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Research Article

Early Vocabulary Profiles of Young Deaf Children Who Use Cochlear Implants

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Purpose: This study examined vocabulary profiles in young cochlear implant (CI) recipients and in children with normal hearing (NH) matched on receptive vocabulary size to improve our understanding of young CI recipients' acquisition of word categories (e.g., common nouns or closed-class words).

Method: We compared receptive and expressive vocabulary profiles between young CI recipients (*n* = 48; mean age at activation = 15.61 months, *SD* = 4.20) and children with NH (*n* = 48). The two groups were matched on receptive vocabulary size as measured by the MacArthur–Bates Communicative Development Inventories (Fenson et al., 2006): Words and Gestures form. The CI group had, on average, 8.98 months of hearing experience. The mean chronological age at completing the MacArthur–Bates Communicative Development Inventories was 23.99 months (*SD* = 5.14) for the CI group and 13.72 months (*SD* = 1.50) for the NH group.

Results: The CI group had a larger expressive vocabulary size than the receptive vocabulary size–matched NH group. The larger expressive vocabulary size was associated with the group difference in social words but not with common nouns. The analyses for predicate words and closed-class words included only children who produced the target categories. The CI group had a larger proportion of predicate words than the NH group, but no difference was found in closed-class words in expressive vocabulary.

Conclusions: Differences found in expressive vocabulary profiles may be affected by spoken vocabulary size and their age. A further examination is warranted using language samples to understand the effect of language input on children's vocabulary profiles.

Our vocabularies are composed of a variety of word categories (e.g., nouns, verbs, adjectives), and the acquisition of words in these categories follows different developmental trajectories (Bates et al., 1994). Children's first words are often socially engaging ones, including "mommy," "daddy," "hi," or "bye" (Caselli et al., 1999; Snedeker et al., 2012; Tardif et al., 2008). Then, the acquisition of nouns increases and dominates early vocabularies (Bates et al., 1994; Caselli et al., 1999; Snedeker et al., 2012). This early noun dominance is particularly well established in the literature for English-speaking children (e.g., Gentner, 1982; Goldfield & Reznick, 1990; Kim et al., 2000; MacRoy-Higgins et al., 2016; McDonough et al., 2011; for language-specific effects, see Choi & Gopnik, 1995; Kauschke et al., 2007; Tardif, 1996; Xuan & Dollaghan, 2013). The proportion of nouns in English-speaking children's vocabularies generally increases until the total size of vocabulary reaches approximately 200 words (Bates et al., 1994; Caselli et al., 1999; Snedeker et al., 2012). In contrast to the early noun dominance, the acquisition of other word categories for English-learning children is slow at first (e.g., predicating words or grammatical closed-class words) but later accelerates as children expand their vocabulary size. For instance, in a study using a parental checklist, Bates et al. (1994) found that closed-class words showed remarkable growth after children had an expressive vocabulary of approximately 400 words. In short, children change the composition of vocabularies as they expand their vocabulary size.

However, very little is known about vocabulary profiles in young children with cochlear implants (CIs). When considering that many children receive their CIs around

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12 months of age or later, they begin auditory-guided language acquisition at a cognitively different stage compared to children with typical hearing. Being relatively more cognitively mature at the beginning stage of learning spoken language may affect early vocabulary development. Indeed, although their perceived input is different due to the degraded nature of sound through CIs, studies have found that young CI recipients show rapid emergence of first words and substantial amount of vocabulary acquisition at the end of the first year (Ertmer & Inniger, 2009; Faes et al., 2017; Fagan, 2015; Koşaner et al., 2013). However, a recent study found that early rapid vocabulary acquisition does not persist past the first year of CI use (Koşaner et al., 2013). In addition, many young CI recipients never acquire vocabulary sizes commensurate with their peers with normal hearing (NH; Dettman et al., 2016; Hayes et al., 2009; Rinaldi et al., 2013). These findings motivate further examination of vocabulary acquisition in children with CI. Understanding the composition of their vocabularies may shed light on the mechanisms in vocabulary acquisition and uncover specific advantages and disadvantages that can be addressed in therapy and educational practices for them.

Potential Factors Affecting Vocabulary Profiles in Children With CIs

Children's vocabulary profiles may not be affected by the same factors that affect vocabulary "growth". For example, it is well known that maternal education level has an effect on input quantity and correlates with vocabulary growth (Hart & Risley, 1995; Hoff & Naigles, 2002; Huttenlocher et al., 1991). However, Bates et al. (1994) conducted a study with a large sample (n = 1,130) and found that the impact of maternal education level on children's vocabulary "profiles" was much weaker—correlations between the proportion of word categories and maternal education level were .13 or smaller (without adjusting vocabulary size). In contrast, they demonstrated that the proportions of word categories were more associated with vocabulary size or age (rs = .31–.36).

In typically developing children, vocabulary size increases as children develop (Fenson et al., 1994). As children grow, so do their cognitive abilities (Brownell, 1986; Hayne et al., 2000). Examining vocabulary profiles in children who begin acquiring vocabulary at a later age may shed light on the role of cognitive maturity on vocabulary acquisition. For instance, the early dominance of nouns indicates that the concepts of this category are generally easy and concrete for young infants (Au et al., 1994; Bates et al., 1994; Bornstein et al., 2004; Caselli et al., 1999; Gentner, 1982; Imai et al., 2006; Kim et al., 2000; McDonough et al., 2011; Pae, 1993; Rescorla et al., 2013; Stolt et al., 2008; Välimaa et al., 2018; Xuan & Dollaghan, 2013). Snedeker et al. (2012) support this notion by finding similar proportional shifts in the vocabulary of internationally adopted children who began to learn English at later than the typical age when compared with native English–learning children. However, Snedeker and colleagues also found that children who were adopted at preschool age acquired adjectives and time words more rapidly than those who were adopted at infancy. The authors argued for the possibility that the older group had motivational and cognitive advantages that allowed them to acquire those two categories more rapidly than the younger group. Taken together, the acquisition of certain vocabulary items is affected by cognitive or maturity factors. The difference in age may result in somewhat incongruent vocabulary profiles.

Children's vocabulary profiles are also affected by language input content, as evidenced by the strong correlation between children's first words and mothers' frequently used words (Harris et al., 1988; Hart, 1991). In English, the early noun dominance may be explained by the finding that mothers use more nouns than verbs to their young infants during their first year of life (Goldfield, 1993). The subsequent decrease in the proportion of nouns in children's profiles (after the acquisition of 200 words) is also compatible with the decrement in maternal use of nouns as children get older (Furrow et al., 1979). The change in maternal vocabulary use as children grow also aligns with findings that maternal input properties have a reciprocal relationship with children's cognitive development (Song et al., 2013). Another support for the effects of language input comes from many cross-linguistic studies. English-speaking mothers' vocabulary composition to young infants favored nouns more than the vocabulary compositions of mothers who speak some other languages (e.g., Chinese or Korean), and the pattern was reflected in children's early vocabulary composition (Choi, 2000; Choi & Gopnik, 1995; Tardif, 1996; Tardif et al., 1997, 1999; Xuan & Dollaghan, 2013). Examining English-speaking young CI recipients' vocabulary profiles may shed additional light on the effects of cognitive maturity (i.e., age) on early vocabulary acquisition, and if differences in vocabulary profiles are found, it may motivate additional research on the role of language input on vocabulary acquisition.

