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Music Therapy for Preschool Cochlear Implant Recipients

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Abstract

This paper provides research and clinical information relevant to music therapy for preschool children who use cochlear implants (CI). It consolidates information from various disciplinary sources regarding (a) cochlear implantation of young prelingually-deaf children (~age 2-5), (b) patterns of auditory and speech-language development, and (c) research regarding music perception of children with CIs. This information serves as a foundation for the final portion of the article, which describes typical music therapy goals and examples of interventions suitable for preschool children.

Introduction

The cochlear implant (CI) is an assistive hearing device designed for persons with severe-to-profound losses (typically bilateral) who receive marginal to no benefit from conventional hearing aids.[1], [2] In the United States, roughly 23,000 adults and 15,500 children have been implanted (National Institutes of Deafness and Other Communication Disorders, 2009). An important trend is earlier age of implantation. Children have been implanted as young as 4 months of age (Colletti, 2009), though implantation between 12 to 24 months is more common. Preschool children who use CIs have emerged as a growing population in typical and special needs classrooms. Furthermore, recent studies have suggested potential benefits of music training for this population (Abdi, Khalessi, Khorsandi, & Gholami, 2001; Chen et

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[1]The issue of whether or not children should receive cochlear implants is a complex issue that includes cultural, familial, community, and cultural as well as medical factors.
In 2000, The National Association of the Deaf published a position on cochlear implants, which included the following statement: “The NAD recognizes the rights of parents to make informed choices for their deaf and hard of hearing children, respects their choice to use cochlear implants and all other assistive devices, and strongly supports the development of the whole child and of language and literacy. Parents have the right to know about and understand the various options available, including all factors that might impact development. While there are some successes with implants, success stories should not be over-generalized to every individual.” The following website provides a more in-depth position regarding factors to consider and pros and cons: http://www.nad.org/issues/technology/assistive-listening/cochlear-implants.
This article does not focus on the pros and cons of implantation, but rather provides practical information that can be helpful to music therapists whose caseload includes preschool children who have already been implanted. The aforementioned position statement by NAD provides a useful point of reference for familiarizing one’s self with the complex issues surrounding implantations.
[2]More detailed descriptions of the CI can be found in other sources (Gfeller, 2000; Wilson, 2000).

al., 2010); consequently, music therapists are increasingly likely to work with young implant recipients in clinical or educational settings.

Optimally, a music therapist will collaborate with hearing professionals (audiologists, speech-language pathologists, deaf education specialists, otologists) in determining goals, objectives, and interventions appropriate for each child. In order to make appropriate clinical choices and to communicate effectively with other professionals and parents, music therapists require the following information: (a) technical knowledge about CIs and how young children develop auditory perception following implantation; (b) typical communication goals established by speech-language pathologists and audiologists; and (c) empirical findings regarding the music perception and enjoyment of pediatric CI recipients. Because CIs do not transmit a “normal” representation of musical sounds, music therapists should be familiar with research regarding perception and enjoyment, and how perceptual differences can influence clinical practice.

At present time, the overwhelming majority of articles regarding music perception of CI recipients appears in journals and proceedings published outside the field of music therapy. Consequently, for busy music therapists, many who serve clients with a variety of disabilities, locating and keeping abreast of research relevant to preschool children with CIs can be problematic. This article provides a consolidated source of information that can inform assessment and the selection of goals, objectives, and interventions appropriate for young (~age 2-5) prelingually-deaf children who use CIs.

CIs and Preschool Children: Auditory Development

Technical characteristics of the CI

Music therapists who work with this population should be familiar with the technical characteristics of CIs and how they differ from conventional hearing aids. As noted previously, this information informs clinical decisions, and is often relevant during professional interactions with families and other professionals. A conventional hearing aid, which is worn externally, amplifies sound, using an acoustic pathway to deliver the signal via the ear canal. In contrast, the CI system has both an externally-worn sound processing unit (often referred to as a speech-processing unit) and surgically-implanted internal parts.[3] CIs provide direct electrical stimulation to the stereocilia (hair cells/sensory cells) in the cochlea (Gfeller, 2000).

The external portion of the CI includes a sound processor (a miniature computer), the microphone, a controller, and a transmitting coil with a magnet, which is worn behind the ear. The sound processor, which includes controls for loudness, is powered by batteries that must be changed regularly. The external portions of the CI pick up the acoustic signal, extract and process the features of the sound most salient to speech perception, and transmit the processed signal to the internal array in the cochlea (Gfeller, 2000; Gfeller & Darrow, 2008).

The external portions can be removed when the child sleeps, swims, bathes, or for repair. However, when the external components are removed, or if the batteries die, the child will be unable to hear sound. Therefore, it is important that the child use a properly activated CI during music therapy or other music experiences. Music therapists should confer with a

[3]The selection criteria for implantation have changed somewhat over the past decade in that persons with more residual hearing (e.g., up to 30 or 40% accuracy on word recognition) are now considered suitable candidates for CIs. Some CI recipients, with sufficient residual hearing, use hearing aids in conjunction with their cochlear implant.

hearing professional in order to learn basic management of the device, including parts of the device (e.g., controls on the sound processor), basic device care, and battery use.

The internal portions of the CI include the receiver-stimulator bundle, which is surgically implanted under the skin into a bony portion of the skull behind the ear, and the electrode array, which is inserted into the cochlea. The electrode array has between 6 and 22 electrodes and transmits frequencies ranging from approximately 120 to 8000 Hz. While this is an important frequency range for speech sounds, it is considerably narrower that the frequencies associated with music (around 27-16,744 Hz) (White, 1970). The pattern of stimulation presented within the cochlea is then transmitted via the 8^{th} nerve (auditory nerve) to the brain, where the sounds are interpreted for meaning. The CI does not cure deafness (i.e., when the device is turned off, the child is functionally deaf), nor does it instantly restore a functional level of hearing.

Surgical implantation often follows an evaluation of extent of benefit from conventional hearing aids. If this assessment reveals that the child receives minimal benefit from hearing aids, implantation may be considered. After surgical implantation of the internal components, there is typically a brief period of recovery (between two weeks and one month). Once the surgical site has healed, the recipient returns to the CI center to have their external components activated by an audiologist. During the initial activation of the sound processing unit, the patient’s processor is programmed so that it transmits a comfortable and beneficial pattern of stimulation.

