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The Perception of Prosody in English-Speaking Children with Cochlear Implants: A Systematic Review

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THE PERCEPTION OF PROSODY IN ENGLISH-SPEAKING CHILDREN WITH COCHLEAR IMPLANTS: A SYSTEMATIC REVIEW

by

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A capstone research project submitted to the Graduate Faculty in Audiology in partial fulfillment of the requirements for the degree of Doctor of Audiology, The City University of New York

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This manuscript has been read and accepted for the Graduate Faculty in Audiology in satisfaction of the dissertation requirement for the degree of Doctor of Audiology (Au. D).

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ABSTRACT

THE PERCEPTION OF PROSODY IN ENGLISH-SPEAKING CHILDREN WITH COCHLEAR IMPLANTS: A SYSTEMATIC REVIEW

by

Grace R. Smith

Advisor: Carol Silverman, Ph.D., M.P.H.

Objective: The goal of this paper was to systematically review literature in order to investigate the perception of prosody in English-speaking children with cochlear implants.

Methods: A comprehensive search utilizing various peer-reviewed databases accessible through the City University of New York (CUNY) Graduate Center Library was conducted to identify relevant studies. Inclusion criteria included studies that examined prosody perception in pre-and post-lingually deafened children with cochlear implants. Children who utilized unilateral, bilateral, and bimodal configurations of cochlear implants were therefore included in this search.

Results: 9 studies met the inclusion criteria for this systematic review. The findings demonstrated both negative and positive outcomes for pediatric users of cochlear implants. Of the 9 studies included in this systematic review, 6 (66%) included an outcome measure that assessed emotion perception, and 3 (33%) included an outcome measure that examined specific domains of speech prosody perception. Additionally, 2 of the 9 (22%) included studies specifically investigated the connection between music and the perception of emotional speech prosody.

Discussion: Results support the use and continued development of intensive (re)habilitation emphasizing suprasegmental and paralinguistic aspects of speech through prosody perception measures sensitive to both emotional and linguistic components. Positive effects of music training were also found in audio-only conditions for the perception of emotional prosody. Future research needs to be based on larger sample sizes, and should offer more alternative choices in the identification of emotional or prosodic cues, heightening prosody classification difficulty for prosody perception tasks. Incorporating differing levels of background noise and reverberation during prosody perception tasks is also recommended to simulate situations which are more representative of complex listening situations encountered by pediatric cochlear implant users.

Conclusions: Performance on emotion recognition and other aspects of prosody perception including music perception is generally poorer in children with cochlear implants than in participants in comparison groups, such as normal-hearing children. Specifically, the findings of this systematic review support the use and validation of intensive (re)habilitation measures emphasizing suprasegmental and paralinguistic aspects of speech, as well as emotion and music prosody perception.

Key Words: “prosody”, “perception”, “cochlear implants”, “child”, “speech”, “intonation”, “aural rehabilitation”, “music”, “communication”.

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INTRODUCTION

As candidacy guidelines for cochlear implantation are becoming more inclusive in terms of eligibility for implantation, pediatric candidates are gaining access to the world of sound at younger ages. With this increased accessibility, comes more opportunities for assessing effects secondary to hearing electrically, including speech and language skills. The ability to detect subtle nuances of speech that normal-hearing listeners are able to detect often is overlooked in those with severe to profound hearing impairment. Specifically, prosody elevates speech to a higher level of sophistication in its identity as an acoustic signal. Suprasegmental components of speech are critical for conveying information that contribute to the expressive functions of language, including semantic, attitudinal, psychological, and social domains (Peng et al., 2012). The cues that such elements provide are instrumental for detecting and monitoring communicative intent as well as for conveying emotional states (Peng et al.). With the innovation of cochlear implants, enormous strides have been made to help users with hearing impairments to understand speech and develop language successfully. However, cochlear implant information processing algorithms begin to reveal their weaknesses when the variable of vocal pitch is introduced. That is, the subtle changes provided by pitch embedded in communicative functions like irony or sarcasm are often lost on users of cochlear implants as they struggle to correctly recognize a natural utterance's emotional content (Peng et al.). Unfortunately, the current processing strategies used by cochlear implants encode a limited spectral resolution, with limited low-frequency information, so poor pitch perception typically results (Lassaletta et al., 2008). Changes in pitch are the foundation of prosody and so it follows that if the resolution of pitch in cochlear implants is limited, then users' recognition of prosody in speech also will be restricted.

As Fuller et al. (2018) indicate, “due to limited insertion depth and the position of the [cochlear implant] electrodes relative to healthy neurons, there is often a tonotopic mismatch between the acoustic input and the cochlear place of stimulation. Because of the limited number of electrodes, and spread of excitation, there is only limited spectral resolution” (p. 2). Therefore, the electric, rather than acoustic, stimulation of the auditory nerve is resigned to an approximation of what is supposed to be a fine-tuned neural response to an acoustic signal. Although this suffices for detecting the temporal and rhythmic aspects of speech, the absence of these fine-tuned structural cues becomes regretfully apparent when information dependent on the manipulation of pitch like prosody or music cannot be accurately deciphered. Furthermore, for non-tonal language speakers (e.g., English speakers), accurate pitch perception assists with understanding paralinguistic functions of language, such as the age, sex, and emotional states of the speaker, along with dialect and prosody (Jayakody et al., 2012). Although cochlear implants are doing more than ever before, the more refined characteristics making speech and music such complex acoustic signals, but which contribute to their identity as signals, are still just out of reach for cochlear implant users.

The significance in identifying prosodic elements of speech becomes especially apparent in pediatric users, as its function becomes two-fold; prosody does not only serve to carry intonation, but also to facilitate expressive language development (Jusczyk et al., 1992; Soderstrom et al., 2003 as cited in Peng et al., 2012). Previous research suggests that prosodic sensitivity facilitates children’s reading development (Whalley & Hansen, 2006; Miller & Schwanenflugel, 2008 as cited in Kalathottukaren et al., 2017) and language acquisition (Morgan & Demuth, 1996; Jusczyk et al, 1999; Soderstromet al, 2003; Thiessen et al., 2005 as cited in Kalathottukaren et al., 2017). Therefore, assessment and intervention for prosodic difficulties should be considered in children with hearing loss, who are at risk for reading and language delay (Moog & Geers, 1985; Allen, 1986; Geers et al, 2008 as cited in Kalathottukaren et al., 2017).

As the population of users of cochlear implants continues to become younger and younger, the motivation to better understand how the perception of prosodic cues can be effectively improved also grows. Currently, children as young as twelve months old can be candidates for cochlear implants in the United States (Peng et al.). Because increasingly younger children are using cochlear implants and suprasegmental cues play a large role in early expressive language development, it is critical to understand how pediatric cochlear implant users are able to improve their detection of these cues, such as question–statement distinctions, vocal emotion recognition, differentiating word boundaries, and understanding the use of contrastive stress (Roach, 2000; Wells et al., 2004 as cited in Kalathottukaren et al., 2017).

Music is known to be a vehicle for emotion and is often viewed as a universal language amongst listeners. It is also known that emotional cues are paramount for communication. The ability to identify and differentiate emotions, such as deciding whether someone is happy or sad, is the basis for an individual's own feelings, reasoning, decision-making, and action planning (Damasio, 2000 as cited in Hopyan et al., 2011). Furthermore, the ability to identify emotions requires the ability to understand the emotions that people feel, and which is a foundation for the communication of emotions and social relationships, and fundamental for normal social development and interaction (Blair et al., 2001 as cited in Hopyan et al.). A marriage between music and language exists, recruiting both brain hemispheres in such a way that creates a complementary relationship between the domains. Johansson (2008) asserts that the left hemisphere lateralization of language and predominantly right hemisphere lateralization of music is being challenged by the alternative view that language and music are closely related cognitive and neural systems. This relationship is further strengthened as musical experiences are being shown to shape human brainstem encoding of linguistic pitch patterns (Johansson).

With this knowledge that music has the power to be a medium for emotion and its connection to human language in the brain, it follows that manipulating one domain could have effects in the other. Since music and language are related, training on one weakness could have benefits that are generalizable to a different, but related weakness. That is, by working to improve music perception in patients with cochlear implants with targeted auditory/music training programs, the detection of prosodic speech cues could also improve due to a shared characteristic of pitch being strengthened. As Woodson (2017) highlights, "musical training/therapy programs for children with cochlear implants who are pre-lingually deafened have gained popularity as a habilitation tool. Whether formally or informally implemented, these programs seek to enhance basic perceptual attributes of music including pitch, melody, timbre, rhythm, and music appraisal" (p. 1). Even if music is more difficult to perceive in users of cochlear implants because of poor pitch perception, music is a vital means for gaining access to emotional cues. Children using cochlear implants may be better able to hear the emotional cues in music than in speech – which can then be exploited to improve these cues (Hopyan et al., 2011). This ability to access emotion through music may be a vital means for obtaining and stimulating relevant auditory percept of emotion in children using cochlear implants (Hopyan et al.). In other words, due to the emotional potency of music for pediatric cochlear implant users, using this type of acoustic stimulus as a tool during auditory training may be a means of fruitfully bolstering the detection of prosodic cues and thus emotion.

Consequently, because of the increased number of pediatric candidates for cochlear implants; the consistently documented difficulties users of cochlear implants face in utilizing pitch cues to perceive intonation, emotion, and the contours of speech; the adverse impact of prosody deprivation on communicative and social development in children; and the noted benefit of repurposing music to improve speech skills, an examination between cochlear implants and speech understanding is warranted. Therefore, the purpose of this investigation is to systematically review the effects of cochlear implants in pre-lingually and post-lingually deafened children with cochlear implants on the perception of prosody. The results of such examination may enlighten researchers and clinicians alike on improving the role of cochlear implants in the auditory (re)habilitation process.