Young CI Recipients' Vocabulary Profiles

It may not be surprising that young CI recipients' vocabulary size is relatively small compared to that of age-matched typically developing children (Hayes et al., 2009; Rinaldi et al., 2013) when considering their auditory deficit. In contrast, it is remarkable that their vocabulary acquisition during the first year of CI use is rapid and substantial (Ertmer & Inniger, 2009; Faes et al., 2017; Fagan, 2015; Koşaner et al., 2013). Koşaner et al. (2013) found that young children who had 10–12 months of CI experience acquired approximately 100 spoken words (see also Fagan, 2015). These numbers considerably exceed what typically developing infants acquire with the same amount of hearing experience, suggesting that vocabulary acquisition in children with CIs benefit from their maturity levels (e.g., nonverbal cognition and physical maturity) relative to their peers matched with hearing experience during the early phase of CI use.

For instance, given that many deaf children develop their nonverbal cognitive skills within a normal range (Geers et al., 2003), cognitive maturity could facilitate not only early emergence of words but also the acquisition of a certain subcategory of words (Snedeker et al., 2012). In addition, as children with hearing loss (HL) develop intact communicative intent (Nicholas et al., 1994) and motor skills (Leigh et al., 2015), they may generate different parent–child interactions, which could, in turn, affect children's vocabulary profiles (Tardif et al., 1999). However, studies have shown that mothers of young CI recipients adapt their speech-language input according to their children's hearing experience or language ability rather than chronological age (Bergeson et al., 2006; Lund & Schuele, 2015; Morgan et al., 2014). That is, their relative maturity may not be represented in their maternal input, and children's vocabulary profiles may be similar to typically developing children matched on language ability or hearing age. In short, we lack knowledge about their vocabulary profiles.

Many studies have been conducted on young CI recipients' language "growth" (e.g., outcomes in standardized test scores, mean length of utterances, grammatical complexity, vocabulary size; Chen et al., 2017; Connor et al., 2006; Fagan, 2015; Szagun & Stumper, 2012; Välimaa et al., 2018). In contrast, studies on vocabulary profiles in young CI recipients are emerging. To our knowledge, two recent studies have examined young CI recipients' composition of word categories using parental checklists (in Turkish and Finnish; Koşaner et al., 2013; Välimaa et al., 2018), and another additional study examined Australian English profiles in young CI recipients using a diary (Nott et al., 2009). Koşaner et al. (2013) compared the vocabulary composition of Turkish children's first 100 receptive and expressive words between the CI and NH groups (mean hearing experience for the CI group = 6–9 months vs. mean hearing experience for the NH group = 16–18 months). The authors concluded that the two groups did not differ in the distribution of vocabulary items that children acquired. However, they compared the raw size of vocabulary with large variance from 21 separate semantic classes of the checklist (e.g., animal sounds, animal names, vehicles). Therefore, it was not clear whether the profiles would look similar when using composite scores to represent word class categories (e.g., common nouns or predicate words). Välimaa et al. (2018) used five word class categories (i.e., common nouns, social words, verbs, adjectives, and grammatical function words) to examine receptive and expressive vocabulary development in Finnish-speaking children using bilateral CIs. The vocabulary profiles in bilateral CI recipients followed typical trajectories as the function of vocabulary size across the first year of CI use (e.g., Bates et al., 1994; Caselli et al., 1999; Koşaner et al., 2013; Nott et al., 2009; Stolt et al., 2008). However, because they did not employ a control group, it was only possible to observe the global trajectories rather than fine-grained comparisons between groups.

By contrast, Nott et al. (2009) analyzed vocabulary profiles of Australian English–speaking children with NH to those with HL (23 of 24 were CI users; range of age at activation = 7–29 months). Children's expressive vocabularies were tracked via diaries beginning from when they spoke their first word (mean chronological age: 17.5 months for the HL group vs. 12.4 months for the NH group) until they accumulated 100 vocabulary items (mean chronological age: 30.1 months for the HL group vs. 21.3 months for the NH group). The authors analyzed the proportion of four major categories of words at two different levels—when children acquired 50 and 100 spoken words. The categories were (a) nouns (i.e., common nouns, onomatopoeic words, and proper nouns), (b) predicate words (i.e., words that take arguments, such as verbs and adjectives), (c) grammatical function words (i.e., question words [e.g., what, who, when], conjunctions, prepositions, pronouns, determiners, and adverbs), and (d) paralexical words (i.e., interjections, social words [e.g., bye, hello, thank you], yes/no words, and frozen phrases). Both groups exhibited vocabulary profiles in which nouns constituted the largest proportion (> 50%) at each level, while the remaining categories were small.

However, even though nouns dominated the vocabulary profiles of both groups, the magnitude of this dominance differed between them. The group with HL produced a significantly smaller proportion of nouns but a greater proportion of predicate words (i.e., verbs and adjectives) than the group with NH. The remaining categories (i.e., grammatical function words and paralexical words) were similar between groups across levels (50 and 100). When analyzing the subcategories, fewer children from the HL group used pronouns and grammatical word types than the NH group, but the proportions of these categories were very small in the given vocabulary size.

Taken together, these studies suggest that CI recipients' vocabulary profiles may differ from those of NH children. Because certain word categories have a close relation to later language outcomes (e.g., verbs and grammatical skills; McGregor et al., 2005; Thal et al., 1996), examining young CI recipients' vocabulary profiles is an important step to better understand the nuances of their language development. However, the fine-grained profiles reported may be affected by differences in methodological approaches.

Methodological Differences in Vocabulary Categories and Assessment Tools

The findings in the previous study (Nott et al., 2009) draw attention to an important methodological issue regarding word categories. While onomatopoeias can be considered nouns, their usage often differs from other nouns and may be better classified as something else. For example, onomatopoeic words were defined as "social" words in other studies using checklists (e.g., Snedeker et al., 2012; Välimaa et al., 2018). In addition, the effect of social contexts on this category was discussed in the study by Nott et al. (2009).They proposed the possibility that children with HL hear more onomatopoeia in language input due to receiving speech and language therapy. In addition to onomatopoeia, the noun category in Nott et al.'s study included common nouns and proper nouns, whereas other studies examined common nouns independently (e.g., Bates et al., 1994). Moreover, a study by Snyder et al. (1981) revealed that, in early vocabularies (i.e., at age 13 months), proper noun growth was independent of common noun growth. The authors argued that the proper nouns in early lexicons represent children's social environments, such as people whom they meet rather than their knowledge regarding reference. In short, to compare the vocabulary profile in young CI recipients to existing studies more easily, a few word types are needed to be adapted into different categories, such as classifying onomatopoeic words as "social" words.