The parameters of stimulation (e.g., the rate of stimulation and pulse-width of the signal), along with other components are referred to as the patient’s MAP, or program. Through the programming process, the audiologist determines the thresholds (the smallest amount of stimulation required to detect sound) as well as comfort levels (the largest amount of stimulation that can be tolerated) that will be transmitted to each CI user’s internal array.[4] In addition, specific frequencies will be distributed to the array of 6 to 22 electrodes which are implanted in the cochlea. For example, one electrode may be stimulated in response to acoustical sounds in the environment ranging from approximately 1300 to 1600 Hz, while the neighboring electrode may cover frequencies of approximately 1600 to 2100 Hz (Tyler et al., 2010). While a normal ear can detect very small changes in pitch over a range of 20 to 20,000 Hz, the CI has only a small number of electrodes that stimulate a fairly narrow frequency range (approximately 120 to 8000 Hz). As will be discussed in greater detail later in the paper, the technical features of the electrode array are problematic for music, especially for perception of pitch and melody (Gfeller et al., 2007).

Adjusting to the sound transmitted by the CI

Children with congenital or prelingual severe-to-profound sensorineural hearing loss have typically had little if any stimulation to their auditory systems prior to implantation, and therefore react differently than adult CI recipients to initial stimulation. The initial activation of the device comprises a major perceptual change for children with congenital or prelingual deafness. The sudden presence of sound is a new perceptual experience that will require adjustment (acclimatization) in order to interpret the acoustic stimulation and as a result, giving it meaning. What is that sensation? Where is it coming from?

Because auditory skills will develop gradually as a result of listening experience, young implant recipients typically have frequent sound processor programming sessions in the first year of implantation (approximately 8-10 visits). These programming sessions (changes in

[4]The terms used to describe the threshold and comfort levels can differ depending upon the type of device used, and the terms used by the manufacturer of a given device.

the MAP), can alter percepts of loudness, tone quality, and sometimes pitch. Visits may include assessment of speech perception, speech production, and language development as well as sound processor programming and troubleshooting. After the first year, visits are more likely to take place on an annual basis unless problems arise that require additional attention. The information gathered in these assessments may provide important clinical input for music therapists in understanding the child's on-going development of perceptual capabilities, which should influence the choice of appropriate goals and objectives in music therapy.

While CIs are, generally speaking, quite effective in supporting speech perception, clinicians need to keep in mind that the sounds transmitted through the CI are not the same as those heard by normal-hearing (NH) children. For some recipients, initial stimulation from the CI is perceived as a tactile rather than an auditory sensation. Those who do perceive the signal as sound may hear beeps or other noises (e.g., a radio station not tuned-in properly; or Mickey Mouse/computer-like speech). Over time, the quality of the sound may change. The sounds often become more "natural" over time as the recipients' brains becomes accustomed to the sound and as they gain more experience with speech and other sounds in their environment. The notion of "natural" is relative, however. While postlingually-deaf individuals can compare the CI signal to their mental memory of "normal" sounds, children who have grown up listening through a CI do not have a "normal" idea of sound characteristics such as discrete pitches, and tone quality (Gfeller, 2000).

For persons with severe-to-profound hearing losses, the CI is much more effective than hearing aids in the detection of sound, especially those speech sounds in the higher frequency range (Robbins, 2009). Nevertheless, CI recipients vary with regard to the extent of benefit they will receive in auditory acuity. Implant benefit is influenced by the recipient's (a) hearing history (e.g., age at implantation, length of deafness, cause of deafness, previous experience with sound or lack thereof), (b) health of the auditory system (e.g., hair cell and nerve survival), (c) variables related to the CI (e.g., placement of the electrode array within the cochlea), and (d) environmental circumstances (e.g., access to therapy services, and involvement of family and educational professionals) (Kirk & Choi, 2009;Ryugo & Limb, 2009). Consequently, the capabilities and needs of CI recipients of similar age and with similar devices can vary considerably.

Auditory input from the CI as well as aural habilitation influences the rate of speech and language development. The following section focuses on speech and language development as well as aural rehabilitation.

Speech and Language Development and Habilitation of Young CI Recipients

Because the primary therapeutic needs of most CI recipients are likely to be in the area of speech and language, a music therapist who works with this population should and be ready to collaborate closely with the audiologist or speech language pathologist (SLP) and understand the habilitation process. The audiologist or SLP can provide important assessment of the child's development based on their chronological age, hearing age, and hearing ability as well as key goals and objectives that can in turn inform music therapy practice.

Children with CIs will develop speech and language goals at different rates and to a greater or lesser extent (Tyler et al., 1997). Therefore, goals and objectives for hearing, speech, and language need to be individualized for each child and modified over time. However, even the best CI users will require some direct accommodation and habilitation in order to achieve milestones similar to normal hearing children in speech perception and production, language, and language arts (e.g., reading and writing) (Kirk & Choi, 2009).

Young recipients of CIs may require up to a year or longer of listening experience with the implant before they produce their first words. Because of an initial period of auditory deprivation (prior to implantation), the child's "hearing age" and auditory milestones will not be equivalent to what one would expect for their chronological age. Children who are prelingually deaf show the greatest gains in the first 3 years following implantation, whereas those who were post- or peri-lingually deaf show the greatest gains in the first year after implantation (Fryauf-Bertschy, Tyler, Kelsay, & Gantz, 1992).

Optimal benefit from a CI is dependent upon ample experience in using the device on a regular basis over time (Fryauf-Bertschy & Tyler, 1997; Quittner & Stech, 1991). Experiences should include numerous social and educational opportunities to communicate verbally, as well as ongoing and appropriate exposure to environmental stimuli (e.g., environmental sounds such as sounds of cars, dogs barking, ringing phones, door bells, etc.) including music. Through ongoing exposure to sounds, children can eventually master awareness, discrimination, recognition, and comprehension of words and environmental sounds in their lives (Langman, Quigley, & Souliere, 1996).