METHODS

The search words were selected a priori as a way to include the maximum number of studies that are relevant to prosody perception in English-speaking children with cochlear implants. Search words in the MEDLINE/PubMed (NLM) database included “prosody,” “perception,” “cochlear implants,” “child,” “speech,” and “intonation.”

The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guided the inclusion of published studies in this systematic review. The PRISMA statement consists of a 27-item checklist and a four-phase flow diagram (Fig.1) to increase the transparency and improve the reporting of systematic reviews and meta-analyses (Moher et al., 2009).

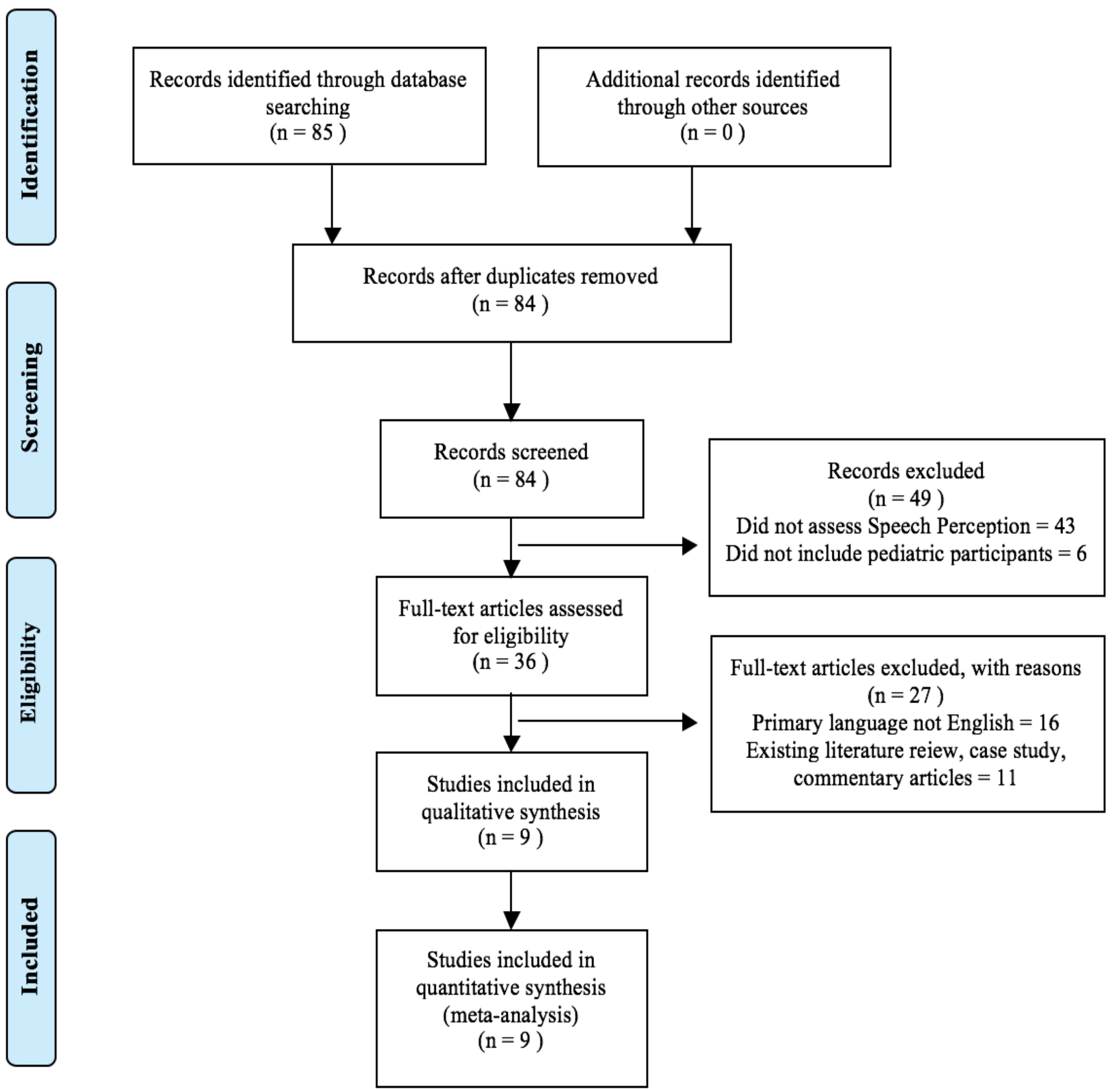
This review utilized the following inclusion criteria: articles published in English examining speech perception; pre-and post-lingually deafened participants with cochlear implants; persons who are under 18 years old; male or female gender; and persons whose first language is English.

RESULTS

Figure 1 shows a PRISMA flowchart for the literature search and retrieval process of this systematic review. In total, the database search yielded 85 studies. After excluding studies that did not meet the criteria, 9 studies received systematic review.

Figure 1

PRISMA Flowchart



Note. This figure illustrates the literature search, retrieval process, and selection of studies for this systematic review. The PRISMA Group (2009).

Study and Participant Characteristics

Table 1 provides an overview of the 9 included studies by study characteristics and participant characteristics. Study characteristics include independent and dependent variables, stimulus and procedures, and the experimental task(s). Participant characteristics were described in terms of sample size, mean age (and standard deviation), gender, and amplification status.

As shown in Table 1, only 1 of the 9 studies (11%) had a sample size exceeding 30 for the group of children with cochlear implants (Chatterjee et al., 2015). Of the 9 studies, 1 (11%) had a sample size of 26 for the group of children with cochlear implants (Whipple et al., 2015), 1 (11%) had a sample size of 18 for the group of children with cochlear implants (Good et al., 2017), and 1 (11%) had a sample size 14 for the group of children with cochlear implants (Volkova et al., 2013). The remaining 5 of the 9 studies (56%) had groups of users of cochlear implants varying in size from 6 to 14. Of the 9 studies in the review, 5 (56%) included children with normal-hearing sensitivity to act as comparison groups in their study (Chatterjee et al.; Kalathottukaren et al., 2017; Most & Michaelis, 2014; Volkova et al.; Whipple et al.). Of the 9 studies in the review, 1 (22%) had a comparison group comprising adults with cochlear implants (Chatterjee et al.) and 1 (22%) had a comparison group comprising children with Autism Spectrum Disorder. Core et al. (2014) did not employ a comparison group. The mean age for the children with cochlear implants ranged from 4.7 to 12.4 years. The effects of music training on emotional prosody perception was investigated in just 1 of the 9 (11%) studies (Good et al.).

The characteristics of the groups using cochlear implants varied across studies with respect to their implant device arrangement between ears, as well as whether those groups included users of hearing aids. That is, studies differed with regard to whether participants utilized unilateral or bilateral cochlear implants, and whether participants used only cochlear implants or were bimodal (i.e., cochlear implant on one ear and a hearing aid on the contralateral ear). Some studies included participants with hearing loss (unilateral and bilateral) who were not users of, or candidates for, cochlear implants and/or participants who were users of monaural or binaural hearing aids. These users of hearing aids were integrated with users of cochlear implants, but not bimodal users, to create a larger group of participants with hearing loss in 2 of the 9 (22%) studies (Kalathottukaren et al., 2017; Most & Michaelis, 2012). Of the 9 studies containing groups with users of cochlear implants, 6 (67%) involved only users of cochlear implants (Chatterjee et al., 2015; Core et al., 2014; Good et al., 2017; Snow & Ertmer, 2009; Volkova et al., 2013; Whipple et al., 2015). Of the 9 studies containing groups of users of cochlear implants, 2 (22%) included participants who used bimodal amplification (Hegarty & Faulkner, 2013; Whipple et al.) Volkova et al.'s group of users of cochlear implants comprised users of only bilateral cochlear implants.

All studies examined in this review included both female and male pediatric users of cochlear implants, as seen in Table 1. However, the ratio of female to male participants varied amongst studies. Inspection of Table 1 shows that the majority of studies had more male than female users of cochlear implants, with 6 of the 9 studies (67%) demonstrating this gender difference (Core et al., 2014; Good et al., 2017; Hegarty & Faulkner, 2013; Kalathottukaren et al., 2017; Volkova et al., 2013; Whipple et al., 2015).