It is also noteworthy that numerous studies used the MacArthur–Bates Communicative Development Inventories (MBCDI; Fenson et al., 2006) to investigate vocabulary profiles of children with NH (e.g., Bates et al., 1994; MacRoy-Higgins et al., 2016; Snedeker et al., 2012; Tardif et al., 2008). For children with CIs, MBCDI is also a helpful tool to understand the characteristics of vocabulary acquisition (e.g., Guo et al., 2015; Han et al., 2015). However, just a few studies have examined vocabulary profiles in young CI recipients using MBCDI, and neither of those examined English (Koşaner et al., 2013; Välimaa et al., 2018). The study conducted by Nott et al. (2009) examined English vocabulary composition but used diaries. Although the use of diaries may be a powerful approach, Koşaner et al. (2013) observed challenges for caregivers in reporting words using the diary method and opted to use the Turkish version of the MBCDI. In addition, for children with CIs, the MBCDI (i.e., Words and Gestures, and Words and Sentences) has been validated for assessing early language skills in children with CIs by comparing with a standardized test (i.e., Reynell Developmental Language Scales; Reynell & Gruber, 1990) and other criterion-based measures (i.e., number of word types, mean length of utterances, or index of productive syntax; Scarborough, 1990; Thal et al., 2007).

The measure-specific features may affect the assessment of children's vocabulary profiles. Pine et al. (1996) compared a checklist method (i.e., counting based on fixed items) to a direct observation method, which is as limitless in the number of words per category as the diary method. They found that the assessment of children's vocabulary profiles was affected by the data collection method used (e.g., the proportion of common nouns in the direct observations was smaller than in checklists). A biased proportion of common nouns endorsed on the checklists often is found, given that checklists contain a large proportion of common noun items (e.g., 52% of the MBCDI: Words and Gesture version). This finding was further supported by Tardif et al. (1999) examining children's and mothers' vocabulary use in English and Mandarin using MBCDI and diverse playing contexts (e.g., book reading, regular toys, and mechanical toys). Using the checklists resulted in noun-biased composition in both language users, but playing contexts showed various patterns depending on the types of playing (i.e., book reading was more a noun-biased activity than playing with toys).

Taken together, we proposed to use a standardized format in examining vocabulary profiles in young CI recipients, which would be more comparable to previous studies than to use nonstandardized playing contexts. In addition, it is noteworthy that checklists contain typical words used by many peers, which can help to determine differences between the profiles of young CI recipients and their NH peers within a representative set of vocabulary items.

The Purpose of the Current Study

The current study complements the study of Nott et al. (2009) for English-speaking children with CIs by using a checklist measure—the MBCDI (Fenson et al., 2006). Whereas the previous study used the diary approach provides information about individual-specific vocabulary items, the MBCDI, which is normed on a large population of children, provides representative items for English-speaking young children. Therefore, using the checklist is effective for comparing CI and NH groups' profiles within a set of words that many children may know. At the same time, the checklist contains a large, comprehensive set of items (e.g., 396 items for children between 8 and 18 months of age), so it reflects individual variability as well. Given that the current study employed the MBCDI: Words and Gestures form that can track receptive and expressive vocabularies, this study builds on Nott et al.'s examination of expressive language, expanding our understanding of young CI recipients' English vocabulary development.

In contrast to Nott et al.'s (2009) study examining vocabulary profiles when children produced 50 and 100 words, we matched groups by receptive vocabulary size during the first year of CI use. Children acquire receptive vocabulary before speaking words (Bates et al., 1988; Benedict, 1979; Fenson et al., 1994; Hallé & de Boysson-Bardies, 1994), but many factors can influence which of the words a child understands are produced by the child. Instead of matching expressive vocabulary, matching by receptive vocabulary size allowed us to examine differences in vocabulary use when children had approximately equal amounts of word knowledge according to parent report.

Method

Participants

Children With CI

This retrospective investigation used data collected from three research centers (Indiana University School of Medicine, Children's Hospital Colorado, and Callier Center for Communication Disorders at The University of Texas at Dallas) between December 2006 and June 2015. All procedures and analyses were approved by institutional review boards of The Ohio State University, Indiana University, The University of Texas at Dallas, and the University of Colorado Boulder.

We reviewed vocabulary size during the first year of CI use, measured by MBCDI: Words and Gestures checklists (Fenson et al., 2006) from 63 children with CIs who participated in various projects (more detailed procedure for inclusion can be found in the section for vocabulary size matching). All participants underwent cochlear implantation by 24 months of age, before their speech and language development (i.e., prelingual HL; Schow & Nerbonne, 2012). They had no additional disabilities at the time of data collection. The current analysis included children who had at least five spoken words in receptive and expressive vocabulary so that a single vocabulary item represented no greater than 20% in profile. The final sample included 48 children (27 boys and 21 girls; for audiologic and demographic information, see Tables 1 and 2). The mean age at activation was 15.61 months old (*SD* = 4.20, range: 8.00–23.60 months). The current data for the CI group were collected during the first year after CI activation, except one child whose appointment for the 12-month session was made a month later (range of CI experience at completing the checklist: 0–13.41 months, median of CI experience = 8.98 months, interquartile range [IQR] = 5.82).[1] Because the primary interest of this study was to examine vocabulary profiles based on vocabulary size, not based on hearing experience, the range of CI experience was relatively wide, and half of the participants had more than 8 months of robust hearing experience.

All families' primary language at home was spoken English: None of the families was native American Sign Language users. Thirty-one families reported that they used spoken language only, and 10 families used at least one supplementary manual mode (e.g., baby signs, signed English, cued speech, just a few signs, or sign language) with the oral mode. The remaining seven families' communication modes were not known. All participating families indicated that their goal was to develop oral language skills in their children. This study examined only spoken vocabulary items.

Table 1. Audiologic and demographic characteristics of children with cochlear implants.

Variable	*n*
Degree of hearing loss[a]	
Moderately severe (56–70 dB HL)	1
Severe (71–89 dB HL)	8
Severe sloping to profound[b]	4
Profound (≥ 90 dB HL)	35
Device configuration at data collection	
Unilateral CI	14
Bimodal (CI and contralateral hearing aid)	9
Bilateral CI	25
Race	
Caucasian	26
African American	2
Other	3
Unknown	17
Ethnicity	
Hispanic	2
Non-Hispanic	29
Unknown	17

Note. The "Other" racial category collapses data from participants identified as Asian and Hawaiian/Other Pacific Islander and those reporting more than one race. CI = cochlear implant.

[a]Degrees of hearing loss match categories described by the American Speech-Language-Hearing Association (n.d.). [b]Configuration of hearing loss slopes from severe hearing loss in the low frequencies (e.g., 250 or 500 Hz) to profound hearing loss in the high frequencies (e.g., 3000 or 4000 Hz).

Table 2. Description of onset and experience with auditory technology.