Speech-language therapy and aural (re)habilitation of young children with implants focus on both perception and production of speech. Therapy goals (which are also relevant to music therapy) include: detection (sound/no sound), discrimination (e.g., determining whether or not two sounds are the same), identification (recognizing a sound) and comprehension (the meaning of a sound, such as a knock on the door meaning a request to enter) (Gfeller & Darrow, 2008; Robbins, 2009).

Detection, the most basic goal, is being able to determine the presence or absence of sound. When initially presenting sounds to aid detection, many clinicians recommend an approach referred to as an "auditory sandwich" (Koch, 1999). Through this approach, the therapist first presents the sound without any visual cues, and then introduces the sound within view of the child to promote the mental pairing of the source and its sound. Finally, the therapist presents the sound once again, but without the visual cues, thereby creating a "sandwich" of auditory only, auditory and visual, and auditory only again. This approach may also be appropriate to use in some music therapy interventions.

After establishing skills of sound detection, the therapist can focus on discrimination. Discrimination is the determination of whether two or more sounds are the same or different. Identification involves being able to recognize what has produced the sound, based upon distinctive acoustic features. The final goal, comprehension, requires that the listener understands the "meaning" or significance of a particular sound (such as a knock or door bell meaning that you should go to the door to greet a visitor).

Speech production goals for CI recipients are similar to those of hearing aid (HA) recipients. They include production of: stress patterns, consonants, vowels, syllable number identification, intonational contour/pitch variation, pattern matching, and consonant strings that include reduplicated patterns (e.g., baba) followed by variegated strings (e.g., oh my, baby) (Tomblin, Barker, Spencer, Zhang, & Gantz, 2005).

Clinicians can expect to see wide variation in rate of improvement and patterns of development for speech reception, production and language in children with either HAs or CIs, though CI recipients may benefit to a greater extent than HA users with regard to incidental learning from acoustic input. CIs are well suited to transmit the most salient features of speech. Improvements in CI technology over the past decade as well as changes in CI candidacy have both contributed to impressive documented benefits in speech perception and production for many CI users, especially in quiet listening conditions (Robbins, 2009). Background noise, however, will compromise the listening acuity for CI users (Fetterman & Domico, 2002; Turner, Gantz, Vidal, Behrens, & Henry, 2004). This can be a particular problem in classrooms or in group therapy, which by nature are filled with environmental noises.

Auditory, speech and language goals can be addressed in a variety of settings such as speech-language therapy, through a rich communicative environment in the child's home, in preschool programs that foster interactions with adults and peers, and in early childhood music and music therapy. When using music as a therapeutic intervention for young CI recipients, it is important to understand the technical limitations of the CI with regard to music perception and enjoyment. Because technical characteristics of the CI are not ideally suited to transmitting particular features of music, accommodations and realistic expectations are essential to success in musical settings The next section will provide a summary of research regarding music perception, enjoyment, and production of children who use CIs, along with practical implications for choosing or modifying musical stimuli and types of activities.

Music Perception, Enjoyment, and Participation of Pediatric CI Recipients

A growing body of research on music perception and enjoyment of pediatric CI recipients can help in the selection of appropriate musical materials and appropriate expectations for clinical outcomes. At present time, little empirical evidence is available specific to preschool CI recipients. However, studies of school-aged children help predict which aspects of music will be most accessible to preschool recipients as long as developmental differences in cognitive, communicative, behavioral and music skills of school-aged and preschool children are also taken into account. For example, even normal hearing (NH) youngsters of age 3 or 4 will have difficulty singing the melodic contour and exact intervals of simple nursery songs with complete accuracy. NH youngsters of age 3 or 4 may also have difficulty understanding the musical concept of high and low (versus high and low as a spatial construct). Thus, one would not expect complete competency by most preschoolers on some types of musical tasks regardless of hearing status.

The following section describes empirical findings from group studies regarding music perception of CI recipients. These findings imply general guidelines for which musical sounds are most accurately perceived and enjoyed for the majority of CI users. However, CI recipients do vary considerably with regard to music perception and enjoyment, thus, individualized dynamic assessment is important in order to provide the most appropriate interventions and/or accommodations for each client.

Rhythm perception of CI recipients

Of all the structural features of music, rhythm is the most accessible to children with hearing losses, with or without assistive hearing devices. Because rhythm can be readily perceived as a tactile sensation as well as aurally, even profoundly deaf children can garner experience with rhythm prior to implantation. Activities such as playing drums or other rhythm instruments can also include a clear visual representation of the rhythm as the instrumentalist plays the beat, or shakes the maraca (Gfeller & Darrow, 2008).

With regard to CIs, the device is technically well-suited for transmitting the basic beat or melodic rhythm of music. Children with CIs are similar to NH children in the perception of rhythmic information such as basic beats, rhythm patterns, or melodic rhythms that are presented at tempos that would be considered typical for music repertoire (as opposed to temporal tasks in psychophysical testing) (Gfeller, Witt, Spencer, Stordahl, & Tomblin, 1999; Gfeller et al., 2000; Gfeller, 2000; McDermott, 2004; Olszewski, Gfeller, Froman, Stordahl, & Tomblin, 2005; Olszewski, Gfeller, & Driscoll, 2006; Stordahl, 2002). Pediatric

CI recipients enjoy participating in musical activities that have a strong rhythmic component (such as movement or playing rhythm instruments). Specific to early childhood, parents report that preschoolers may sway or “dance” to the beat of the music, or clap or play simple patterns on rhythm instruments (Gfeller et al., 2000; Gfeller, 2000).

In short, developmentally appropriate rhythm-based activities can be an area of successful participation for young children with CIs. Rhythmic activities have the advantage of multi-sensory (tactile, visual, auditory) perceptual input. However, levels of loudness do need to be monitored. Loud volume can result in distorted sound quality or discomfort (Gfeller, 2000). The clinician or educator should observe the child’s facial expressions or gestures to ensure that instruments and sound equipment are being played at a level comfortable for the child, and/or turn down the volume on the implant as needed.