Table 1

Study Characteristics and Demographics

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
Chatterjee et al. (2015)	31 normal-hearing children (cNH)	10.8 (3.1)	16:15	12 sentences from HINT[b] Sentences spoken by a male and a female talker with 5 emotions.	Identify emotion from a closed set.	Emotion (5 conditions) 1. Angry 2. Happy 3. Neutral 4. Sad 5. Scared Group (4 conditions) 1. cCI 2. cNH 3. aCI 4. aNH Speech signal spectral resolution in cNH and aNH (4 conditions) Talker gender	Voice emotion recognition (% correct)
	36 children with CI[a] (cCI)	12.15 (3.5)	21:15				
	10 normal-hearing adults (aNH)	23.9 (2.8)	7:3				
	9 adults with CI (aCI)	52.1 (13.2)	4:5				

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
Core et al. (2014)	10 children w/ binaural CIs (implanted prior to 3.0 years, wore implant for ≥ 1.0 year)	4.7 (1.0)	3:7	HVHP[c] for presenting stimuli.	Looking time for old versus novel stimuli.	Stimulus: 1. Old stimuli 2. Novel stimuli	Perception of vowel height (looking time) for non-words /iti/ and /ata/ Perception of lexical stress (looking time) for real word /beIbi/ and a non-word /b 'bi/ Perception of intonation (looking time) for real word /beIbi/ and a non-word /b 'bi/
Good et al. (2017)	18 children with CIs enrolled in schools using oral communica tion as	10.2 (2.8)	6:12	Experimental group (n = 9) received 6 months of music training; Control group (n = 9) received 6	Participants indicate whether standard and comparison melodies were "same" or "different".	Training type: 1. Music 2. Visual art	MBEMA[d] total score, scores on subtests (i.e., pitch perception, rhythm perception,

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
	primary means of instruction			months of visual art training.			incidental memory)
					For evaluation of emotional prosody, assess emotion conveyed under audio only & audio-visual conditions.	Emotional prosody stimulus: 1. Audio-only 2. Audio-visual	Emotional speech prosody (% correct)
Hegarty and Faulkner (2013)	9 bimodal stimulated children (CI & HA[e]) who used a CI for at least 1 year and a HA for at least 3 months	10.2 (2.6)	4:5	*Experiment 1*: Stimulus was (Baba) vs. (baBA); F_0 (pitch) or amplitude varied. Adaptive threshold measure to obtain difference heard on 71% of trials.	Indicate if stimulus pairs were same or different.	Amplification: 1. CI alone 2. Bimodal F_0 range: 1. Low 2. High	F_0 threshold Amplitude threshold
				Experiment 2: Focus sentence test w/ naturally produced focus & neutrally produced version (no focus). Presentation of 45 sentences w/ pictures.	Select pictures representing the perceived focus.	Amplification: 1. CI alone 2. Bimodal Speech: 1. Manipulated 2. Natural F_0	Proportion correct score (focus sentence test)

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
						Speaker (female/male)	
Kalathottukaren et al. (2017)	16 children with H[f] (4 w/ unilateral and 12 w/ bilateral HL; 6/16 w/ monaural or binaural CI, 9/16 w/ monaural or binaural HAs, 1/16 unaided)	8.7 (1.4)	6:10	6 receptive subtests of PEPS-C[g] and the DANVA-2[h] used to evaluate receptive prosody. Contour & interval subtests of MBEA[i] used to measure musical pitch discrimination. Raters judged reading samples & pitch variations on a scale from 1-7 (high) & overall prosody on a scale from 1-4 (normal).	Children (HL group wore their amplification devices) instructed to read aloud passages clearly & with emotions).	Hearing status: 1. Normal hearing 2. Hearing loss	PEPS-C prosody perception DANVA-2 prosody perception MBEA musical pitch discrimination Prosody production ratings (pitch, pitch changes overall) of reading samples
	16 children with NH[j] sensitivity, age- and gender matched to HL group	8.9 (1.5)	6:10				

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
Most and Michaelis (2012)	26 children with HL (17 w/ HA, 9 w/ CI)	Unknown	15:11	EIT[k] developed for study, containing 24 video recorded items, yielding 6 items each for anger, fear, sadness, happiness. Emotions presented through use of nonsense sentence ("bado mino gana").	Child asked to point to 1 of 4 pictures representing schematic expression of 1 of the 4 emotions.	Hearing Loss Status: 1. Bivalent (NH vs. HL) 2. Multivalent (profound vs. severe vs. mod-severe vs. moderate vs. NH) Stimulus Condition: 1. Auditory 2. Visual 3. Auditory-Visual	Emotion perception score on EIT (overall and by emotion)
	14 children with NH	4.91 (1.0)	7:7				

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
Snow and Ertmer (2009)	6 CI children implanted 10-36 months; children were within 2 SD of mean for age on dev. inventory; 5/6 children obtained scores on non-verbal play skills in line w/ CA[1]	Unknown	4:2	Spontaneous utterances examined for retrospective study of changes in F_0 range following cochlear implantation. Spontaneous longitudinal speech samples recorded from child-mother interactions.	Mothers instructed to play with their child in their usual way using an assortment of familiar toys.	CI experience: 1. Pre-implant 2. Month1 post 3. Month2 post 4. Month3 post 5. Month4 post 6. Month5 post 7. Month6 post 8. CA for implantation	Utterance accent range Utterance duration
Volkova et al. (2013)	14 children with bilateral CI	5.8 (0.6)	5:9	*Experiment 1*: Recorded happy and sad versions of linguistically neutral sentences.	Children asked to select photo representing emotion heard.	Hearing status 1. CI 2. NH Implant experience	Emotion identification score (% correct)
	18 children with NH	5.4 (0.5)	12:6				

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
	14 children with bilateral CI	5.8 (0.8)	6:8	*Experiment 2*: Happy and sad synthesized piano excerpts.	Children asked to select photo representing emotion heard.	Emotion 1. Happy 2. Sad Stimulus: 1. Speech 2. Music Talker gender (female vs. male)	
	18 children with NH	5.4 (0.5)	12:6				
Whipple et al. (2015)	26 children who use CI (unilateral, bilateral, bimodal ≥ 12 months of CI use)	12.4 (3.1)	9:17	Recorded excerpts of original classical tunes composed and performed on violin.	Participants listened to excerpts and selected labeled photo depicting emotion or movement (based on tempo).	Group 1. CI 2. ASD 3. TD-NH Emotion 1. Happy 2. Sad 3. Fear 4. Anger 5. Disgust	PEMM[m]
	24 children with Autism Spectrum Disorder (ASD)	14.3 (2.2)	2:22				

Author (Year)	Sample Size (N)	Age (Years) Mean (SD)	Gender F:M	Stimulus & Procedure	Task	Independent Variable(s)	Dependent Variable(s)
	35 typically developing children with NH (TD-NH)	11.1 (2.8)	19:16			Age	

Note: [a] HINT (Hearing in Noise Test); [b] CI (Cochlear implant); [c] HVHP (Hybrid Visual Habituation Procedure); [d] MBEMA (Montreal Battery for Evaluation of Musical Abilities); [e] HA (Hearing Aid); [f] HA (Hearing Loss); [g] PEPS-C (Profiling Elements of Prosody in Speech-Communication); [h] DANVA-2 (Child Paralanguage subtest of the Diagnostic Analysis of Nonverbal Accuracy 2); [i] (MBEA) Montreal Battery of Evaluation of Amusia; [j] NH (Normal hearing); [k] ETI (Emotion Identification Test); [l] CA (Chronological age); [m] Perception of Emotions and Movement in Music (PEMM)

All studies in this review included an outcome measure that assessed prosody perception in pediatric users of cochlear implants. The majority of reviewed studies explored the processing of emotional prosody in this population. Additionally, some studies investigated other aspects of prosody perception. Specifically, these included speech prosody, as well as musical prosody perception.

Of the 9 studies included in this systematic review, 5 (56%) included an outcome measure that assessed emotion perception identification with percentage correct scores to assess emotional understanding with various stimuli (Chatterjee et al., 2015; Good et al., 2017; Kalathottukaren et al., 2017; Most & Michaelis, 2012; Volkova et al., 2013). Furthermore, Kalathottukaren et al. utilized the Child Paralanguage subtest of the Diagnostic Analysis of Nonverbal Accuracy 2 (DANVA-2) to assess recognition of emotions, in addition to the Profiling Elements of Prosody in Speech-Communication (PEPS-C). Specifically, this DANVA-2 subtest uses sentence level stimuli to assess perception of four different emotions (i.e., happy, sad, angry, and fearful) with sentence stimuli at either high or low intensities, whereas the PEPS-C Affect Reception subtest only assesses two emotions (i.e., like/dislike or happy/sad) using single-word test items (i.e., names of food). Of the 9 studies, 2 (22%) developed outcome measurement tools specific to their experiments (Chatterjee et al., 2015; Most & Michaelis, 2012). Chatterjee et al. utilized voice recordings that were noise vocoded and presented in various spectral resolutions to assess emotional recognition abilities. Most and Michaelis utilized the Emotion Identification Test (EIT), specifically developed for the purpose of the study to gather overall scores and emotion-specific scores to analyze perception of emotions.

Out of the 9 studies, 3 (33%) included an outcome measure that examined specific domains of prosody perception. Core et al. (2014) assessed perception of vowel height, perception of lexical stress, and perception of intonation. Kalathottukaren et al. (2017) alternatively utilized a combination of standardized outcome measures and subjective rating scales, including the PEPS-C prosody reception subtests (i.e., Short-Item Discrimination, Long Item Discrimination, and Turn-End, Affect, Chunking, and Contrastive Stress Receptions). Snow and Ertmer (2009) focused on utterance accent range and utterance duration. Hegarty and Faulkner's (2013) first experiment examined F0 threshold and amplitude threshold detection, while their second experiment assessed focus (i.e., stress) in natural and pitch-altered sentences.

Other outcome measurements of prosody involved musical perception in 4 of the 9 (44%) studies. Emotional prosody perception shares several variables with music perception, such as pitch, intensity, and timbre. Of the 9 studies, 2 (22%) utilized formal standardized assessments to examine music perception (Good et al., 2017; Kalathottukaren et al., 2017). Good et al. included the Montreal Battery for Evaluation of Musical Abilities (MBEMA) total scores, as well as select subtests (i.e., scale, contour, interval, rhythm, and memory) in addition to a perceived emotional prosody measure. Kalathottukaren et al. used contour and interval subtests of the Montreal Battery of Evaluation of Amusia (MBEA) to assess musical pitch discrimination as a complement to PEPS-C and DANVA-2 prosody and emotional perception measures, respectively. Finally, the Perception of Emotions and Movement in Music (PEMM) was expressly developed for another study to test the ability of children to recognize intended emotional recognition (i.e., affective prosody) in musical movements (Whipple et al., 2015). Volkova et al. (2013) utilized happy and sad synthesized piano excerpts to assess emotional identification in their second experiment, in addition to sentence stimuli used in their first experiment.

