Morphological Accuracy in the Speech of Bimodal Bilingual Children with CIs

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Abstract

Sign language use in the (re)habilitation of children with cochlear implants (CIs) remains a controversial issue. Concerns that signing impedes spoken language development are based on research comparing children exposed to spoken and signed language (bilinguals) to children exposed only to speech (monolinguals), although abundant research demonstrates that bilinguals and monolinguals differ in language development. We control for bilingualism effects by comparing bimodal bilingual (signing-speaking) children with CIs (BB-CI) to those with typical hearing (BB-TH). Each child had at least one Deaf parent and was exposed to ASL from birth. The BB-THs were exposed to English from birth by hearing family members, while the BB-CIs began English exposure after cochlear implantation around 22-months-of-age. Elicited speech samples were analyzed for accuracy of English grammatical morpheme production. Although there was a trend toward lower overall accuracy in the BB-CIs, this seemed driven by increased omission of the plural -*s*, suggesting an exaggerated role of perceptual salience in this group. Errors of commission were rare in both groups. Because both groups were bimodal bilinguals, trends toward group differences were likely caused by delayed exposure to spoken language or hearing through a CI, rather than sign language exposure.

Keywords: American Sign Language; Bilingualism; Cochlear implants; Deafness; Morphological development; Sign Language

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Although cochlear implants (CIs) greatly improve the potential to develop spoken language skills in children who are deaf, wide variability in outcomes has been observed (e.g., Niparko et al., 2010; Peterson et al., 2010). Individual characteristics, such as female sex, high IQ, and absence of additional disabilities have all been associated with better spoken language outcomes in children with CIs (e.g., Boons et al., 2012; Carter, Dillon & Pisoni, 2002; Dillon, Cleary, Pisoni & Carter, 2004; Edwards & Anderson, 2014; Geers, 2002; Geers, Moog, Biedenstein, Brenner & Hayes, 2009). Family features, such as higher parental education level, higher socio-economic status (SES), and fewer siblings are also associated with better outcomes (e.g., Geers, Brenner & Davidson, 2003; Geers et al., 2009; Geers & Sedey, 2011; Szagun & Stumper, 2012). Audiological characteristics are integral as well, with better pre-implant hearing, later onset of deafness, earlier implantation, implantation in the right rather than left ear, and bilateral cochlear implantation or contralateral hearing aid use correlating with better spoken language outcomes (e.g., Anderson et al., 2004; Barnard et. al., 2015; Boons et al., 2012; Bouchard, Ouellet & Cohen, 2009; Caselli, Rinaldi, Varuzza, Giuliani & Burdo, 2012; Colletti, Mandalà & Colletti, 2012; Dettman, Pinder, Briggs, Dowell & Leigh, 2007; Dillon et al., 2004; Geers, Nicholas, Tobey & Davidson, 2016; Henkin et al., 2008; Spencer, 2004). While all this research demonstrates an intense focus on the factors that affect spoken language development in children with CIs, the role of sign language in their (re)habilitation remains controversial. A recent review concluded that there is insufficient high-quality evidence to determine whether children with CIs should be exposed to a sign language (Fitzpatrick et al., 2016). One complicating factor in this debate is the diversity of manual systems that are used with children,

ranging from various systems for representing English manually to American Sign Language

(ASL), which is a distinct language with its own grammar (first demonstrated by Stokoe 1960).

In this study, we assert that children exposed to two languages should be considered

bilinguals, even when one language is produced in the visual/manual modality. We examined the

English morphological development of children with CIs who were acquiring ASL and English,

compared to children with typical hearing who were acquiring the same language pair. Both

groups of children were born to Deaf[1] parents who used ASL with them from birth. This

comparison allowed us to investigate the effects of delayed exposure to spoken English and

hearing through a CI on spoken language outcomes while controlling for the effects of

simultaneous exposure to ASL. We focused on morphological development because it has been

found to be delayed in children with CIs compared to monolingual hearing children (e.g., Guo,

Spencer & Tomblin, 2013; Werfel, 2018).

Effects of Sign Exposure on Language Outcomes in Children with CIs

Some researchers have found that placement in total communication educational settings

(i.e., those that include some form of a signed communication system) rather than oral-only

communication settings is associated with worse spoken language outcomes, especially speech

perception and intelligibility (e.g., Cullington, Hodges, Butts, Dolan-Ash & Balkany 2000;

Dillon, Pisoni, Cleary & Carter 2004; Geers et al., 2000; Geers et al., 2017; Geers, Spehar, &

Sedey, 2002; Jiménez, Pino, & Herruzo, 2009; Tobey, Rekart, Buckley & Geers, 2004). Other

studies (e.g., Yoshinaga-Itano, Baca & Sedey, 2010) have found that children with CIs exposed

to both sign and spoken language can achieve age-appropriate vocabulary and grammar skills

based on standardized test norms. Additionally, several studies have found benefits of exposure

to sign language in total communication educational settings. The types of advantages that have been observed include earlier first words/signs, more mature early communicative functions (informative and heuristic rather than directive) and greater verbal fluency (e.g., Jiménez et al., 2009; Nicholas & Geers 2003). Most of these advantages only become apparent when both signed and spoken communication are taken into consideration, and they tend to diminish with age.