Perception of song lyrics

Song lyrics provide children with playful and natural exposure to vocabulary acquired in the preschool years. Because speech sounds are effectively transmitted through current implant technology, it is not surprising that the lyrics of songs are often more accessible to CI recipients than pitches or melodic patterns (Olszewski, Gfeller, Froman et al., 2005). School-aged pediatric CI recipients can recognize familiar nursery songs most readily when the song lyrics are included (Olszewski, Gfeller, Froman et al., 2005; Olszewski, Gfeller, & Zhang, 2005; Trehub, Vongpaisal, & Nakata, 2009). Thus, the presence of lyrics can be a distinct advantage as young implant recipients engage in music activities.

The availability of lyrics does not guarantee accurate song recognition, however. Word recognition can be more difficult if the vocabulary within the songs is unfamiliar or within complex syntactical form. Songs should initially be chosen with lyrics appropriate to current development. More unique or complex linguistic structures should be introduced especially carefully and with suitable visual aids, meaningful gestures, or simple explanations to support the child’s participation (Gfeller, Olszewski, Turner, Gantz, & Oleson, 2006; Vongpaisal, Trehub, & Schellenberg, 2006).

Singing (as opposed to speaking) can alter prosody (inflection), timing, and production of lyrics (Gregg & Scherer, 2006), which can in turn compromise intelligibility and ease of speech reading (often referred to as lip reading), especially when development of speech recognition is still tentative. Therefore, a music therapist or educator should sing with a “natural” vocal quality and avoid over enunciation, which may hinder speech reading. It may also help to pair song lyrics with visual aids, or to initially say the lyrics prior to singing in order to help the child pick up the key vocabulary in a given song. Multiple repetitions and singing the song at a moderate or slower tempo can help the child process the sounds. If using recorded songs, select songs that are presented at moderate tempi and with clear articulation (Gfeller, et al., 1999).

Background accompaniment can also compromise perception of the lyrics because it can mask (cover up) the words of the song (Fetterman & Domico, 2002; Gfeller et al., 2008). Starting the song *a capella* and gradually layering the rhythmic component gives a child a greater chance of mastering the lyrics before adding on competing background music. In summary, song lyrics can be helpful in perceiving, enjoying, and singing along to music as long as the vocabulary is suitable and efforts are made to support comprehension (e.g., clear singing style, minimal background accompaniment, etc.).

Timbre perception and appraisal

While NH infants are able to recognize changes in musical timbres as early as 12 months of age, discrimination (same or different), recognition (identification of the sound source), and appreciation (ratings of sound quality) of instrumental timbre can be problematic for implant recipients. The unique tone qualities that we associate with each musical instrument are poorly represented or omitted in CI signal processing (Gfeller, 1997; Looi, McDermott, McKay, & Hickson, 2008b).

Pediatric implant recipients can often hear the difference between two very distinctive instrumental sounds (such as a piano vs. a violin). However, it can be difficult to differentiate between more similar sounds (such as a maraca vs. the shaking jingles on a tambourine, or a flute versus a clarinet). In addition, CI recipients are significantly less accurate than normal hearing persons on identification of the sounds source ("What instrument did you just hear?") (Gfeller, Knutson, Woodworth, Witt, & DeBus, 1998). Therefore, discrimination or recognition tasks should begin with comparisons of instruments with distinctly different timbral characteristics (e.g., a maraca and a drum beat, as opposed to a maraca vs. an egg shaker). As the child increases perceptual acuity, more difficult comparisons can be used, especially when training is paired with dynamic assessment.

Although timbre perception is not "normal" through an implant, the CI provides enough spectral information that pediatric CI recipients can improve recognition of different musical instruments as a result of training and direct and focused exposure to musical instruments (Gfeller, Witt et al., 2002; Gfeller, Knutson, Oleson, Olszewski, & Breheny, 2006; Olszewski et al., 2006). Thus, music therapists and educators can assist young CI recipients in recognition of various musical instruments as long as the sound qualities of the different instruments are adequately distinct within the CI signal.

If sound recognition is a goal for the child's aural habilitation, the music therapist should consult with the audiologist or speech-language pathologist regarding different methods for introducing sounds in a manner consistent with their program. For example, verbotonal approaches emphasize listening to the sound prior to providing visual cues (the auditory sandwich) (Asp, 1985), while in other protocols; it may be preferable to present the musical stimuli simultaneously with the visual cues (Grant, Walden, & Seitz, 1998; Norrix, Plante, Vance, & Boliek, 2007).

The enjoyment of musical sounds is as fundamental to successful participation in music therapy or education as is perceptual accuracy. If music sounds like noise, or is harsh or shrill, children will be unlikely to engage in music listening or production. Some instruments sound more pleasant to CI recipients than others, (as is also the case for NH children), and individual CI recipients will also report individual preferences (Gfeller et al., 1998; Gfeller, 1998; Looi, McDermott, McKay, & Hickson, 2008a; Looi, et al., 2008b). Many children with CIs do like listening to music (Gfeller et al., 1999), though some sounds may be more pleasant than others. Through trial and error or simple assessment, therapists and educators can determine which instruments sound most pleasant to their young clients.

Pitch and melody perception

Listening to and singing children's songs are favorite pastimes of most children. The youngest of infants respond with cooing and facial expression in response to caregiver lullabies. By age 4, melodies are becoming increasingly accurate and recognizable with regard to melodic contour and exact interval changes. With proper training, NH children can eventually develop impressive levels of precision in singing with or without an external pitch (Campbell & Scott-Kassner, 1995). These sorts of tasks that seem effortless for NH children are the most challenging and problematic, however, for young children who use CIs. Because of the technical characteristics of CIs, most pediatric CI recipients are unlikely to develop at the same rate or advance to the same level of achievement as NH children with comparable training in this musical domain.

As stated earlier, CIs are technically ill-suited for transmitting pitch. Several aspects of implant design contribute to this problem. First, the CI covers a limited range of approximately 120 to 8000 Hz (the frequency range associated with salient speech sounds). Thus, many of the fundamental frequencies of instruments played in the orchestra or on the piano (27 to 16,744 Hz) are not represented via the internal electrode array. The fundamental frequencies played by many instruments in the bass or tenor range will not even be conveyed via the implant.