Study Outcome Results

As seen in Table 2, all of the 9 studies employed inferential statistics (parametric and non-parametric), such as analysis of variance (ANOVA), correlational analysis, *t* tests, Wilcoxon signed-rank test, and stepwise regression analyses.

Emotion Recognition

Inspection of Table 2 shows that in 5 of the 7 (71%) studies (Chatterjee et al., 2015; Kalathottukaren et al., 2017; Most & Michaelis, 2012; Volkova et al., 2013; Whipple et al., 2015) on emotion recognition in children with cochlear implants (some studies included children with hearing aids and/or children with bimodal amplification), the results revealed significantly poorer emotion perception in the children with cochlear implants than in the children with normal-hearing sensitivity. Chatterjee et al. also found no significant difference in emotion recognition between children with cochlear implants and adults with cochlear implants. Additionally, they observed significantly better emotion recognition performance for female talkers than for male talkers. Most and Michaelis found significantly poorer emotion recognition performance in children with cochlear implants as compared with the children having normal-hearing sensitivity, regardless of mode of stimulus presentation (i.e., auditory vs. auditory-visual). Volkova et al. found that children with cochlear implants readily distinguished happy from sad-sounding music, although not with the accuracy demonstrated by their peers with normal-hearing sensitivity. Furthermore, their accuracy of identifying happiness and sadness in speech was also significantly below that for children with normal-hearing sensitivity. Nevertheless, their accuracy was still well above chance levels. Similarly, Kalathottukaren et al. showed that the recognition of happy, sad, and fearful emotions was significantly poorer in children with hearing loss than in children with normal-hearing sensitivity.

Whipple et al. (2015) also found that emotion recognition was significantly poorer in children with cochlear implants than in children with Autism Spectrum Disorder and recognition of movement cues was significantly poorer in children with cochlear implants than in children with normal-hearing sensitivity and in children with Autism Spectrum Disorder. Whipple et al.'s findings further revealed that emotion recognition performance was significantly higher for happy and sad emotions than for disgust and anger emotions in the cochlear implant group. Importantly, the children with cochlear implants performed above chance on several emotions, consistent with the findings of Volkova et al. (2013). Similar findings were obtained by Most and Michaelis (2012) who observed that the best emotion recognition performance was obtained for happiness; in the auditory condition, confusions were most frequent between fear and sadness.

Other Aspects of Prosody Perception

Inspection of Table 2 reveals that only 1 of 4 studies (25%) on speech prosody perception also had a comparison group (Kalathottukaren et al., 2017). Kalathottukaren et al. found that speech prosody perception (i.e., short-item discrimination, turn-end reception, affect reception) in children with cochlear implants (including unaided children with hearing loss and children with hearing aids) was significantly poorer than in the group with normal-hearing sensitivity. Also, ratings of pitch, pitch variation, and overall impression of prosody in the group of children with hearing loss were more variable as compared with the children with normal-hearing sensitivity. Lastly, increasing age and better hearing sensitivity were associated with better speech prosody perception abilities.

Hegarty and Faulkner (2013), Core et al. (2014), and Snow and Ertmer (2009) did not employ a comparison group in their investigations of speech prosody perception (i.e., vowel height, lexical stress, intonation, utterance accent range and duration). Hegarty and Faulkner found that speech prosody performance in their group of children with cochlear implants (bimodal amplification) did not differ significantly between the bimodal condition and the cochlear-implant only condition, so low-frequency input from hearing aids did not enhance perception of stress and intonation. Adaptive thresholds for F_0 and amplitude revealed the performance did not differ significantly between the bimodal condition and the implant only condition. Performance on the focus sentence test, which furnishes information on the ability to use intonation, demonstrated (a) no significant advantage in the bimodal versus implant only condition; and (b) significantly higher performance for sentences with a natural F_0 contour than for sentences with a manipulated F_0 contour (containing only pitch cues), indicating that amplitude and duration cues contribute to perception of stress and intonation in children with cochlear implants. The authors concluded that children with cochlear implants rely on duration cues for perceiving stress and intonation when pitch and amplitude cues are unavailable.

Core et al. (2014) investigated speech prosody perception utilizing a modified Hybrid Visual Habituation Procedure (HVHP) for presenting stimuli; their findings revealed that the HVHP was successful in showing discrimination of the speech features tested in individual children. Their findings revealed that 7 of 9 children perceived at least one speech feature (i.e., vowel height, lexical stress, and/or intonation). These results suggest that this HVHP method can be used to assess both phonetic contrasts (i.e., vowel height) and prosodic contrasts (i.e., lexical stress and intonation) in pre-school age children who utilize cochlear implants.

Snow and Ertmer (2009), who examined the effect of implant experience on utterance accent range and utterance duration, found no significant effect of implant experience on these speech prosody measures, but children were not followed for longer than six months post-implantation. Similar findings were obtained for the effect of chronological age on these prosody measures. However, there was a robust interaction between implant experience and age. That is, the effects of the first two months of implant experience on intonation varied depending on the child's age. This interaction indicated that the initial effects of post-implant hearing experience on the children's intonation development were different for younger as compared to older children. At two months post-activation, children with cochlear implants matched the same developmental milestones as normally hearing children, but at different chronological ages. Moreover, older recipients (24-46 months of age) showed more development in the initial months of implant experience than younger recipients (9-24 months of age), suggesting that the effects of early implant experience are related to age at implantation.

In the one study assessing the effects of 6 months of music training (i.e., individualized piano training) on music perception in children with cochlear implants (Good et al., 2017), the findings revealed that music perception and emotional prosody perception improved significantly over time in children with cochlear implants who received music training, but not in children with cochlear implants who received art training. Another study in regards to music's contribution to success found that poorer hearing (i.e., poorer unaided pure-tone average in the better-ear) was associated with less musical experience (Kalathottukaren et al., 2017).

Table 2

Study Statistical Analysis and Results

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation

Chatterjee et al. (2015)	Emotional recognition score (% correct) w/ full spectrum stimuli	Repeated-measures mixed ANOVA[a]
		• WS[b] Factors
		  ○ CA[c]
		  ○ IA[d]
		  ○ Duration of experience
		• BS[e] Factors
		  ○ Talker
		  ○ Speech signal spectral resolution in cNH[f] and aNH[g]
		  ○ Subject Group
		  ○ Emotion
			Significant main effect of talker (***[h] $p < 0.001$)
			
			Significant interaction b/w talker & subject group (*** $p < 0.001$)
				Mean emotion recognition scores:
				• Significantly higher for female than male talkers
				• cCIs’ scores significantly lower than cNHs’ scores
				• No significant difference b/w cCI[i] scores & aCIs[j] scores.
				• No significant difference in scores among CI manufacturers
				• Male talker vocal emotions harder to recognize, most notably in aCI group

		Mixed ANOVA: Talker as WS factor and CI device manufacturer as BS factor	Main effect of talker remained significant (*** $p < 0.001$) No significant effect of device manufacturer No significant interactions	

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		Correlational analysis	Correlation between cCI scores & duration of experience with CI[k] weak but significant ($r = 0.37$, *[l] $p = 0.029$), controlling for age at implantation	Changes in emotion recognition score seen positively correlated with changes in duration of experience with CI in cCI groups

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
Core et al. (2014)	Looking time on modified HVHP^{m} for presenting stimuli	2 sample *t* tests (mean of looking times to novel vs. old stimuli) used to give initial comparison for individual child • Mean looking time (across 3 features) for old vs. new stimuli *t* tests applied to times from separate speech feature tests • Mean looking time (each individual feature) for old vs. new stimuli Bayesian linear regression analysis	6 of 9 children had significantly longer mean looking times to novel than old stimuli for at least 1 speech feature test For vowel height, 2 of 4 children had significantly longer looking times to novel than old stimuli; For lexical stress, 1 child of 6 had significantly longer looking times to novel than old stimuli; For intonation, 3 of 7 children had significantly longer mean looking times for novel than old stimuli 7 of 9 children perceived at least 1 speech feature based on Bayesian analysis. 1 child out of 9 demonstrated perception of all 3 speech features.	For most children in study, modified HVHP was successful in showing discrimination of speech features tested in individual child Looking at results by feature assessed, most children successfully discriminated all three features

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
Good et al. (2017)	MBEMA[n] total score & subtest scores	MBEMA Total Score ANOVA: • Group (music vs. art training) as BS factor • Time (pre-, mid-, and post-training) and subtest (scale, contour, interval, rhythm, memory) as WS factors	Significant main effect of time No significant main effect of subtest Significant interaction b/w time and group Significant main effect of time found in music group but not art group Significant improvement from mid- to post training, but not from pre- to mid-training in music group Significant effects of time found only for contour, rhythm, and memory subtests and not for interval subtest.	Music training improved music perception and emotional prosody perception

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
	Emotional speech prosody (% correct)	Emotion Prosody ANOVA • Group (music vs. art training) as BS factor • Time (pre-, mid-, post-training) and modality (AV[o] vs. A[p]) as WS factors	Significant main effect of time (**[q] $p < 0.005$) Significant main effect of modality (***$p < 0.001$) No significant interactions for time by group, modality by group, or time by modality by group Significant main effect of time for music but not art group Significant improvement in music group found between pre- and post-training and between pre- and mid-training	Mean emotional prosody scores higher pre-training than post-training Mean prosody scores higher for audiovisual than for audio-only stimuli