Variable	*M* (*SD*)	Range
Age at first fitting of hearing aids (months)	6.30 (4.76)	1–21
Duration of hearing aid use before cochlear implantation (months)	9.33 (4.30)	2–19
Age at cochlear implant activation (months)	15.61 (4.20)	8–23.6

Children With NH

The same number of children with NH (*n* = 48, 24 boys and 24 girls) whose receptive vocabulary size, as measured, were matched to the CI group based on receptive vocabulary size measured by the MBCDI. All children passed newborn hearing screening and were confirmed by the parents to have typical hearing sensitivity. Mean chronological age of the NH group was 13.72 months old (*SD* = 1.50, range: 8.87–16.03 months). The age at which they contributed to the data was significantly younger than that of the CI group, $t(54.95) = 13.30$, $p < .001$. All families used spoken English at home. The children had no history or concerns of cognitive or physical developmental delays.

Matching With Spoken Receptive Vocabulary Size

Children's spoken vocabulary size was measured using the MBCDI: Words and Gestures form. The MBCDI has two versions for typically developing children according to their chronological age and language level. For example, MBCDI: Words and Sentences form is available for children between 16 and 30 months of age and examines only expressive vocabulary with grammatical abilities. By contrast, the Words and Gestures version is appropriate to examine development of receptive vocabulary, expressive vocabulary, and gesture in infants between 8 and 18 months old. For CI recipients, the choice of which version of the MBCDI to administer often depends on estimated vocabulary size and children's hearing experience (Bavin et al., 2018; Thal et al., 2007). Given that the current sample all had less than 14 months of hearing experience, all caregivers completed the Words and Gestures form.

Initially, a total of 126 (i.e., 63 pairs) children's MBCDI were matched at the individual level for receptive

[1]There were two children who had less than 1 month of CI experience. In the analyses, we present the results, including these two, because, regardless of removing them or not, there were no significant differences.

vocabulary size (range: 1–396 for the CI group and 1–395 for the NH group; mean difference in number of receptive words for pairs = 3.40, SD = 4.15). However, in the process of removing children whose expressive vocabulary size was smaller than five, the pairing was not possible because many pairs that were matched on receptive vocabulary included a child with an expressive vocabulary size smaller than five. Therefore, the matching was made on the group level. The mean receptive vocabulary size for the CI group was 163.35 (SD = 91.09, range: 15–396), and for the NH group, it was 166.29 (SD = 79.28, range: 14–352). There was no difference in receptive vocabulary size between the two groups, $t(94) = -0.169$, $p = .867$. Although the matching at pair level was not possible, comparison of the group mean on receptive vocabulary size yielded a high p value. According to Mervis and Robinson (2003), if a group comparison yields a p value of greater than .5, the two groups are sufficiently well matched.

Vocabulary Categories in MBCDI

The MBCDI: Words and Gestures checklist contains 396 word types, comprising 19 word classes (e.g., sound effects and animal sounds, animal names, toys, action words, pronouns). We classified the 19 classes into four categories as follows: (a) common nouns: animal names, vehicles, toys, food and drink, clothing, body parts, furniture and rooms, small household items, and outside things and places; (b) predicate words (argument-taking words): action words and descriptive words; (c) social words: sound effects and animal sounds, people nouns, and games and routines; and (d) closed-class words: words about time, pronouns, question words, prepositions and location, and quantifiers (see the Appendix). This categorization resulted in 209 items included in the common noun category (52.78%), 92 items in predicate words (23.23%), 51 items in social words (12.88%), and 44 items in closed-class words (11.11%).

Our categorization was adapted to include entire word classes from the checklist. For instance, to classify common nouns and closed-class words, we followed Tardif et al. (2008), who integrated "outside things and places" into common nouns and "words about time" into closed-class words. By contrast, three classes (i.e., sound effects and animal sounds, people nouns, and games and routines) were incorporated as social words following Snedeker et al. (2007), because the three classes are a group of words that can be classified based on pragmatic functions (e.g., "woof woof," "hi," and "mommy"). We also collapsed action words and descriptive words into one category (i.e., predicate words), following Bates et al. (1994), MacRoy-Higgins et al. (2016), and Nott et al. (2009). These two classes are usually acquired later, constituting a small proportion in early vocabulary development, and have similar argument-taking functions. Given that our examination focused on the first year of CI use, collapsing the two classes was expected to provide a clearer profile than analyzing them as separate categories.

Statistical Analysis

Group comparisons of continuous outcomes were conducted using either an independent two-sample t test when the outcome was normally distributed or a Wilcoxon rank-sum test for data not normally distributed. The normality was examined visually and assessed using the Shapiro–Wilk test. Predicate words and closed-class word categories had many children who did not yet produce words belonging to these two categories at all. Therefore, we used a two-level statistical approach for these categories. First, we used chi-square tests to compare the proportion of children who showed a response to these categories (i.e., nonzero). Second, we compared the proportions of the predicate words and closed-class words between the two groups. The effect size was also calculated using Cohen's d for parametric analysis and correlation in r for nonparametric analysis (Fritz et al., 2012). For Cohen's d values, 0.2 represents a small effect, 0.5 shows a medium effect size, and 0.8 shows a large effect size. For the values of r, .1 represents a small effect size, .3 represents a medium effect size, and .5 represents a large effect size (Maher et al., 2013). All reported results are two-tailed tests.

