.,* 2013; Kraus and Anderson, 2014; Strait and Kraus, 2014). Our contention that musical experiences enhance auditory and cognitive development in children with CIs is not a data-based research finding. Rather, we put it forth as a reasonable assumption, based upon the relevant information available to date.

It has been documented that children with CIs consistently have lower music perception scores than do their peers with NH. Two responses to this finding seem to be in order. On the one hand, the finding matters a great deal, because it provides parameters for setting reasonable expectations and highlights the work still needed to be done to improve signal processing with the devices, so that they more accurately transmit music to CI listeners. On the other hand, the finding might not matter much if we assume that music, even in its less-than-optimal state, functions for CI children, as for NH children, as a developmental jumpstarter, a language-learning tool, a cognitive enricher, a motivator, and an attention enhancer. We believe it is possible for these two responses to exist side by side as clinicians and researchers work together to better serve the children in our care.

Do music. Real music. Everyday!

Acknowledgement

The authors thank Derek Houston for helpful comments during the preparation of this manuscript.

Disclaimer statements

Contributors None.

Funding None.

Conflicts of interest CB and AMR disclose that they have served as consultants to Advanced Bionics, LLC.

Ethics approval None.

References

AG Bell Academy 2007. Principles of LSLS Auditory–Verbal Therapy viewed 22 March 2015. http://www.listeningandspokenlanguage.org/AcademyDocument.aspx?id=563

Aigen, K. 2005. Music-centered music therapy. Gilsum, NH: Barcelona Publishers.

Alain, C., Zendel, B.R., Hutka, S. and Bidleman, G.M. 2013. Turning down the noise: the benefit of musical training on the aging auditory brain. *Hearing Research*, 308: 162–173.

Altenmüller, E. and Schlaug, G. 2015. Apollos gift: new aspects of neurologic music therapy. *Progress in Brain Research*, 217: 237–252.

Barton, C. 2011. Music experience book, *First Years.* Unpublished manuscript.

Barton, C. 2013. Children with hearing loss. In: M. Hintz, (ed.). Guidelines for music therapy practice in developmental health. Gilsum, NH: Barcelona Publishers, pp. 233–269.

Barton, C. and Robbins, A.M. 2007. TuneUps™: a music program designed to foster communication development. Valencia, CA: Advanced Bionics, LLC.

Bergeson, T.R., Miller, R.J. and McCune, K. 2006. Mothers' speech to hearing-impaired infants and children. *Infancy*, 10: 221–240.

Bluestine, E. 2000. The ways children learn music: an introduction and practical guide to music learning theory. Chicago: GIA Publications, Inc.

Bruscia, K.E. 1998. Defining music therapy, 2nd ed. Gilsum, NH: Barcelona Publishers.

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

Chen, J.K., Chuang, A.Y., McMahon, C., Hsieh, J.C., Tung, T. and Li, L.P. 2010. Music training improves pitch perception in prelingually deafened children with cochlear implants. *Pediatrics*, 125(4): 793–800.

Cole, E.B. 1994. Encouraging intelligible spoken language development in infant and toddlers with hearing loss. *The Transdisciplinary Journal*, 4(4): 263–284.

Collier, G. and Logan, G. 2000. Modality differences in short term memory for rhythm. *Memory and Cognition*, 28(4): 529–538.

Conway, C., Pisoni, D., and Kronenberger, W. 2009. The importance of sound for cognitive sequencing abilities: the auditory scaffolding hypothesis. *Current Directions in Psychological Science*, 18(5): 275–279.

Corbeil, M., Trehub, S.E., Peretz, I. 2013. Speech vs, singing: infants choose happier sounds. *Frontiers in Psychology*, 4(372): 1–11.

de L'Etoile, S.K. 2006. Infant-directed singing: a theory for clinical intervention. *Music Therapy Perspectives*, 24(1): 22–29.

Driscoll, V., Oleson, J., and Gfeller, K. 2009. Effects of training on recognition of musical instruments presented through cochlear implant simulations. *Journal of the American Academy of Audiology*, 20: 71–82.

Duchan, J.F. 2004. Framework in language and literacy. New York: Guilford Press.

Elliott, D.J. 1995. As cited in Nordoff, P. and Robbins, C. 2007 Creative music therapy: a guide to fostering clinical musicianship, 2nd ed. Gilsum, NH: Barcelona Publishers.

Erber, N. 1982. Auditory training. Washington, DC: AGBell.

Estabrooks, E. and Birkenshaw-Fleming, L. 2003. Songs for listening! Songs for life! Washington DC: AGBell.

Fey, M.E. 1986. Language intervention with young children. Boston, MA: Allyn and Bacon.