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		Analysis of the % of correct responses for AV and A trials (planned pairwise comparison safer than ANOVA) to investigate main effects	AV trials: no significant improvement in music or art group A trials: significant improvements seen in music group but not for art group; significant difference seen only between mid- and post-training	For AV trials in music group, mean emotional prosody scores higher post-training than pre-training and higher mid-training than pre-training For A trials in music group, mean emotional prosody scores higher post-training than mid-training Mean correct % scores for emotional prosody perception in music group were higher at mid-training than at pre-training on AV trials Mean correct % scores for emotional prosody perception in music group were higher at post-training than at pre-training and were higher at post-training than at mid-training on A trials

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		Correlations with demographic variables	No significant correlation between pre-training MBEMA, age at testing, age of implantation, and CI experience. Similar findings for improvement in MBEMA No significant correlation between pre-training emotional prosody perception, age at testing, age of implantation and CI experience. Similar findings for improvement in emotional prosody perception Unilateral vs. bilateral implantation & age of implantation didn't correlate with improvements seen on tasks	Baseline MBEMA scores unrelated to participant's age at testing, age at implantation, and CI experience Improvements in MBEMA scores unrelated to participant's age at testing, age at implantation, and CI experience
Hegarty and Faulkner (2013)	*Experiment 1*: Adaptive threshold measurement (% correct)	Repeated-measures ANOVA: condition (CI alone and bimodal CI+HA[r]) and range (F_0 low and F_0 high) were WS factors Paired samples *t*-test comparing amplitude	No significant effect of condition No significant effect of F_0 range No significant interaction between condition and range	Children were poor at hearing differences in both pitch and amplitude as thresholds were often larger than changes found typically in the speech

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		thresholds in the CI alone and bimodal conditions	No significant difference in amplitude threshold between conditions	
	Experiment 2: Focus sentence test (proportion correct scores)	Repeated-measures ANOVA: condition (CI alone & bimodal), speech (manipulated & natural), and speaker (male & female) were WS factors • For individual analysis, after pooling data from two speakers (male and female), proportion correct scores for speech conditions (manipulated and natural) and listening conditions (CI alone and bimodal) were examined	Whenever lower 95% confidence limit was greater than chance score of 0.333, participants' score was taken to significantly exceed chance Significant main effect for speech (manipulated and natural) listening condition (**$p = 0.016$) There was no significant effect of mode of stimulation (CI alone, bimodal CI+HA) or speaker (male, female) 6 of 9 children were able to perceive focus from natural speech above chance	Results failed to support hypothesis that proportion correct score for focus sentences was higher for children in bimodal condition than CI only Naturally produced focus sentences perceived significantly better than manipulated focus sentences (pitch cues only) supported hypothesis that other cues (i.e., amplitude or duration) may contribute to perception of stress and intonation. Performance best in bimodal condition for natural speech (bimodal + natural speech)

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
Kalathottukaren et al. (2017)	PEPS-C[s] prosody perception (% correct scores)	Wilcoxon signed-rank test Instead of Bonferroni corrections for multiple comparisons, p set conservatively at < 0.01 Stepwise regression analyses	Median scores on all PEPS-C subtests (except for long-item discrimination, chunking, and contrastive stress receptions) and total PEPS-C score were significantly lower for children with HL[t] compared to controls (** $p < 0.01$) Scores on happy, sad, and fearful emotions were significantly poorer for children with HL than for controls Musicality (i.e., music scores on the MBEA[u] and musical experience combined) was not a significant factor in regression analyses	Wilcoxon signed-rank tests showed differences in performance between children with HL and controls for some prosody perception measures Lack of statistical significance in regression analyses suggested co-linearity between predictor variables (e.g., HL and musicality) Poorer hearing associated with less musical experience, lower MBEA scores
	MBEA musical pitch discrimination (% correct)	Spearman correlations among age, hearing level (better-ear PTA), musicality, and prosody perception measures	PEPS-C total scores significantly correlated with age, hearing level, and musicality (i.e., music scores on the MBEA and musical experience combined). Significant negative correlation between hearing level and musicality	Children with HL have difficulty detecting subtle variations in acoustic cues necessary for adequate perception of speech prosodic features Increasing age and better hearing sensitivity are associated with better

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (*p* set at 5%)	Statistical Findings	Interpretation
			(r_s = - 0.354).	prosody perception abilities
	DANVA-2 prosody perception	Wilcoxon signed-rank test Spearman correlations among age, hearing level (better-ear PTA), musicality, and prosody perception measures	Scores obtained by children with HL on happy, sad, and fearful emotions were significantly poorer than for controls. HL group performed more poorly overall than control group for DANVA-2 low (V = 14.00, ***p* = 0.005) but not high (V = 17.50, **p* = 0.015) emotion intensity items. Significant correlation between DANVA-2 low emotion intensity scores and musicality (r_s = 0.507, N = 32, ***p* = 0.004) No significant correlation between DANVA-2 high-intensity scores and musicality (r_s = 0.114, N = 32, *p* = 0.540). No significant association between age and musicality (*p* = 0.814)	Children with HL have difficulty in perceiving different aspects of prosody compared with typically developing peers. HL alone explained 29.5% of the variance in PEPS-C and total scores Age and HL together accounted for 55.4% of the variance in PEPS-C total scores Musical skills may help children recognize vocal emotions presented with subtle emotional cues, or alternatively perhaps children with good prosodic skills are more musical.

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
Most and Michaelis (2012)	ETI[w] (emotion-perception score)	1-way ANOVA with repeated measures: hearing status (i.e., NH[x] and HL) was BS factor and repeated measures were four emotions (i.e., anger, fear, sadness, happiness) Children divided into 3 groups according to HL severity, defined by pure-tone average (PTA) of 500 Hz, 1000 Hz, and 2000 Hz in better ear 9 children had moderate HL (40–55 dB HL), 8 children had moderate-to-severe HL (56–90 dB HL), and 9 children had profound HL (poorer than	*Auditory Condition*: Significant main effects for hearing status (**$p < .01$), and for emotion (***$p < .001$), but no significant interaction between hearing status and emotion. Multiple comparisons among four emotions revealed significant differences between happiness and sadness (**$p = .006$); happiness and fear (**$p = .005$); anger and sadness (*$p = .024$); anger and fear (***$p = .001$); sadness and fear (***$p < .001$), but not between happiness and anger.	A and AV emotion identification perception was significantly lower in children with HL compared to children with NH Poorer performance rates resulted from children with profound HL. All other groups with HL did not significantly differ in emotion-perception ability from children with NH All children in present study, those with NH and those with HL, exhibited significantly higher performance in recognizing emotions correctly when given both auditory and visual cues than when given

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		90 dB HL). All 9 children w/ profound HL used CIs and used HAs prior to implantation; 4 used single CI; 2 used bilateral Cis; 3 used CI in 1 ear and HA in contralateral ear To examine differences in 3 conditions, multiple comparisons using studentized maximum modulus adjustment (Hochberg, 1974) conducted. Significant difference between combined condition and each condition alone (***$p < .001$)	*Visual Condition*: Significant main effects for hearing status (**$p = .011$) and for emotion (***$p < .001$). No significant interaction between hearing status and emotion. Multiple comparisons among four emotions revealed significant differences between happiness and anger (***$p < .001$); happiness and fear (***$p < .001$); anger and fear (***$p < .001$); sadness and fear (***$p < .001$), but not between happiness and sadness or between anger and sadness.	cues from only 1 sensory mode Both NH children and children with HL exhibited no significant difference b/w perception scores in auditory and visual conditions alone

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
			AV Condition: Significant main effects for hearing status (**$p = .006$), and for emotion (***$p < .001$), but no significant interaction between hearing status and emotion. Multiple comparisons among four emotions revealed significant differences between happiness and anger (*$p = .048$); happiness and fear ***($p < .001$); fear and anger (***$p < .001$); fear and sadness (p*** $< .001$), but not between happiness and sadness or between anger and sadness.	

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
Snow and Ertmer (2009)	Utterance accent range (i.e., width of pitch contour) Utterance duration	ANOVA with a mixed 4x2 factorial design: Age group (2 levels) as the BS factor and session (4 levels) as the WS factor. ANOVA with a mixed 2x2 factorial design: Age group (2 levels) as the BS factor and session (2 levels) as the WS factor	4x2 ANOVA: No significant main effects or interactions 2x2 ANOVA: No significant main effect. The interaction between chronological age and implant experience (i.e., the number of months preceding or following activation of the implant) was significant, (**$p = .009$)	The absence of significant findings was probably due to the large variability within and across children The findings indicated that neither amount of CI experience nor CA alone predicted development of intonation. However, there was a robust interaction between implant experience and age. Initial effects of post-implant hearing experience on children's intonation development therefore were different for younger vs. older children.
Volkova et al. (2013)	Emotion identification score (% correct)	*Experiment 1* Non-parametric tests • Binomial test (normal approximation, correcting for continuity, $p < 0.05$, one-tailed)	Binomial test revealed performance surpassed chance levels in 12 of 14 child users of CI and in 17 of 18 NH children Median score of NH children significantly higher than that of	Accuracy of identifying happiness and sadness in speech in children with CIs well above chance levels but significantly below that in children with normal hearing