Results

Group Difference in Expressive Vocabulary Size

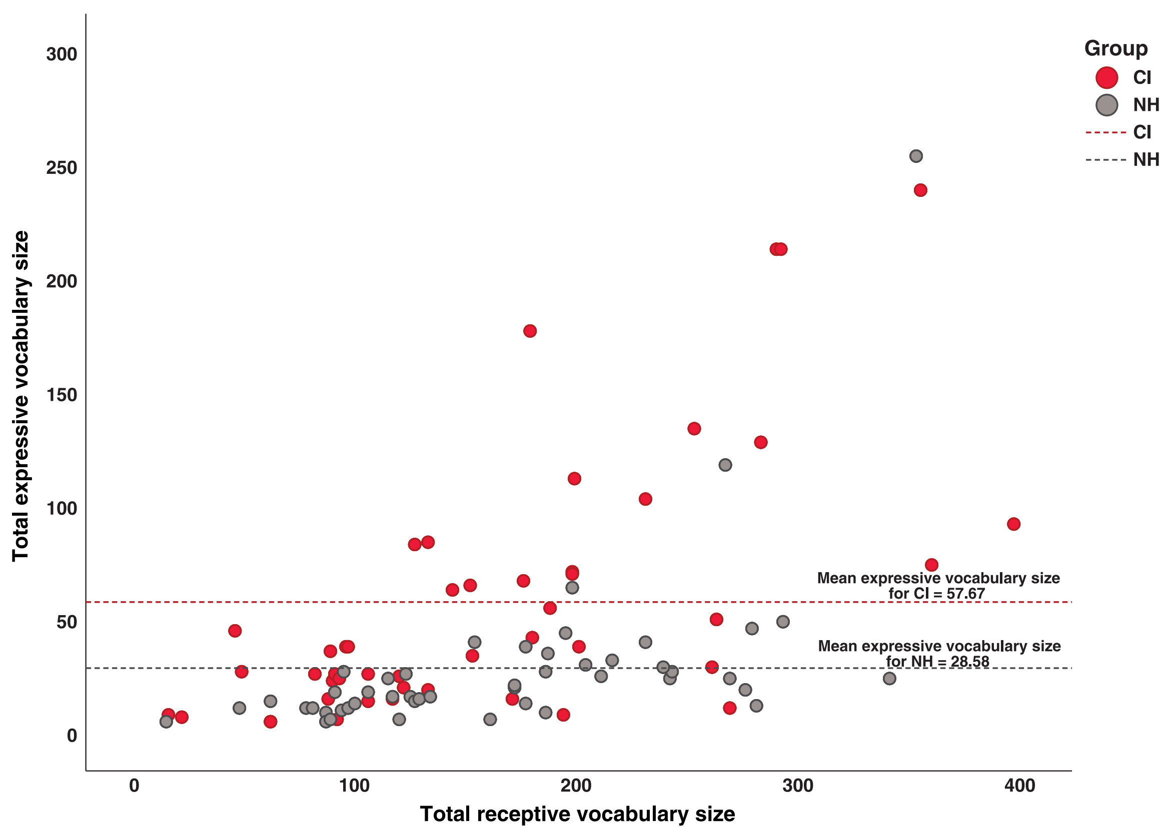
We compared the expressive vocabulary size to determine whether the CI group produced a similar number of spoken words as the NH group when they had comparable amounts of receptive word knowledge. The median expressive vocabulary size for the CI group was 38.00 (range: 5–239, IQR = 53.00), whereas it was 19.50 (range: 5–254, IQR = 18.00) for the NH group. The two groups' expressive vocabulary sizes were significantly different, $z = 3.26$, $p = .002$, $r = .33$. We confirmed that the children in the NH group showed typical expressive vocabulary development by examining their percentile scores on MBCDI norms. Their mean gender-specific percentile score was 62.70 (SD = 23.03), and all scores were at or above the 20th percentile. Figure 1 presents the expressive vocabulary size measured by MBCDI based on each individual's receptive vocabulary size. The CI group had more expressive words when they had a similar size of receptive vocabularies to the NH group.

Group Differences in the Composition of Receptive and Expressive Vocabulary

Receptive Vocabulary Categories

The two groups did not differ significantly in the categorical proportions in receptive vocabulary when matched for vocabulary sizes. Figure 2 presents receptive vocabulary profiles for the four categories. Overall, common nouns dominated receptive vocabulary for both groups (CI: M = 50.09%, SD = 8.37; NH: M = 49.59%, SD = 9.08). Predicate words and social words each comprised about one fifth of words understood. Closed-class words constituted

Figure 1. The expressive vocabulary size relative to receptive vocabulary size. The straight dotted lines represent group means. CI = cochlear implant; NH = normal hearing.



about 5%–6% of parent-reported receptive vocabulary (CI: $M = 6.55\%$, $SD = 3.12$; NH: $M = 5.72\%$, $SD = 3.39$).

Expressive Vocabulary Categories

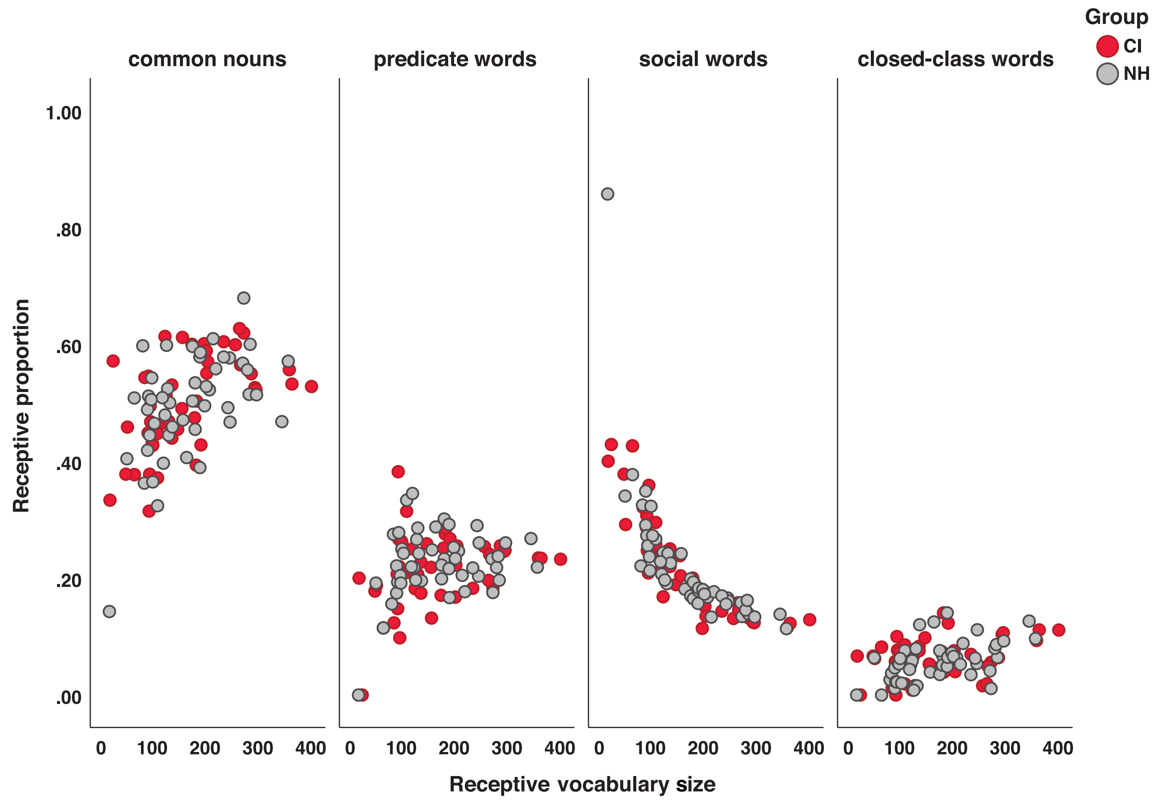
The proportions of the four expressive word categories were compared between the two groups. All children were reported to use some common nouns and social words, demonstrating that these constitute the major categories of early expressive vocabulary. The mean proportion of common nouns did not differ significantly between the CI group ($M = 34.96\%$, $SD = 14.68$) and the NH group ($M = 34.42\%$, $SD = 19.93$). In contrast, the social word category comprised a smaller proportion of the expressive lexicon in the CI group ($M = 43.87\%$, $SD = 19.86$) compared to the NH group ($M = 56.24\%$, $SD = 22.31$), resulting in a statistically significant difference, $t(94) = -2.87$, $d = 0.59$, $p = .005$ (see Figure 3).