Another problem with pitch perception, even for those frequencies within the implant's frequency bands, has to do with pitch resolution (how small of a pitch change can be detected). Many implant recipients have difficulty perceiving small changes (Gfeller et al., 2008). The implant has between 6 to 22 electrodes, and each electrode in the cochlear array is assigned a broad range of frequencies. For example, one electrode can be mapped to result in stimulation for as many as 8 to 10 semitones. Consequently, an implant recipient may perceive two tones a perfect fourth apart as sounding like essentially the same pitch.

In most studies, recipients of CIs are significantly less accurate than NH listeners at detecting pitch change (frequency difference limens), as well as determining direction of a pitch change (i.e., whether the second pitch of a pair of notes is higher or lower than the first) (Gfeller et al., 2002; Looi, McDermott, McKay, & Hickson, 2004; McDermott & Looi, 2004). The concept of higher and lower, or interval size, is even more problematic for prelingually-deaf children whose entire hearing history is through a CI, and who have therefore never heard a normal representation of pitch.

As a group, CI recipients are significantly less accurate in pitch perception tests than normal hearing persons; however, there is considerable variability among CI recipients when it comes to pitch perception. Some implant recipients report hearing no real pitch (notes sound more like a booming or percussive sound); others may hear a change in sound quality rather than what normal hearing people characterize as pitch change. Still other implant recipients can hear a change in pitch as long as the interval changes are large enough. Implant recipients may also hear pitch reversals (meaning that an interval change that is higher may actually sound lower, or vice versa) or interval changes that (in comparison with NH listeners) are altered or compressed. A very small proportion of CI recipients achieve surprisingly accurate pitch perception, though their accuracy may vary depending upon which frequencies are presented (e.g., greater accuracy in a higher pitch range) (Gfeller, Turner et al., 2002) as well as whether they have had specialized music training that has been suitable for the child's capabilities (Rocca & Tucker, 2008).

Research indicates that some CI recipients can improve pitch perception with training, but there is considerable variability among CI recipients, and the level of perceptual accuracy remains significantly poorer than that of NH persons (Galvin, Fu, & Nogaki, 2007; Galvin, Fu, & Shannon, 2009). Interestingly, group data indicate little difference in pitch perception as a result of the particular brand or type of signal processor used. Objective data document that a select number of CI users of each of the primary types of devices (Advanced Bionics, Cochlear, MedEl) obtain exceptional benefit for music perception and/or enjoyment. In addition, case studies indicate that individual users may find one processor or MAP superior to another (e.g., Gfeller & Lansing, 1991; Gfeller, Lansing, Fryauf-Bertschy, & Firszt, 1991; Gfeller & Lansing, 1992;Gfeller & Witt, 1997; Gfeller et al., 2002; Kong, Cruz, Jones, & Zeng, 2004; McDermott, 2004); however, these individual cases should not be generalized to most CI recipients. Popular media stories and marketing information about a "star" user (who may be more an exception than the rule) can be very persuasive. Unfortunately, this sometimes results in unrealistic expectations and parents making unfair comparisons (Gfeller, et al., 2008).

Because melodies are made up of pitches, it is no surprise that CI recipients (regardless of device type) are significantly less accurate than NH non-musicians in recognition of melodies, especially when lyrics or rhythmic cues are unavailable (Fujita & Ito, 1999; Gfeller et al., 2002; Kong et al., 2004; McDermott, 2004; Olszewski, Gfeller, Froman et al., 2005; Pijl, 1997; Schultz & Kerber, 1994). However, some CI recipients make excellent use of rhythmic cues or context (e.g., situational cues such as a birthday cake in recognizing the song, "Happy Birthday).

How do these research findings apply to music therapy and education? CI users may have difficulty with the detection of small pitch differences (such as hearing changes in pitch between two neighboring notes on a xylophone or piano, based upon auditory cues only), labeling the direction or size of pitch changes (including melodic contours), or recognizing melodies based upon pitch patterns alone. Some children may show some improvement in pitch-based tasks as a result of training, but others may not, in large measure because of limitations with their implant or peripheral hearing mechanism.

Singing

Given the problems with pitch perception, it is not surprising that singing in tune is perhaps the most daunting task for many CI recipients (even for "star" users who exceed expectations on many music tests). Some CI recipients who have been quite successful in playing some instruments (e.g., piano) have found participation in a choir extremely difficult (Gfeller et al., 2006). One study by Nakata et al. (2005) indicated that young CI recipients ages 4 to 9 were significantly less accurate than children with normal hearing in pitch matching, accuracy of pitch contour and singing exact intervals. Another by Xu et al. (2009) revealed similar results in children ages 4 to 8 compared to normal hearing peers, but found no significant difference in rhythm-based measures. Some clinicians have reported that implanted children have been able to improve melodic pattern production as a result of practice over many months (Rocca & Tucker, 2008). Interestingly, clinical observation indicated that accuracy was better within a particular frequency range.

Despite these limitations, young CI recipients can enjoy singing activities in preschool music programs. After all, even very young children with normal hearing do not match external pitches or sing melodies with consistent precision (Campbell & Scott-Kassner, 1995; McDonald & Simons, 1989). In most cases, music therapists and educators encourage preschool children to participate at their current level of competence during group singing, with little concern about pitch accuracy. Consequently, although young CI recipients may not replicate the actual melody, implanted preschoolers can typically enjoy participating in preschool singing activities. Singing provides an opportunity for young CI recipients to practice speech production (e.g., stress, duration, inflection, articulation) as well as use of vocabulary and syntax. Furthermore, singing beloved songs of childhood exposes children to an important part of their culture.

Music enjoyment and participation

CI recipients vary considerably not only in perceptual accuracy, but also with regard to music enjoyment and participation. Some children have a complete lack of interest in music, while other children love music, and are actively involved in many musical activities (Gfeller, 2000). Studies indicate that pediatric CI recipients participate in music classes or groups, listening to recordings, watching music videos, attending programs, and dancing (moving) to music. CI recipients with some residual hearing may also find music more pleasant in quality when hearing aids are used in conjunction with their CI (Gfeller et al., 2008; Gfeller, 2009; Looi, et al., 2008b).