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		• Mann–Whitney U test • Wilcoxon signed rank tests) • Pearson's Correlation (r)	child users of CI (*p =.047, Mann–Whitney U test) For female talker, but not for male talker, performance was significantly higher for NH children than for child users of CI, (*$p = 0.029$), Mann–Whitney U tests) Improvement from first to second block of trials was significant in NH children, (**$p = 0.013$), but not in child users of users (Wilcoxon signed rank tests) Performance of child users of CI collapsed across talkers was associated positively with duration of implant use, ($r = 0.60$, **$p = 0.012$ (one-tailed))	
		Experiment 2 Non-parametric tests • Kolmogorov–Smirnoff tests • Levene's Test • Binomial test, $p < 0.05$, one-tailed	NH children, who only received 1 block of trials, performed near ceiling (97.8% correct), and were much less variable than the child users of CI, ($p < 0.001$, Levene's test) On 1st block of trials, performance levels in 5 of 14	Child users of CI readily distinguished happy- from sad-sounding music although not with the accuracy demonstrated by their normal hearing peers For 12 users of CIs who participated in both

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		• Mann–Whitney U test • Wilcoxon signed rank tests) • Pearson's Correlation (r)	children with CIs and 17 of 18 NH children exceeded chance in a binomial test. On 2nd block, 10 of 14 CI children surpassed chance. On 1st block (i.e. the only block completed by both groups), proportion of children exceeding chance levels significantly higher in NH than children with CI group, (***$p < 0.00$) A nonparametric comparison of actual scores, contrasting NH children with users of CI (1st block), also confirmed advantage for NH group over CI group, (***$p < 0.001$) (Mann–Whitney U test) For child users of CI, improvement across trial blocks was not significant (Wilcoxon signed rank test) For child users of CI, association b/w duration of implant use (i.e. months since first implant activation) and performance collapsed across blocks was	experiments, performance on speech task correlated significantly with performance on music task Implant experience was correlated with performance on both tasks

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
			significant, (Pearson's $r = 0.49$, $^{*}p = 0.038$) Correlated performance on 1st block trials for Experiment 2 with performance from Experiment 1 for 18 NH children and for 12 users of CI who participated in both experiments. For NH group, the correlation was not significant, ($p = 0.367$), presumably because of high levels of performance and little variation in either experiment. For CI group, however, there was a positive association, (Pearson's $r = .51$, $^{*}p = .043$).	
Whipple et al. (2015)	PEMM[y]	GLMM[z] - Outcome variable analyzed as correct/not correct in relation to emotion or movement, intended by composer/performer of excerpts. To account for within-subject correlation introduced by the repeated measures design (each	*Recognition of Emotions* • Group, ($^{***}p < .0001$), emotion, ($^{***}p < .0001$), and their interactions, ($^{***}p = .0002$) were all statistically significant predictors of emotion recognition performance • Pairwise comparisons accuracy of emotion recognition accuracy	No significant difference in identification of musical emotions or movements occurred between ASD and TD-NH groups In contrast with both ASD and TD-NH groups, CI group was significantly less accurate in recognizing both emotional and movement

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		participant judged the emotions or movement stimuli three times), a random intercept was included for participants, using an unstructured covariance matrix. Group membership of users of CI, users of CI diagnosed with ASD[aa], and TD-NH[bb], emotion (i.e., happy, sad, anger, fear, disgust) or movement (i.e., run, walk, skip, climb), chronological age, and an interaction between group and emotion or movement were included in model. Spearman (r) correlations computed for relevant individual characteristics. For variables not collected on all 3 groups, their relationships with recognition were examined to assess if they were significantly	significantly better in ASD group than CI group, (*$p < .02$) for all emotions except anger; TD-NH group significantly better than CI group for all emotions, (**$p < .005$) except for disgust, (*$p = .09$). • Main effect of emotion: Emotional recognition performance accuracy highest for happy (89%) and sad (87%) emotions (no significant difference in performance b/w them) and lowest for disgust (63%) and anger (58%). Performance accuracy significantly higher for happy and sad than for disgust and anger, (**$p = .0029$, ***$p = .0001$). No significant difference in performance between disgust and anger. • CA not a significant predictor of correct emotion identification.	cues, despite CI group performing above chance on several emotions For this ASD sample, their social communication deficits did not limit their recognition of emotion and movement categories in musical excerpts Mixed effects logistic regression revealed different patterns of accuracy for specific emotions as a function of group. In both ASD and TD-NH groups, categories of happy and sad distinguished from each other and from other three categories. Anger, fear, and disgust—all negative emotions, were more commonly confused with one another. Both TD-NH and ASD

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
		different from zero. ASD group compared with TD-NH on CA and verbal age (measured by PPVT-III[cc]). Spearman correlations also computed for recognition accuracy with PPVT-III for CI group, PPVT-III for ASD group, and CELF-4[dd] for ASD group. Mixed effects logistic regression model to compare those percentages of correct identification and to compare each group by movement category.	• Emotion recognition performance positively correlated with CELF for ASD group, (Spearman ρ = .03). • For CI group, musical instruction (i.e., previous formal musical instruction experience as measured through musical background questionnaire) not significantly correlated with emotion identification performance *Movement Recognition* • Significant main effect of group, (***p <.0001) • Significant main effect of movement, (***p <.001) • No significant interaction between group and movement • CA significant predictor, (*p < .0308) of movement accuracy • Main effect for group. Movement recognition significantly higher for	groups tended to confuse disgust with sadness

Author/ Year	Measure of Speech Prosody Perception	Method of Statistical Analysis (p set at 5%)	Statistical Findings	Interpretation
			ASD and TD-NH groups than CI group, (*** p < .0001) • No significant difference for performance between ASD and TD-NH groups. • Main effect for movement categories. Recognition of climbing significantly poorer than other 3 movements • No significant differences in movement perception (run, walk, skip, climb) • ASD recognition accuracy for movement positively correlated with standard PPVT-III score, (Spearman ρ =.02)	

Note: [a] ANOVA (Analysis of Variance); [b] WS (Within-subject); [c] CA (Chronological age); [d] IA (Implantation age); [e] BS (Between-subject); [f] cNH (Children with normal hearing); [g] aNH (Adults with normal hearing); [h] *** ($p < 0.001$); [i] cCI (Children with cochlear implants); [j] aCI (Adults with cochlear implants); [k] CI (Cochlear implant); [l] * ($p < 0.05$); [m] HVHP (Hybrid Visual Habituation Procedure (HVHP); [n] MBEMA (Montreal Battery for Evaluation of Musical Abilities); [o] AV (Audio-visual condition); [p] A (Auditory only condition); [q] ** ($p < 0.01$); [r] HA (Hearing aid); [s] PEPS-C (Profiling Elements of Prosody in Speech-Communication); [t] HL (Hearing loss); [u] MBEA (Montreal Battery of Evaluation of Amusia); [v] DANVA-2 (Child Paralanguage subtest of the Diagnostic Analysis of Nonverbal Accuracy 2); [w] ETI (Emotional Identification Test); [x] NH (Normal hearing); [y] PEMM (Perception of Emotion and Movement in Music); [z] GLMM (Generalized Linear Mixed Model); [aa] ASD (Autism Spectrum Disorder); [bb] TD-NH (Typically developing-Normal hearing); [cc] PPVT-III (Peabody Picture Vocabulary Test-III); [dd] CELF-4 (Clinical Evaluation of Language Fundamentals-4)

DISCUSSION

The purpose of this investigation was to perform a systematic review of the existing literature on the perception of prosody in English-speaking children with cochlear implants.

Emerging Themes

The 9 studies included in this review indicate that pediatric users of cochlear implants experienced mixed results on assorted outcome measures assessing prosody perception relating to emotion recognition, as well as to other aspects of prosody perception, including speech and music prosody perception. Out of the 9 studies, 5 (56%) found emotion recognition in children with cochlear implants to be significantly poorer than in the children with normal-hearing sensitivity (Chatterjee et al., 2015; Kalathottukaren et al.; Most & Michaelis, 2012; Volkova et al., 2013; Whipple et al., 2015). Additionally, 2 of the 9 studies (22%) found children with cochlear implants to be generally poor at hearing differences in prosodic cues (Hegarty & Faulkner, 2013; Kalathottukaren et al.). However, children demonstrated promise in these tasks, such that 2 of the 9 (22%) studies supported the use of multiple sensory modalities and providing increased cochlear implant experience to improve performance in prosody understanding (Most & Michaelis; Snow & Ertmer, 2009). Furthermore, of the 9 studies, 3 (33%) presented precise aural (re)habilitation assessment measures for monitoring vowel height, lexical stress, and intonation, as well as musical training techniques improving prosodic and emotional understanding (Core et al., 2014; Good et al., 2017; Kalathottukaren et al.). These positive results yielded support for auditory development in populations of pediatric users of cochlear implants.

Prosody Perception Relating to Emotion Recognition

Of the 9 studies, 3 (33%) demonstrated that although children using cochlear implants could detect emotional differences in various tasks, their performance was still compromised compared to that of normal-hearing control participants (Chatterjee et al., 2015; Kalathottukaren et al., 2017; Most & Michaelis, 2012). Scores obtained by children with hearing loss on happy, sad, and fearful emotions were significantly poorer than those for control participants (Kalathottukaren et al.). Children with cochlear implants were found to recognize emotion in voices; however, a significant proportion did not perform as well, with performance amongst that achieved by normal hearing adults listening to degraded speech that mimicked spectral smearing (Chatterjee et al.). These results emphasize that despite speech's natural redundancy, much of it is lost when signals are spectrally degraded, such as with cochlear implants. Children with hearing loss also overall had lower auditory and auditory-visual perception of emotions, especially those with profound degrees of hearing loss, but were found to identify emotions more successfully when given auditory and visual cues in combination than when given cues in only one modality (Most & Michaelis).