A higher proportion of children from the CI group produced predicate words (77% CI vs. 56% NH), $\chi^2(1, n = 96) = 4.69$, $p = .030$. In closed-class words, 83% of children with CI showed a nonzero response, but only 42% in the NH group produced at least one closed-class word, $p < .001$. The analysis for zero and nonzero responses is presented in Table 3. Among children who showed responses (i.e., nonzero response) for each category, the analysis indicated that the CI group produced significantly more predicate words than the NH group, $z = -2.94$, $r = -.36$, $p = .005$. The proportion of closed-class words was also higher in the CI group ($Mdn = 0.09$, IQR = 0.07) than the NH group ($Mdn = 0.08$, IQR = 0.04), but this difference was not statistically significant ($z = -1.97$, $r = -.25$, $p = .054$; see Table 4). Figure 4 shows that one child in the CI group was an outlier: Of their six expressive words, four of them (66%) were closed-class words. Excluding that child, the result remained nonsignificant, $z = -1.86$, $r = -.242$, $p = .063$.

Post Hoc Tests

The differences in expressive vocabulary profiles might have been due to the fact that the CI group had a larger expressive vocabulary size than the NH. Therefore, we examined a subset of the children with CI and NH who were broadly matched on expressive vocabulary size. Specifically, additional tests were conducted for children whose expressive vocabulary size was between five and 50 words, a vocabulary range that can be compared with previous studies (e.g., Bates et al., 1994). The subset analysis included 30 children (62.50%) from the CI group and 45 children (93.75%) from the NH group. The mean for expressive vocabulary size was 24.17 words ($SD = 13.64$) for the

Figure 2. Receptive vocabulary profiles for the four categories. CI = toddlers with cochlear implant; NH = toddlers with normal hearing.



CIgroup and 20.80 words (SD = 11.71) for the NH group, $t(73) = 1.142$, $d = 0.265$, $p = .257$. For this subset, we did not find group differences in common nouns, social words, and closed-class words. However, children with CIs used significantly more predicate words (M = 14.43%, SD = 7.08) than the NH children (M = 10.69%, SD = 7.69), $z = -2.056$, $r = -.31$, $p = .040$.

Discussion

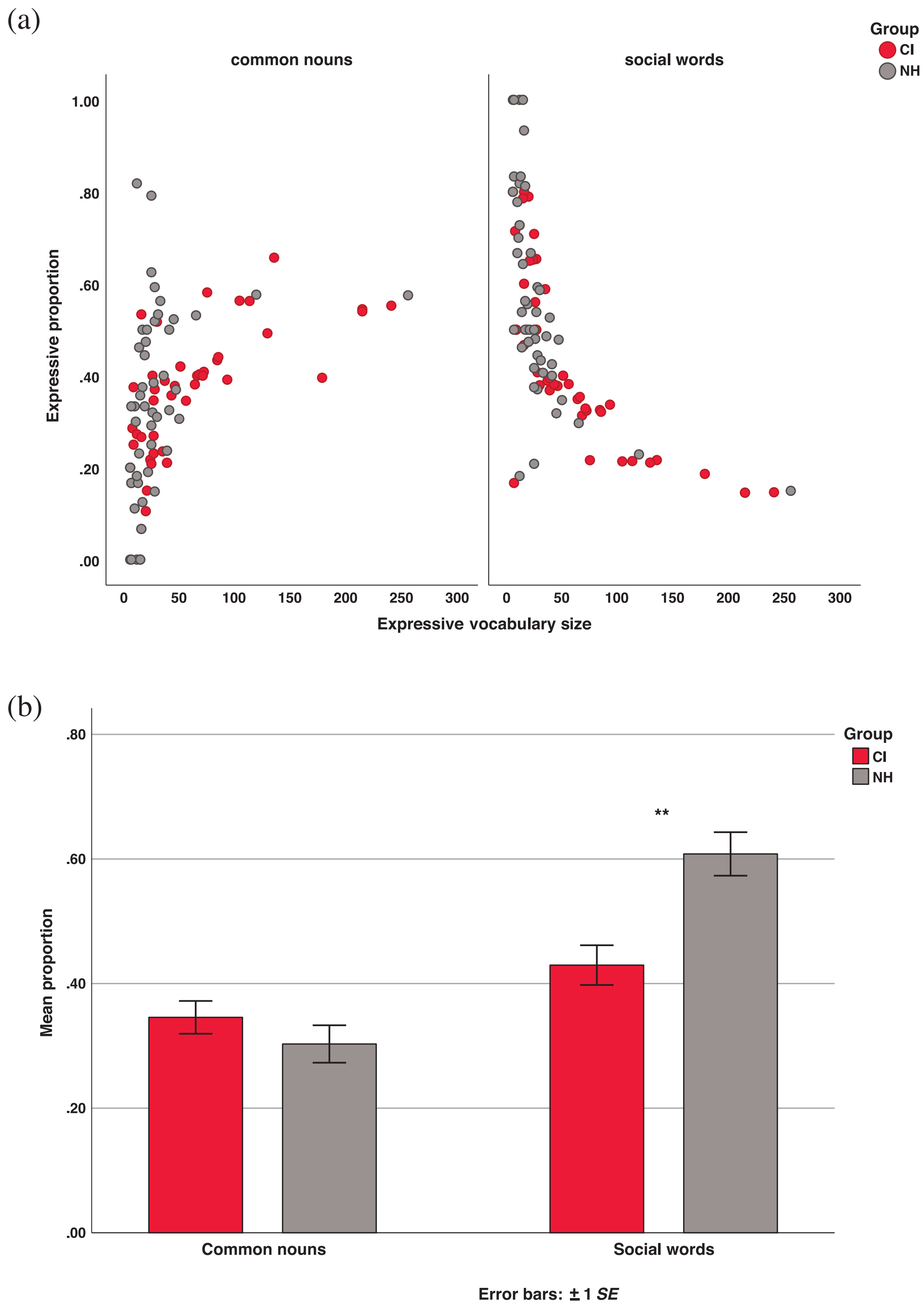
Vocabulary Size and Composition

The current findings indicated that the overall profile of receptive vocabulary was similar to previous findings of expressive vocabulary (Bates et al., 1994). Previous studies have shown that early expressive vocabulary profiles in various populations are dominated by nouns with a slow increase in predicate words and closed-class words, whereas the proportion of social words sharply declines (Bates et al., 1994; Snedeker et al., 2012; Välimaa et al., 2018). A visual inspection also indicated that all four categories shifted following the typical trajectories as a function of vocabulary size almost identical across the groups (see Figure 2). In contrast, the expressive vocabulary size was larger in the CI group than the NH group. Comparing the two groups, the finding of a relatively larger expressive vocabulary size for the CI group matches previous findings (Lund, 2015; Lund & Schuele, 2015), suggesting that children with CIs may have more challenges in receptive vocabulary acquisition than in expressive vocabulary.