Gfeller, K., Driscoll, V., Kenworthy, M. and Van Voorst, T. 2011. Music therapy for preschool cochlear implant recipients. *Music Therapy Perspectives*, 29(1): 39–49.

Glenn, S.M. and Cunningham, C.C. 1983. What do babies listen to most? *Developmental Psychology*, 19: 332–337.

Glenberg, M.A. and Jona, A. 1991. Temporal coding in rhythm tasks revealed by modality effects. *Memory and Cognition*, 19: 514–522.

Gordon, E. 2003. A music learning theory for newborn and young children. Chicago, IL: GIA Publications.

Hillecke, T., Nickel, A. and Bolay, H.V. 2005. Scientific perspectives on music therapy. Annals of the New York Academy of Sciences, 1060: 271–272.

Hopyan, T., Gordon, K.A. and Papsin, B.C. 2011. Identifying emotions in music through electrical hearing in deaf children using cochlear implants. *Cochlear Implants International*, 12(1): 21–26. doi: 10.1179/146701010X12677899497399

Hopyan-Misakyan, T.M., Gordon, K.A., Dennis, M. and Papsin, B. 2009. Recognition of affective speech prosody and facial affect in deaf children with unilateral right cochlear implants. *Child Neuropsychology*, 15: 136–146.

Houston, D.M. 2009. Attention to speech sounds in normal-hearing and deaf children with CIs. In: The 157th Meeting of the Acoustical Society of America, Portland, Oregon.

Houston, D.M. and Bergeson, T.R. 2014. Hearing versus listening: Attention to speech and its role in language acquisition in deaf infants with cochlear implants. *Lingua*, 139: 10–29.

Hsiao, F. and Gfeller, K. 2011. How we do it: adaptation of music instruction for pediatric cochlear implant recipients. *Cochlear Implants International*, 12(4): 205–208.

Hsiao, F. and Gfeller, K. 2012. Music perception of cochlear implant recipients with implications for music instruction: a review of literature. *Update University S C Department Music*, 30(2): 5–10. Doi: 10.1177/8755123312437050

Jung, K.H., Won, J.H., Drennan, W.R., Jameyson, E., Miyasaki, G., Norton, S.J., and Rubinstein, J.T. 2012. Psychoacoustic performance and music and speech perception in prelingually deafened children with cochlear implants. *Audiol. Neurootol.*, 17: 189–197.

Koelsch, S. 2009. A neuroscientific perspective on music therapy. The neurosciences and music III–disorders and plasticity.*Annals of the New York Academy of Sciences*, 1169: 374–384.

Kraus, N. and Anderson, S. 2014. Music benefits across lifespan: Enhanced processing of speech in noise. Hearingreview.com

Kraus, N. and Chandrasekeran B. 2010. Music training for the benefit of auditory skills. *Nature Reviews Neuroscience*, 11: 599–605.

Limb, C.J. 2006. Structural and functional neural correlates of music perception. *Anatomical Record*, 288A(4): 435–446.

Ling, D. 2001. Does auditory–verbal therapy include using music? In: W. Estabrooks, (ed.). 50 FAQs about AVT: frequently asked questions about auditory–verbal therapy. Toronto, ON: Learning to Listen Foundation, pp. 98–103.

Locke, J.L. 1993. The child's path to spoken language. Cambridge, MA: Harvard University Press.

Looi, V., McDermott, H., McKay, C. and Hickson, L. 2008. Music perception of cochlear implant users compared with that of hearing aid users. *Ear & Hearing*, 29: 421–434.

Marin, M.M. 2009. Effects of early musical training on musical and linguistic syntactic abilities. *Annals of the New York Academy of Sciences*, 1169: 187–190.

Mitani, C., Nakata, T., Trehub, S., Kanda, Y., Kumagami, H., Takahasaki, K., *et al.* 2007. Music recognition, music listening, and word recognition by deaf children with cochlear implants. *Ear and Hearing Supplement*, 28(2): 29S–33S.

Mithin, S. 2006. The singing Neanderthals: the origins of music, language, mind, and body. Cambridge, MA: Harvard University Press.

Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S.L., and Besson, M. 2008. Musical training influences linguistic abilities in 8-year-old children: more evidence for brain plasticity. *Cerebral Cortex*, 19(3): 712–23.

Nordoff, P. and Robbins, C. 1971. Creative music therapy: A guide to fostering clinical musicianship, 2nd edition, Gilsum, NH: Barcelona Publications.

Nordoff, P. and Robbins, C. 2007. Creative music therapy: a guide to fostering clinical musicianship, 2nd ed. Gilsum, NH: Barcelona Publishers.

Parbery-Clark, A. Skoe, E., Lam, C., and Kraus, N. 2009. Musician enhancement for speech-in-noise. *Ear and Hearing*, 30: 653–661.