Of the 9 studies, 2 (22%) had positive conclusions veiled in their negative outcomes, highlighting the natural resilience of the auditory system's development before implantation and in the greater scheme of emotional processing development in children (Volkova et al., 2013; Whipple et al., 2015). Volkova et al. observed child users of implants to accurately identify emotion in speech, despite their performance being lower than normal-hearing peers. Child users of implants' successful identification of emotion in music, even if poorer compared to controls, suggests that relevant cues are accessible at a relatively young age. On the music frontier, children with cochlear implants were found to perform above chance when detecting emotional categories through the medium of music, suggesting that music therapy may still be a viable option for this population, even if they performed lower than both normal hearing peers and those with Autism Spectrum Disorder (Whipple et al.). This can be particularly manipulated when clinicians take into account which structural aspects are more accurately perceived when selecting musical stimuli during therapy sessions for these patients.

Other Aspects of Prosody Perception

Of the 9 studies, 4 (44%) included an assessment of other aspects of prosody perception in pediatric users of cochlear implants (Core et al., 2014; Hegarty & Faulkner, 2013; Kalathottukaren et al., 2017; Snow & Ertmer, 2009). Children with cochlear implants were found to be generally poor at hearing differences in both pitch and amplitude, as their difference detection thresholds were typically larger than changes found in natural speech, even in bimodal configurations (Hegarty & Faulkner, 2013). However, individual children demonstrated improved pitch perception with bimodal stimulation, underscoring the benefits to exploit any residual hearing whenever possible to take advantage of all possible prosodic cues, even if group data did not highlight this trend. This perhaps was due to the differences in age and degree of residual hearing of participants, as well as stimuli used. Young recipients of cochlear implants appeared to progress through stages similar to those observed in children with normal-hearing sensitivity, such that children with cochlear implants match the same developmental milestones, but acquire those milestones at different chronological ages (Snow & Ertmer). That is, intonation development of children with a cochlear implant was found to interact with chronological age at implantation and the amount of the child's cochlear implant experience. Therefore, the age at which a child is implanted affects early implant performance. Fittingly, once older children are able to perceive speech through cochlear implants, they make greater short-term gains in intonation development than younger children with the same amount of cochlear implant-assisted hearing experience.

Of the 9 studies, 2 (22%) focused on the (re)habilitative options available for prosody understanding in pediatric users of cochlear implants (Core et al., 2014; Kalathottukaren et al., 2017). Children with cochlear implants have less overall auditory experience than children with normal-hearing sensitivity, so their language abilities can lag behind those of their peers with normal-hearing sensitivity. Moreover, children with hearing loss have been found to have difficulty in detecting subtle variations in acoustic cues that are necessary for adequate perception of prosodic features in speech.

The Relation Between Music Perception and Prosody Perception

Of the 9 studies, 2 (22%) specifically investigated the connection between music and the perception of emotional speech prosody in pediatric users of cochlear implants; and both studies utilized control groups (Good et al., 2017; Kalathottukaren et al., 2017). Good et al. found that music training led to improved performance on tasks requiring the discrimination of melodic contour and rhythm, as well as incidental memory for melodies, in addition to improved performance on emotional prosody perception tasks between pre- and mid-training sessions. Improvements in musical training were not unusual findings, but findings regarding improvement in perception of emotional speech prosody were novel and potentially important to auditory rehabilitation in the pediatric cochlear implant population (Good et al.). In addition to supporting music perception, these results demonstrate that music and auditory training explicitly support the perception of emotional prosody, which may enhance communicative skills and interactions, contributing positively to quality of life.

Poorer hearing sensitivity was also found to be associated with less musical experience (Kalathottukaren et al., 2017). The findings of Kalathottukaren et al.'s regression analyses show that increasing age and better hearing sensitivity (i.e., better-ear unaided pure tone average) are associated with improved prosody perception. The contribution of musical experience to prosody perception in pediatric populations with hearing loss was also investigated, revealing moderate positive correlations between the two variables. However, larger sample sizes are needed to better assess this variable of musicality (Kalathottukaren et al.).

Limitations

The inclusion criteria across all 9 studies in the review lacked uniformity in their definitions of hearing loss in experimental groups. Some studies included only users of cochlear implants in their experimental groups (Chatterjee et al., 2015; Core et al., 2014; Good et al., 2017; Snow & Ertmer, 2009; Volkova et al., 2013; Whipple et al., 2015). Of these groups, some studies included only users of bilateral cochlear implants (Volkova et al.), whereas other studies included more varied configurations that included users of unilateral, bilateral, or bimodal cochlear implant configurations (Hegarty & Faulkner, 2013; Whipple et al.). Even so, studies also included users of hearing aids only, in addition to users of cochlear implants in experimental groups (Kalathottukaren et al., 2017; Most & Michaelis, 2012). This variability introduces confounding variables that threaten the validity of the studies' findings. Findings may have differed had researchers been more or less homogenous in their inclusion or exclusion criteria.

The use of control groups and composition of experimental groups varied amongst studies, regardless of which aspect of prosody was being assessed in pediatric users of cochlear implants. Of the 9 studies, 5 (56%) assessed pediatric users of cochlear implants on emotional processing tasks and included the use of control groups (Chatterjee et al., 2015; Kalathottukaren et al., 2017; Most & Michaelis, 2012; Volkova et al., 2013; Whipple et al., 2015). Alternatively, of the 9 studies, 4 (44%) included an assessment of speech prosody perception in pediatric cochlear implant users, but only 1 study utilized a control group (Kalathottukaren et al.). The size and homogeneity of controls varied amongst these studies, leading to variability in their external validity as a result. The smallest control group included 14 subjects and the largest featuring 35 subjects with normal hearing (Most & Michaelis; Whipple et al.). Of the 4 studies including an assessment of speech prosody perception, small experimental sample size limitations (n = 6) were also observed in 1 study, restricting statistical power in the interpretation of results (Snow & Ertmer, 2009).

In addition, the variability in subject demographic factors was also seen across studies. Because of Hegarty and Faulkner's (2013) extremely heterogeneous population, the detection of clear trends regarding bimodal stimulation was likely compromised from excessive individual variation in cochlear implant characteristics, as well as by a lack of a control group. Although the degraded representation of melody, harmony, and timbre transmitted by cochlear implant hardware is the likely culprit of poorer recognition of conveyed emotions in Whipple et al.'s (2015) hearing loss group, it is also possible that differences in life experiences associated with hearing loss may have been an influential factor that was not accounted for.

Some studies were less representative of real-life communicative variables. Only a single speaker was used by Most and Michaelis (2012), along with a forced choice task that is not necessarily representative of daily communicative interactions, and which may not translate to emotional perception abilities in real life by those with hearing loss. A limitation of the Volkova et al. (2013) study was the use of a forced choice task that is not necessarily representative of emotion identification in speech and music stimuli in real life; this limitation also characterized the Most and Michaelis study. Chatterjee et al. (2015) also employed limited speakers, with only two talkers using child-directed speech, and without any active practice trials for participants to take advantage of any training effects.

Not being able to fully randomize group assignments was noted in Good et al. (2017), as well as the contribution of test-retest effects, such that a child's familiarity with emotional prosody perception tasks may have at least partially accounted for the marginal improvements across training groups. Furthermore, lack of monitoring of at-home practice that occurred in training groups over the 6-month time period may have also affected outcomes. Moreover, results of the study were reported to be somewhat inconsistent with prior music training studies that found limited evidence of improved emotional prosody perception due to music training only. This is surmised to be due to different inclusion criteria compared to previous studies that focused on adults, not children, who were implanted within one year or less, and which therefore included the first three months of usage when the greatest auditory gains in auditory perception are reportedly made. The present study, in contrast, had a mean time since implantation of 5.9 years. Despite this, the presence of a control group (i.e., visual training) gives further weight to these positive findings.

Clinical Implications

These findings highlight the obstacles children using cochlear implants face in daily communication and the depth of which their speech prosody understanding abilities are affected. One of the most difficult aspects of hearing electrically with cochlear implants is the spectral degradation that occurs through excessive spread of electrical current away from internal electrodes. The results of these studies suggest children using cochlear implants experience more difficulty in processing prosodic and emotional cues in speech as compared to their normal-hearing peers. Hence, hardware advancements and sensitive auditory (re)habilitative efforts will continue to be necessary as the age at implantation becomes younger. Moreover, findings generally suggest children learning to detect these subtle prosodic cues via electrical stimulation with cochlear implants will require intensive support to catch up to their normal hearing peers' emotional and prosodic understanding skillsets.

Of the 9 studies, 3 (33%) found that children with cochlear implants perform significantly more poorly than the participants in controls groups on measures of prosody perception, even in bimodal conditions and despite increased implant experience (Hegarty & Faulkner, 2013; Kalathottukaren et al., 2017; Snow & Ertmer, 2009). Prosody understanding plays an important role in social communication and incidental learning for children due to its influence on communicative intent and a speaker's mood. Toddlers and children continue learning speech and language from cues provided from speech in their surroundings. Infants and children especially, who have congenital or early onset deafness, do not have the advantageous mental representation of normal pitch relations gathered through experience that most post-lingually deafened adults do. These younger users of cochlear implant also have the added hurdle of developing perceptual skills of prosodic aspects of speech needed for linguistic functions and for their own spoken language development (Peng et al., 2012). As children grow older, the information that pitch provides also grows, with children becoming sensitive to the meaning (i.e., semantic interpretation) that variations in pitch provide after mastering phonetic changes delivered by prosody as an infant that signal stress and phrase information. Therefore, children with cochlear implants during this critical period of modeling, experience, and development will need targeted prosodic assessment to strengthen their perceptual skills as they continue mastering language in order to accomplish the already difficult task of intuiting emotion from prosody.