Given the differences from one CI recipient to the next, a music therapist should not only understand “typical” results from group data, but also assess the music perception and enjoyment capabilities of each child. For example, a child who dislikes the sound of a triangle may well enjoy playing a drum. Some experimentation and careful observation by the therapist and parents can help to determine which children will most benefit from participation in early childhood music or music therapy programming for young children.

In conclusion, research regarding music perception and enjoyment of pediatric CI recipients suggests a number of guidelines with regard to preschool CI users. First, clinicians and educators should account for the fact that CIs transmit some aspects of music better than others. That being said, CI recipients vary in music perception and enjoyment. With suitable accommodations, and developmentally-appropriate objectives, most implanted children can enjoy and successfully participate in some types of musical activity. Using this information as a foundation for determining capabilities, needs, and most suitable aspects of music, the following section presents examples of music therapy goals, objectives, and interventions suitable for young CI recipients (ages 2-5) who are congenitally or prelingually deaf.

Music Therapy Interventions for Preschool CI Recipients

Ideally, a music therapist will have an opportunity to collaborate with the audiologist or SLP when working with a pediatric implant recipient. Through collaboration, the music therapist can learn in greater depth about the hearing history of the child, as well as their current level of development in listening, speech and language. The audiologist or SLP can also provide important insights regarding the communicative priorities for habilitation, and specifics regarding the child’s implant. In turn, the music therapist can explain typical musical development to the treatment team and parents, helping them to understand that some aspects of development (e.g., pitch perception) are likely to be slower or different in children who use CIs. The music therapist can also provide guidance on how music therapy can reinforce speech and language goals.

In order to determine whether music therapy is an appropriate choice, and which goals and objectives might be suitable for music therapy, the music therapist would benefit from reviewing or discussing available audiological and speech-language assessments. Music therapy assessment can be administered for other functional areas most likely to be addressed in music therapy sessions (e.g., social skills) that have not already been addressed by prior assessment. The music therapist can also establish a profile of response to those instruments likely to be used in music to determine preferred sounds that are more likely to be engaging and motivating.

If music therapy is determined to be a suitable treatment option, then the following issues should be worked out in collaboration with the team:

- What mode of communication (oral only, total communication, cued speech, other?) or therapeutic methodologies (e.g., verbotonal, other) will be used?
- What steps should be taken to check and maintain proper functioning of the implant and/or hearing aid (e.g., battery use, etc.)?
- Will special sound equipment such as FM systems be used?
- How can the acoustic environment of the room be optimized (reducing echo, background noised, etc.)?
- What will be the role of the parents in the sessions (e.g., sitting in on the sessions, observing)?

- What is a suitable adult-to-child ratio in the session; what is the proper supporting role for adults attending with the child?
- What protocols will be used for documenting treatment?
- What are the highest priorities with regard to goals and objectives, and which goals are best suited for reinforcement or primary coverage in music therapy?

When working with implant recipients, it is important to remember the variability in benefit and communicative outcomes documented in the literature and noted earlier in this paper. A therapist may serve two preschoolers who are nearly the same age, who use the same type of implant, and who have had a similar length of CI experience, yet the children may be developing communicative skills at a very different rate. Variability is even greater when it comes to some aspects of music perception and enjoyment (Gfeller et al., 2006, 2007, 2008). These differences can be difficult for parents to understand and accept if they compare the progress of their child with progress of other children. Thus, it is important for the music therapist to offer information and guidance to parents on this matter in order to keep expectations appropriate. In addition, it is important for the entire team to individualize the goals, objectives, and expectations for response within a given activity. The following section presents some goal areas and music therapy examples that are suitable for many preschoolers with CIs.

Common goal areas and music therapy interventions

By and large, music activities chosen for preschoolers with implants should be similar to those used in childhood music session for typically-developing children. Preschool favorites such as “The Wheels on the Bus,” “The Itsy Bitsy Spider,” playing rhythm instruments, and moving to music can be as enjoyable for children with CIs as for typical preschoolers. The activities and format should be suitable for the cognitive, physical, and socio-emotional development of the child, and the sessions should retain the same sort of playful quality similar to that typically observed in early childhood sessions for typically-developing children.

Given the unique issues of CI recipients, however, the selection of activities should also take into account several things: (a) the primary therapeutic and educational goals to be emphasized; (b) the atypical representation of pitch and timbre through the CI signal; and (c) the difficulty of perceiving speech and sung lyrics against background noise or music. These factors should influence the prioritization of activities as well as approach to activity facilitation.

Music therapy for preschool CI recipients should typically be designed to support three primary goal areas: listening skills, speech production, and language development. Other domains such as socialization, cognition, and emotional-behavioral development may be relevant for some CI recipients, but those goal areas of music therapy are beyond the scope of this paper. The type of activity and responses required should reflect the current developmental level of each child, and help the child to move gradually toward the next level.

Goals of listening, speech and language can be addressed through playing instruments, movement, and singing. Music therapists typically have robust repertoires of early childhood songs and activities. The purpose of this paper is not to reiterate a well-documented body of early childhood songs and activities, but (a) to emphasize some ways in which typical early childhood music activities can be implemented in order to focus on those issues most relevant to young CI recipients, and (b) to provide guidance in the selection of musical stimuli that are “CI friendly.”

Playing instruments—Encouraging children to explore their acoustic environment is an important part of acclimatization after implantation. Playing musical instruments offers a golden opportunity for children to explore unique and interesting sounds. As children play instruments, they experiment with the presence and absence of sound (sound detection). When two instruments are presented that have contrasting tone quality (e.g., a drum vs. a shaker), the child can work toward goals such as discrimination and identification.

Instrument playing can be organized around the "auditory sandwich" described earlier in this paper. First, the therapist plays an instrument (such as a drum or shaker) outside the child's visual field (such as behind a screen). Then the child is able to play the instrument and produce the sound, thus pairing the particular sound quality with a specific musical instrument. Next, the therapist or peer plays the instrument out of the visual field, relying on audition only, to discriminate or identify the musical instrument. Through the consistent association of a particular sound (such as special rhythmic beat) with a particular event or meaning (e.g., knocking on the door), instrumental playing can be used to work on sound comprehension.