Patel, A.D. 2008. Music, language and the brain. New York: Oxford University Press.

Patel, A.D. 2012. The OPERA hypothesis: assumptions and clarifications. *Annals of the New York Academy of Sciences*, 1252: 124–128.

Phillips-Silver, J. and Trainor, L.J. 2005. Feeling the beat: movement influences infant rhythm perception. *Science*, 308: 1430.

Pollack, D. 1985. Educational Audiology for the limited-hearing infant and preschooler. Springfield, IL: Charles C. Thomas Pub.

Robbins, A.M. 2009. Rehabilitation after cochlear implantation. In: J. Niparko, (ed.). Cochlear implants: principles and practices. Philadelphia, PA: Lippincott Williams, pp. 267–312.

Rocca, C. 2006. Music time. Berks: Mary Hare School.

Schwartz, E. 2008. Music, therapy, and early childhood: a developmental approach. Gilsum, NH: Barcelona Publishers.

Segal, O. and Kishon-Rabin, L. 2011. Listening preference for child-directed speech versus nonspeech stimuli in normal-hearing and hearing-impaired infants after cochlear implantation. *Ear and Hearing*, 32(3): 358–372.

Sloboda, J. 2005. Exploring the musical mind. Oxford, UK: Oxford University Press.

Strait D. and Kraus N. 2011. Playing music for a smarter ear: cognitive, perceptual and neurobiological evidence. Music Perception, 29(2): 133–146.

Strait, E. and Kraus, N. 2014. Biological impact of auditory expertise across the lifespan: musicians as a model of auditory learning. *Hearing Research*, 308: 109–121.

Strait, D., Kraus, N., Skoe, E. and Ashley, R. 2009. Musical experience promotes subcortical efficiency in processing emotional vocal sounds. *The Neurosciences and Music III–Disorders and Plasticity Annals of the New York Academy of Sciences*, 1169: 209–213.

Thaut, M.H. 2008. Rhythm, music and the brain. New York: Routledge.

Thaut, M.H. and Abiru, M. 2010. Rhythmic auditory stimulation in rehabilitation of movement disorders: a review of current research. *Music Perception*, 27: 263–269.

Thompson, W.F. 2009. Music, thought and feeling: understanding the psychology of music. New York: Oxford.

Tierney, A.T. and Kraus, N. 2013. The ability to tap to a beat relates to cognitive, linguistic, and perceptual skills. *Brain & Language*, 124: 225–231.

Trainor, L.J., Clark, E.D., Huntley, A. and Adams, B.A. 1997. The acoustic basis of preferences for infant-directed singing. *Infant Behavior and Development*, 20(3): 383–396.

Trainor, L.J., Shahin, A.J. and Roberts, L.E. 2009. Understanding the benefits of musical training: effects on oscillatory brain activity. Annals of the New York Academy of Sciences, 1169: 133–142.

Trehub, S.E. 2013. Communication, music and language in infancy. In: Arbib (ed.). Language, music and the brain. Strungmann Forum Reports, vol. 10, Cambridge, MA: MIT Press.

Trehub, S. and Gudmundsdottir, H.R. 2015. Mothers as singing mentors for infants. In: G. Welch, D.M. Howard and J. Nix (eds.). The Oxford Handbook of Singing. DOI 10.1093/oxfordhb/9780199660773.013.25.

Volkova, A., Trehub, S.E., Schellenberg, E.G., Papsin, B.C. and Gordon, K.A. 2013. Children with bilateral cochlear implants identify emotion in speech and music. *Cochlear Implants International*, 12(1): 21–26.

Wang, D.J., Trehub, S.E., Volkova, A. and van Lieshout, P. 2013. Child implant users' imitation of happy- and sad-sounding speech. *Frontiers in Psychology*, 4(351): 1–8.

Weikart, P.S. 1987. Round the circle: key experiences in movement for children. Ypsilanti, MI: High Scope Press.

Woodruff Carr K., White-Schwoch T., Tierney A., Strait D.L. and Kraus, N. 2014. Beat synchronization predicts neural speech encoding and reading readiness in preschoolers. *Proceedings of the National Academy of Sciences*, 111(40): 14559–14564.

Wright, R. and Uchanski, R.M. 2012. Music perception and appraisal: Cochlear implant users and simulated CI listening. *Journal of American Academy of Audiology*, 23(5): 350–379.

Yucel, E., Sennaroglu, G. and Belgin, E. 2009. The family oriented musical training for children with cochlear implants: speech and musical perception results of two year follow-up. *International Journal of Pediatrics Otorhinolaryngology*, 73(7): 1043–52. doi: 10.1016/j.ijporl.2009.04.009. Epub 2009 May 2.