When examining emotional processing abilities, 5 of the 9 (56%) studies found that performance of children with cochlear implants was significantly poorer than that of children with normal-hearing sensitivity, including those with Autism Spectrum Disorder and regardless of mode of stimulus presentation (Chatterjee et al., 2015; Kalathottukaren et al., 2017; Most & Michaelis, 2012; Volkova et al., 2013; Whipple et al., 2015). Perception of speakers' emotional content relies on both auditory and visual cues (Most & Michaelis). Among young children, non-verbal auditory and visual information may hold more weight in social interactions, as their linguistic experience is still developing. As a result, perception of vital auditory non-verbal cues relating to speakers' emotional content during communicative interactions may be impaired when a sensorineural hearing loss exists, possibly leading to a lack of empathy or other social deficits (Mellon, 2000 as cited in Most & Michaelis). These findings emphasize the need to support pediatric users of cochlear implants via (re)habilitation measures that can evaluate users' emotion perception abilities in a precise manner and guide clinicians' intervention plans personalized to a child's strengths and weaknesses.

However, results were not without positive findings that underscore the importance of cochlear implantation in younger populations with hearing loss. Of the 9 studies, 3 (33%) explored promising avenues for (re)habilitative efforts advancing pediatric users of cochlear implants' perception of prosodic and emotional elements in both speech and music media (Core et al., 2014; Good et al., 2017; Kalathottukaren, et al., 2017). These include utilizing a modified version of a Hybrid Visual Habituation Procedure (HVHP) and the Profiling Elements of Prosody in Speech-Communication (PEPS-C) to assess prosodic elements, as well as long-term music training. Perceptual measures, typically not tested in audiological batteries, can provide useful developmental trajectory information in the (re)habilitation process, and therefore are needed to measure phonetic and prosodic perception in children with cochlear implants. The modified version of the HVHP was found to be a useful tool to assess speech perception abilities within individual children with cochlear implants, focusing on specific speech feature contrasts (Core et al.). Additionally, the PEPS-C test was useful for evaluating specific strengths and weaknesses on different aspects of prosody (i.e., linguistic and emotional) in children with hearing loss

(Kalathottukaren et al.). The PEPS-C test therefore also has the potential to assist in developing individualized and targeted intervention plans for prosodic elements of language for this population. Finally, music training (i.e., 6 months of piano lessons) explicitly supported the perception of emotional prosody. Together, these observations suggest that prosodic skills should be routinely assessed in children with hearing loss as they mature and gain more auditory experience.

The results of these studies encourage clinicians to continue exploring avenues of aural (re)habilitation that are individual to a child's prosodic strengths and weaknesses. Specifically, this research supports the use and continued development of intensive (re)habilitation emphasizing suprasegmental and paralinguistic aspects of speech through prosody perception measures sensitive to both emotional and linguistic components. Findings also suggest the potential auditory training with music may have for pediatric users of cochlear implants to improve emotional prosody understanding. However, since music is the primary therapeutic tool in auditory therapy, clinicians are encouraged to consider differential abilities when selecting music for clinical interventions focusing on emotions due to the myriad of communication disorders that may impact the transmission or decoding of stimuli differently.

Theoretical Implications

The effects of communication modality also have clinical relevance in terms of how music can influence emotional prosody perception. Positive effects of music training were found in audio-only conditions for the perception of emotional prosody, whereas minimal improvement was observed in control groups of users of cochlear implants receiving visual art training (Good et al., 2017). The findings in auditory-visual conditions, however, revealed improvements across both music and visual art training groups. As users of cochlear implants typically rely on visual information provided by facial cues, this was not necessarily surprising. As results did not correlate with demographic variables, these findings were deduced to illustrate the benefits of music training on emotional prosody perception.

The contribution of age at implantation in the larger developmental trajectory of children cannot be underestimated as well. Evidence of older children making greater short-term gains in intonation development, compared with younger children with identical amounts of cochlear implant experience, lends itself to the idea that auditory accessibility is not the only variable contributing to perceptual growth. These findings demonstrate support for claims that the linguistic system of intonation is borne from non-linguistic (e.g., cognitive, social-emotional, pragmatic, gestural, etc.) and early developing realms of psychological experience (Snow & Ertmer, 2009).

Future Research

Future research should address the various limitations of the included studies in this review, such as obtaining larger sample sizes, more homogeneous inclusion criteria, the utilization of control groups, and random assignment of participants whenever ethically possible. Furthermore, more realistic acoustic stimuli, both natural and manipulated stimuli, spoken by more variegated talkers with both adult- and child-directed speech materials, in situations that include noisy and reverberant environments that mimic realistic communicative settings should be explored. Taking this one step further, Most and Michaelis (2012) recommend further studies investigate whether children's exposure to experiencing more social emotional situations and emotional tones at school and at home, with peers and adults, could help them learn to recognize emotions better and whether these skills may also be augmented through education.

Core et al. (2014) and Kalathottukaren et al. (2017) discussed the utility of Hybrid Visual Habituation Procedure (HVHP) and the Profiling Elements of Prosody in Speech-Communication

(PEPS-C) methods, respectively for research as well as for clinical assessment. Further investigation of the validity and reliability of these measures of prosody in populations with varying inclusion characteristics would be helpful in determining their effectiveness, as well as examining, developing, and evaluating more measures of prosodic development and auditory progress for children with cochlear implants.

Additionally, several studies included forced-choice tasks in their experiments of emotional processing and prosodic cue detection. Comparable arousal levels in certain emotions often overlap in their acoustic cues, such as intersecting rate and amplitude cues, which users of cochlear implants rely on more than pitch or intonation cues to make their judgments. Continuing further research with tasks that are more representative of emotional speech prosody in daily life situations by offering more alternative choices when identifying emotional or prosodic cues could heighten emotional classification difficulty that is more representative of complex listening situations encountered in daily life. These could have implications for a child's ability to generalize skills learned in therapy sessions to their real-world communicative environments.

Lastly, there is a need to further investigate longitudinal effects of experimental training methods, as well as the inclusion of longer follow-up periods following any training performed. Only one study included in this review incorporated length of cochlear implant experience as an independent variable (Snow & Ertmer, 2009). The limitations of not following study participants for longer periods of time should be addressed to assess whether any observed improvements are short term or long term.

CONCLUSIONS

This systematic review aimed to assess existing literature on the perception of prosody in English-speaking children with cochlear implants. Browsing in the MEDLINE/PubMed (NLM) database led to the inclusion of nine studies meeting search requirements.

Child users of cochlear implants generally performed poorly on prosody perception. In relation to prosody perception concerning emotion recognition, children with cochlear implants were often able to detect emotions, but their performance still lagged behind that of their normal-hearing peers. More specifically, the recognition of happy, sad, and fearful emotions was significantly poorer in children with hearing loss than in children with normal-hearing sensitivity (Kalathottukaren et al., 2017). Confusions were most frequent between fear and sadness in pediatric users of cochlear implants (Most & Michaelis, 2012). Emotion recognition performance was significantly higher for happy emotions as compared to other emotions, including anger, fear, and sadness, as well as disgust (Most & Michaelis; Whipple et al., 2015).

Kalathottukaren et al. (2017) found that speech prosody perception (i.e., short-item discrimination, turn-end reception, affect reception) in children with cochlear implants was significantly poorer than children with normal-hearing sensitivity. The modified Hybrid Visual Habituation Procedure (HVHP) was also found to be effective in examining the discrimination of the speech features relating to prosody perception (i.e., vowel height, lexical stress, and intonation) thereby demonstrating promise as a measure of speech prosody perception in young children (Core et al., 2014).

Nonetheless, music perception and emotional prosody perception improved significantly over time in children with cochlear implants who received music training, but not in children with cochlear implants who received art training, providing support for the connection between music perception and prosody (Good et al., 2017).

Lastly, the findings of one study demonstrated that the effects of the first two months of implant experience on intonation varied depending on a child's age, highlighting that intonation has some non-linguistic (e.g., cognitive, social-emotional, pragmatic, gestural, etc.) roots (Snow & Ertmer, 2009).

Findings summarized in this review highlight the evolving frontier of the post-implantation journey of pediatric users of cochlear implants. The results suggest that children learning to detect these subtle prosodic cues via electrical stimulation with cochlear implants will require intensive support in order for their prosodic performance to catch up to that of their normal-hearing peers. Furthermore, the results of these studies should encourage clinicians to continue exploring avenues of aural (re)habilitation that are individual to a child's prosodic strengths and weaknesses. Specifically, this research supports the use and continued development of intensive (re)habilitation emphasizing emotion recognition, suprasegmental and paralinguistic aspects of speech, and music perception.

Future research on the prosody perception of pediatric users of cochlear implants should include tasks that are more representative of complex listening situations encountered in daily life. This includes offering more alternative choices when identifying emotional or prosodic cues, heightening prosody classification task difficulty and simulating situations which are more representative of complex listening situations encountered in the real world. Moreover, creating prosody identification tasks that incorporate differing levels of background noise and reverberation during prosody perception tasks could also replicate the difficulty of such tasks confronted in daily communicative situations for this population of pediatric cochlear implant users. Future research should include longitudinal research designs with longer follow-up periods so that long-term effects of training and intervention on prosody perception may be assessed.

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