As is true with normal hearing children, playing musical instruments can be modified in a number of ways in order to focus on different listening skills. The therapist can modify elements such as which instruments are played, how many are played in one activity, the complexity of the rhythmic pattern presented, and the responses required in order to match the current level and objectives (e.g., detection, discrimination, identification) for the child. As children improve their listening skills, the difficulty level can be adjusted by playing a larger variety of instruments, by playing more complex patterns, and by requiring more difficult responses (e.g., discrimination of instruments with more similar tone quality, or by removing visual cues).

When selecting instruments for play, the therapist should consider research on timbre recognition and sound quality, keeping in mind that CIs do not provide a "normal" sound quality. Instruments should be selected thoughtfully. As noted earlier in this paper, some instruments may sound shrill or harsh through an implant, and consequently, the child will be less motivated to experiment with the instrument. Trial and error may be necessary in order to find instruments that are pleasant to hear or that may improve with repeated experience. If instruments are to be used for discrimination or identification, select instruments that are sufficiently distinct in sound quality so that the child can differentiate between two or more sounds. For example, the sound of a shaker and tambourine jingles may sound quite similar through the CI, while a drum and shaker are more likely to be readily distinguished from one another.

In addition to promoting good listening skills, instrument playing can be structured to promote speech and language development. As the children explore instrumental sounds, the therapist can pair onomatopoeic sounds with instruments, such as "tap, tap, tap" while playing the drum, or "sh, sh, sh" with shakers. When selecting instruments to play, consider key speech sounds that you wish to encourage. For example, the word, "drum" contains two sounds important to early speech development ('d' and 'm'). The therapist can encourage the child to vocalize the name of the instrument, with an emphasis on the production of the "d" and "m" sounds (Gfeller & Darrow, 2008).

Instruments can be chosen to reinforce specific vocabulary and conceptual development. For example, when working on vocabulary associated with shapes (circle, rectangle, triangle, or square) or sizes (big, little), the physical characteristics of musical instruments provide exemplars for vocabulary use and linguistic concepts. The therapist may present a little and big instrument or a round and a square instrument and then require the child to use the appropriate spoken vocabulary to indicate which instrument they wish to play (Gfeller, 1990; Gfeller & Darrow, 2008).

The music therapist can also use instrumental play as an opportunity to practice following single and multi-step instruction and interactive communication. For example, the therapist might ask who will play first, second, and last. Children can respond to questions such as “which instrument do you wish to play?” Choosing an instrument can provide reinforcement for appropriate use of spoken language (Gfeller, 1990; Gfeller & Darrow, 2008).

As noted previously, background sounds (including music) can make speech perception more challenging (Buzzell, Gfeller, Driscoll & Kinnaird, 2008; Turner et al., 2004). Therefore, communication may be enhanced by presenting initial verbal instructions and then playing instruments rather than presenting instructions and instrumental sounds simultaneously (“Listen to the shaker”---then play the shaker). As the child becomes more adept at listening, you can eventually experiment with the more demanding task of listening to verbal instructions with some competing accompaniment.

Movement activities

Often, therapists think of movement activities to promote motor development, which of course is beneficial for all young children. With that said, movement activities can be implemented in a manner that promotes communication (listening, speech, language) goals as well (Gfeller, 1990). Large muscle movements (such as swaying, marching, or hopping) and fine motor skills (finger plays) often occur in response to musical cues or verbal instructions. Consequently, movement activities can require careful listening.

Musical cues with or without verbal instructions can guide the rate as well as manner of movement. For example, the basic beat of music may determine whether a child moves quickly or slowly. Melodic or rhythmic patterns suggest specific types of movement such as hopping or swaying. Musical imagery can elicit imagery such as fish swimming or snakes slithering. Thus, the movements of the child can be a behavioral indicator of how well the child is attending to, perceiving, and comprehending the meaning of the musical and verbal cues presented (Gfeller & Darrow, 2008).

Activities that require a child to move or stand still in response to an external sound source (such as a drum hidden behind a screen) or silence requires sound detection. Changing movement in response to a change in the musical stimulus requires discrimination. The pairing of particular types of sounds with specific types of movement (e.g., moving like an elephant to slow, plodding music, vs. hopping like a frog to an upbeat, playful tune) requires identification and/or comprehension. Particular songs can become associated with particular actions (e.g., a transition song that “commands” children to march to the door to begin their next activity) (comprehension). Musical elements and/or the lyrics that transmit single or multiple step instructions (e.g., “I’m reaching very tall, and now I’m very small”; “head, and shoulders, knees, and toes”) encourages listening comprehension (Gfeller & Darrow, 2008).

Movement activities can promote language development (Gfeller, 1990; Gfeller & Darrow, 2008). For example, movements related to spatial relations (“Go in and out the circle,” “The people on the bus go up and down”) provide concrete illustrations of linguistic concepts and vocabulary important for preschool children to learn. Movements may be guided through verbal instructions that present sequential concepts (first, second, next, last, etc.). Children can be encouraged to use their best speech and language to describe the movements of a given song or activity.

The facilitation of movement activities with CI recipients will typically resemble sessions with typically-developing children. However, because the movement activity may be used primarily to promote listening skills, the therapist should take extra care in using clear and appropriately paced verbal instructions and accessible, pleasant musical sounds. Here are some practical suggestions for making the listening environment as CI friendly as possible.

- Initiate new activities by simple clear demonstrations, or verbal instructions without background music. Loud background music during a movement activity can obscure verbal instructions (Buzzell et al., 2008).
- Children with CIs may rely to some extent on speech reading (lip reading) as well as audition in order to perceive speech. Offer verbal instruction first, and keep your face toward the child in the line of sight. Then begin the movement.
- Keep the instructions clear, at a reasonable rate of speed, and at a level of complexity (single step, multi-step instructions) that is suitable for the majority of children in the group. Gradually increase the complexity of the listening task.

In addition to these comprehension considerations, the therapist should also keep a watchful eye for any sorts of movements that could result in the external parts of the CI becoming entangled or falling off. In order for the child to hear, the external components must remain on, but care should be taken to prevent damage to or disconnecting of those parts. A brief preliminary conversation with the audiologist regarding proper care of the implant parts would help to prevent these sorts of problems. In summary, as you plan movement activities, keep in mind that the primary goals for children with CIs is receptive and expressive communication and implement the movement activities to optimize communicative objectives.