As the CI group had a larger expressive inventory than the NH group, a greater proportion of common nouns was anticipated for the CI group (Snedeker et al., 2012). However, no statistical differences emerged between groups. This may have resulted from a limitation in our data set: With respect to the variability in common noun proportions, the range for the NH group was quite large (0%–82%), which likely contributed to the lack of a statistically significant effect. We also found that more children with CIs produced any predicate words at all, and predicate words constituted a larger proportion of the CI group's vocabulary than that of the NH group (15% for the CI group vs. 10% for the NH group). The proportion of predicate words among the NH children mirrored the previous literature (Bates et al. 1994), suggesting the currently participating children had typical development. By contrast, the greater proportion in predicate words for the CI group supports the finding in the study by Nott et al. (2009) that children with HL produced more predicate words than children with NH when they were matched with expressive vocabulary size.

There was a significant difference between groups in social words, and we suspect that the smaller proportion of social words in the CI group relates to having a greater

Figure 3. Expressive vocabulary profile for common nouns and social words. (a) Scatter plot for expressive proportion for common nouns and social words. (b) Bar plot for mean proportion of common nouns and social words. CI = toddlers with cochlear implant; NH = toddlers with normal hearing.



$^{**}p < .01$

Table 3. Zero and nonzero response for expressive predicate words and closed-class words by group.

Variable	Response	CI (n = 48)	NH (n = 48)	Total (n = 96)	Chi-square tests and p values
Predicate words	Zero	11 (23%)	21 (44%)	32 (33%)	$\chi^2(1, n = 96) = 4.69, p = .030$
	Nonzero	37 (77%)	27 (56%)	64 (67%)	
Closed-class words	Zero	8 (17%)	28 (58%)	36 (38%)	$\chi^2(1, n = 96) = 17.78, p < .001$
	Nonzero	40 (83%)	20 (42%)	60 (63%)	

Note. CI = cochlear implant; NH = normal hearing.

expressive vocabulary size (see Figure 3a; Snedeker et al., 2012; Välimaa et al., 2018). For closed-class words, more CI recipients produced closed-class words than the NH group; however, in proportional analyses, we did not find statistically significant group difference. This finding is in line with previous work showing no significant difference in the proportion of grammatical function words between children with HL and children with NH (Nott et al., 2009). Taken together, the findings indicated that the CI group had a larger expressive vocabulary size and had a larger proportion of predicate words in their expressive vocabulary.

Maturity and Vocabulary Profiles in Children With CIs

Compared to the NH group, the current CI group had shorter duration of hearing experience (*Mdn* = 8.98 months), similar size of receptive vocabulary, and older chronological age. Of these three factors, only developmental maturity should contribute to a larger expressive vocabulary for the CI group than the NH group. Physical maturity is related to better motor skills (Leigh et al., 2015), which could serve to enhance articulatory abilities and enable the older children with CI to produce more words that are recognizable as words by their parents than their younger NH counterparts. Cognitive maturity is associated with higher levels of communicative function development, which may mean that the older children with CI are more motivated to use language to express their needs and thoughts across a greater variety of situations than the younger NH children (Khan et al., 2005).

It is also possible that relatively higher expressive vocabulary levels for children with CIs reflect the relative difficulty acquiring words receptively. Because the input from CIs is highly degraded, children with CIs may require more exposures to words to add the words into their receptive inventory. That is, young CI recipients may add receptive vocabulary items into their lexicon slowly, but the more exposure to words may also mean more opportunities to produce (e.g., imitation) those same words. Therefore, in addition to greater cognitive and articulatory maturity, greater exposure to words for young CI recipients to understand may explain the relatively higher expressive vocabulary when controlling for receptive vocabulary size.

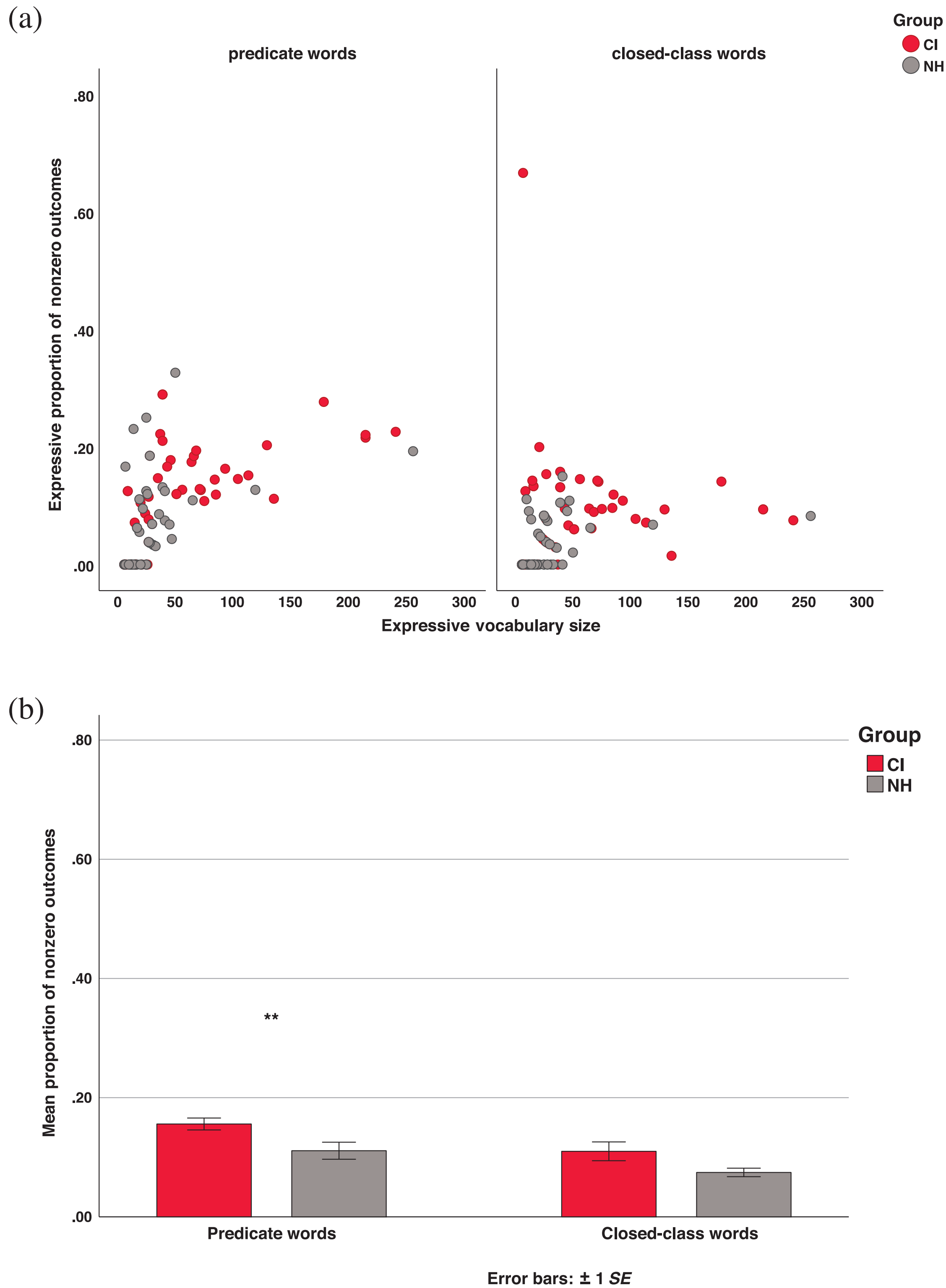
The relative cognitive maturity of the CI group may also affect specific categories of words. Predicate words (verbs and adjectives) require advanced relational knowledge rather than concrete referential understanding between object and meaning (Imai et al., 2006). Thus, the finding that the CI group produced a higher proportion of predicate words than the NH group is consistent with the possibility that cognitive maturity may affect the category of words learned. This argument is also supported by findings that adjectives are more rapidly acquired by internationally adopted children who are adopted at older ages compared with those adopted during infancy (Snedeker et al., 2012). In other words, it may be possible that infants with NH produce mainly common nouns to serve their various communicative intentions (e.g., "cup" for "There is a cup" or "give me the cup"). In contrast, the older children with CIs may be capable of and motivated to acquire adjectives to express their intentions more specifically (e.g., "blue" for "that is a blue cup" or "give me the blue cup"). Examining this possibility is beyond the scope of the current study using a parental checklist. A further examination of vocabulary types and their functions would need to be administered using language samples.