Singing

Because singing resembles speech in production, but with greater inflection, the link between singing and communicative goals is obvious. Singing requires coordination of the same vocal mechanisms used in spoken communication, and singing along with others involves careful listening. The vocabulary and concepts found in children's songs are rich sources for linguistic development (Gfeller, 1990). One benefit of using songs to promote speech and language development is the inherent repetition of vocabulary. For example, in the song, "The Wheels on the Bus", we repeat the phrase, "up and down" 4 times in just one verse, which offers multiple exposure and opportunity for producing and perceiving specific phonemes and/or words. Through the pairing of movements with vocabulary words (such as vocabulary of body parts or directions in space in "The Hokey Pokey"), the child can be given concrete examples to illustrate the meaning of new vocabulary words.

Keep in mind, however, that singing with others is possibly the most difficult of all musical tasks to achieve with any degree of accuracy, given that the implant does not provide good pitch resolution (Nakata, Trehub, Mitani, & Kanda, 2006). In considering this fact, one might question whether singing should be included in music therapy programming for preschool implant recipients. Although the child may not be able to hear and reproduce the pitch patterns with 100% accuracy, singing offers an opportunity to listen to song lyrics and the voice quality of the therapist and peers. Some children may also get a general sense of melodic contour, and some children, with adequate training, may improve considerably in tuneful singing (Rocca & Tucker, 2008).

Even more to the point, NH preschoolers seldom possess perfect pitch matching capabilities, nor do they sing entire songs with complete accuracy (McDonald & Simons, 1989). In a song such as "Old MacDonald," a NH 2- or 3- year-old may chime in only on "e-i-e-i-o" or with "moo, moo." Given that NH children are not yet singing perfectly in tune, why would we expect perfection in singing from children with CIs? More realistic goals include increased use of and enjoyment in vocalizing, repetition of targeted lyrics, with successive approximations toward the general inflection within the song's melodic contour.

As would be the case with any preschooler, songs should be chosen to reinforce vocabulary, speech sounds, and concepts that are relevant to the child's daily life and to their individualized therapy or educational plan (Gfeller, 1990). Just as there is a hierarchy for listening there is also a typical order of acquiring speech sounds. It beings with stress patterns and moves to consonants, vowels, syllable number identification, intonational contours/pitch variation, pattern matching. From there, complexity increases to consonant strings, reduplicated patterns (baba), which are less complicated than variegated (oh my, baby) and, finally, comprehension: when I say *this* word, it means *that* (Nathani, Ertmer, & Stark, 2006). As this list indicates, speech and language development are complex, and in-depth knowledge regarding speech production is seldom a part of the music therapy undergraduate curriculum. Therefore, it is important to seek the input of an audiologist or SLP in establishing developmentally and audiologically suitable goals and objectives with regard to choice of song lyrics. Don't hesitate to rewrite or modify song lyrics in order to better match the linguistic content with the therapy goals of the child.

In order to facilitate good listening (which in turn can help the child reproduce the sounds accurately), songs should be sung at a reasonable rate. In addition, when first introducing a song, it may be helpful to sing the song with a simple tone quality and *a capella* in order to avoid masking lyrics with an accompaniment. The ability to adjust the tempo and other characteristics of the song is a true advantage to using live singing rather than recordings. Some recordings of children's songs present the tunes at a very brisk rate or with noisy and distracting accompaniment that makes comprehension of words more difficult.

In summary, there are endless musical activities that can be used to practice communication skills. The critical element to using them properly with CI recipients is to (a) stay focused with regard to key objectives; (b) select musical stimuli and create an acoustical environment that are appropriate given the technical characteristics of the CI; and (c) adjust the response tasks to the current development of each child, gradually increasing the difficulty. Appendix A provides a quick reference for accommodations or modifications in methods, materials or environment to keep in mind when working with preschoolers who use CIs.

Suitable music activities provide ample opportunity to practice listening, speaking, and use of language. In addition, the cooperative nature of music activities allows children to use these communicative skills toward social goals of following directions, sharing, turn-taking, cooperation, and awareness of others. Through thoughtful consideration of how the CI transmits various aspects of music, and through dynamic assessment of each child's strengths and limitations, most pediatric CI recipients should be able to participate successfully in and benefit from music therapy.

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Appendix

Practical Tips

Environment

- Select rooms with carpets or rugs rather than hard-surfaced floor to reduce excess noise.
- Avoid rooms with reverberation
- Reduce extraneous sounds from other areas (e.g., close door to outside hallways, turn off fans or air conditioners if possible, etc.)

Music

- Select music with a simple and clear form.
- Choose music that has a distinctive beat and rhythmic pattern.
- Initially, play music at slow to moderate tempos to facilitate comprehension
- Begin singing in *a capella*
    - Add instruments after establishing basic vocabulary and concepts
- Incorporate background music judiciously
    - Turn off music when giving instructions
    - Keep background accompaniment relatively quiet in relation to the melody line

Instruments

- Introduce instrumental sounds individually before playing in blends (more than one instrument simultaneously)
    - "Layer" the use of instruments and other sounds
    - Provide verbal instruction regarding instrument use prior to playing the instruments
- Use clearly contrasting timbres (e.g., shaker vs. drum) in listening exercises
- Use instrumental names and sound qualities to promote target speech sounds

Movement

- Avoid damage to the external parts of the CI during movement activities
    - Avoid large motions that can cause the cord connecting the magnet and processor to be pulled
    - Adjust the use of manipulables (streamers, sticks, etc) to avoid entanglement
    - Discuss with the audiologists practical strategies (e.g., head bands) for keeping the external components in place during physicallyactive events.
- Provide physical assistance for children whose hearing impairment affects their balance
- Select movements that foster practice of target speech sounds

- body parts, spatial relations

Implant Maintenance and Troubleshooting

- Learn the specifics of volume and sensitivity control for the particular processor your student will be wearing
- Familiarize yourself with the technology as it changes in your sessions
- Website resources
  - Advanced Bionics Corporation www.advancedbionics.com
  - Cochlear Corporation www.cochlear.com
  - Med-El Corporation www.medel.com

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