Table 4. Univariate group comparisons of nonzero response for expressive predicate words and closed words.

Word type	Level	CI	NH	Test statistics and p values
Predicate words		n = 37	n = 27	
	Mdn (IQR)	0.15 (0.07)	0.10 (0.08)	z = −2.94; r = −.36;
	(min, max)	(0.4, 0.29)	(0.03, 0.33)	p = .005
Closed-class words		n = 40	n = 20	
	Mdn (IQR)	0.09 (0.07)	0.08 (0.04)	z = −1.97; r = −.25;
	(min, max)	(0.01, 0.67)	(0.02, 0.2)	p = .054

Note. CI = cochlear implant; NH = normal hearing.

Figure 4. Expressive vocabulary profile for nonzero responses for predicate words and closed-class words. (a) Scatter plot for expressive proportion for predicate words and closed-class words. (b) Bar plot for mean proportion of predicate words and closed-class words. CI = toddlers with cochlear implant; NH = toddlers with normal hearing.



**$p < .01$

Study Limitations

One limitation of the study is that some of the demographic and audiologic information was not available. Particularly, we were not able to report maternal age at completing the checklist or their education level. However, Bates et al. (1994) reported small effects of maternal education level on children's vocabulary composition (rs < .18). Given that their sample size was very large (> 1,000), the authors even cautioned readers about interpreting that relationship. We also had limited information about children's audiologic background. Information on the age of onset and etiology of HL may allow us to examine the role of auditory experience in vocabulary acquisition further.

The current study also had limitations because it was a retrospective study design. For instance, the MBCDI: Words and Gestures form has norms of children of 8–18 months old only, and therefore, we did not administer the test to older NH children who may have been able to serve as chronological age–matched peers. However, even if we had collected age-matched data, it is possible that many of the children with NH would have their ceiling with the MBCDI: Words and Gestures form and thus not have produced a representative measure of their vocabulary profiles.

Another challenge was that we could not conduct a longitudinal analysis due to the characteristics of the data set. A longitudinal design would reveal the potential effects of vocabulary, hearing experience, and cognitive maturity for young CI recipients more clearly. In addition, employing cognitive measures may help to understand the relationship between cognitive skills and vocabulary acquisition better.

Finally, this study included some children who used a supplementary manual mode. Therefore, it was not clear how close their lexical knowledge was represented by the spoken vocabulary size measured by MBCDI. However, all our participants had a primary goal of developing spoken language, and our investigation only focused on spoken language vocabularies. Therefore, the current study provides insight into the vocabulary development of children's primary communication mode. Further studies on mode-specific and mode-general vocabulary profiles would shed light on the role of communication mode in vocabulary development of children with CIs.

Future Directions and Clinical Implications

A recent study found that mothers of children with CIs used a similar number of different words and unknown nouns for their children compared to mothers of children with NH matched on expressive vocabulary sizes (Lund & Schuele, 2015). In other words, given that the CI and NH groups in the current study did not have equal size of expressive vocabulary, the maternal vocabulary profiles could be different between the two groups of mothers. In addition, although we did not have access to the information about children's intervention experience, in the United States, it is a standard protocol that young children with HL receive early intervention. This fact suggests that there could be some influence of interventions on maternal vocabulary use (Nott et al., 2009). However, although some recent studies have examined maternal language input to young CI recipients (e.g., Cruz et al., 2013; DesJardin & Eisenberg, 2007; Quittner et al., 2013; Wang et al., 2020), there is little research on maternal vocabulary profiles and their relationships with young CI recipients' vocabulary development. This gap of knowledge justifies future examinations of the vocabulary composition of maternal input to understand how this factor impacts vocabulary development in children with CIs.

During the first year after cochlear implantation, assessing vocabulary skills is important in intervention targeting spoken language development because many children show significant vocabulary growth (Ertmer & Inniger, 2009; Fagan, 2015; Koşaner et al., 2013).

In addition, the current findings indicate that clinicians need to assess vocabulary ability in young CI recipients in a comprehensive way.

Given that there is a discrepancy between receptive and expressive vocabulary skills, even if a young child with a CI develops expressive vocabulary as expected, receptive vocabulary acquisition at earlier ages requires close inspection using tools that are available for assessing both receptive and expressive vocabulary skills (e.g., MBCDI: Words and Gestures). Exploration of vocabulary profiles in a more comprehensive manner will benefit both therapeutic intervention and educational settings to maximize early language skills in pediatric CI recipients.

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Appendix

Word Categories and Word Examples

Word category	MBCDI class (number of items)	Examples
Common nouns	Animal names (36)	*animal, cow, kitty, sheep*
	Vehicles (9)	*airplane, car, motorcycle*
	Toys (8)	*ball, book, toy*
	Food and drink (30)	*apple, milk, water*
	Clothing (19)	*hat, pants, shoe*
	Body parts (20)	*ear, hair, tummy*
	Furniture and rooms (24)	*door, potty, TV*
	Small household items (36)	*box, cup, watch*
	Outside things and places to go (27)	*home, snow, zoo*
Predicate words	Action words (55)	*eat, go, love*
	Descriptive words (37)	*all gone, bad, dirty*
Social words	Sound effects and animal sounds (12)	*meow, woofwoof, yum yum*
	People (20)	*babysitter's name, mommy, person*
	Games and routines (19)	*night night, peekaboo, thank you*
Closed-class words	Words about time (8)	*day, now, today*
	Pronouns (11)	*I, it, you*
	Question words (6)	*how, what, who*
	Prepositions and locations (11)	*back, down, up*
	Quantifiers (8)	*all, more, not*

Note. MacArthur–Bates Communicative Development Inventories (Fenson et al., 2006).