Because forcing parents to choose one communication mode for research purposes would be unethical, there are several confounds in this line of research that are difficult to avoid. Many of these studies show trends for children in total communication settings to have mothers with lower levels of education, families with lower income levels, later ages of implantation and worse auditory perception skills (e.g., Cullington et al., 2000; Geers et al., 2000; Geers et al., 2017). All of these factors have been linked to poorer speech outcomes in the broader population of children with CIs. Because the children in total communication and oral communication educational settings often differ on these background characteristics, it is difficult to distinguish the influence of sign language exposure from these other factors. Furthermore, it is likely that early developments in spoken language ability greatly influence later educational placement, with children who show greater early proficiency in speech entering classrooms that use speech only and those struggling with spoken language going into total communication classrooms (e.g., Hall, Hall, & Caselli, 2019).

Another weakness of the existing literature is that children with CIs learning both a signed and a spoken language have often not been considered as bilinguals, despite the fact that they were acquiring two languages. Many differences in language development have been documented between monolinguals and bilinguals (see Serratrice, 2013 for a review). For

instance, bilinguals with typical hearing often have smaller vocabularies than monolinguals when each of their languages are considered separately, although they tend to know a comparable (or even larger) number of words for different concepts across both languages (e.g., Pearson, Fernández and Oller, 1993). While predicting language outcomes in bilingual children is a complex task that depends on various input factors as well as the language domain under question, failure to consider signing children with CIs as bilinguals may set unreasonable standards for them to meet.

It is important to note that more than 90% of deaf children are born to typically hearing parents (Mitchell & Karchmer, 2004), most of whom communicate via spoken and not sign language. While the adoption of universal newborn hearing screening has greatly reduced the age of identification of hearing loss in the United States (e.g. Halpin, Smith, Widen & Chertoff, 2010), many of these children will continue to experience some period of language deprivation before cochlear implantation if sign language use is avoided. Although the United States Food and Drug Administration requires hearing aid trials before cochlear implantation (except when there is a concern for cochlear ossification following meningitis infection), only children who receive little to no benefit from such amplification are considered appropriate CI candidates per FDA label indications (e.g., Carlson et al. 2014; Gifford, 2011). This means that many children who ultimately receive CIs cannot perceive speech sounds at a level that is sufficient for spoken language acquisition before cochlear implantation. Thus, adequate exposure to spoken language is frequently delayed until after cochlear implantation despite earlier identification of hearing loss and pre-implantation hearing aid use.

Despite the lack of consensus regarding whether sign language exposure is helpful, detrimental or inconsequential for the acquisition of spoken language, some clinicians discourage

the use of sign language with children who are deaf, even before cochlear implantation when access to spoken language is minimal (e.g., Mauldin, 2016). In addition to the studies cited above that compared bilingual children with CIs to monolingual benchmarks, concern that a visual language will cause neural reorganization of the auditory cortex for visual input may be used as justification for this recommendation (ibid). However, in the absence of auditory input, this reorganization happens whether or not sign language input is provided, and there is ample evidence of a sensitive period for language exposure regardless of modality (Lyness, Woll, Campbell & Cardin, 2013). Additionally, results from behavioral studies have demonstrated that late first language acquisition leads to reduced proficiency levels in phonology, morphology, syntax, and semantics, even after decades of language experience (see Mayberry & Kluender, 2017 for review). Thus, when sign language exposure is avoided until a child with a CI does not achieve the desired spoken language proficiency, the consequences of this prolonged period of language deprivation can be considerable and long-lasting (see Humphries et al., 2012 for a review of the linguistic, cognitive, social and occupational hazards).

Furthermore, numerous studies have also provided evidence for facilitative effects of early first language acquisition on second language proficiency, irrespective of language modality (Mayberry & Kluender, 2017). For example, two groups of adults with early first language exposure (i.e., deaf individuals with early ASL exposure and hearing individuals with exposure to a spoken language from birth) who learned English as a second language were found to outperform deaf individuals with later simultaneous exposure to English and ASL on English grammaticality judgment tasks (Mayberry & Lock, 2003). Evidence from the study of native bimodal (sign-speech) bilingual children with CIs also suggests that early sign language exposure can positively influence later spoken language development in this population.

Children who are born deaf to at least one Deaf, signing parent represent less than 5% of the total population of children who are deaf (Mitchell & Karchmer, 2004). Of this subset, some (possibly small) proportion receive CIs. Because these children are exposed to sign language from birth, they experience no period of language deprivation, although their exposure to spoken language is delayed until after cochlear implantation. Research with this population indicates that bimodal bilingual children with CIs achieve spoken language outcomes on par with monolingual and bilingual children with typical hearing (Davidson, Lillo-Martin & Chen Pichler, 2014) or even better than spoken-language monolinguals with CIs (Hassanzadeh, 2012).

It is unclear the extent to which the sign language input provided by Deaf parents resembles the input offered to children with CIs born to hearing parents. There is some evidence that bimodal language exposure does not negatively affect spoken language development when hearing parents choose to pursue both sign and spoken language proficiency after their child's hearing loss is identified (e.g., Rinaldi & Caselli, 2014). For Deaf parents, even if they were not exposed to signing from birth, they likely will have used this language for many years before their child is born. In contrast, when a hearing, non-signing parent decides to use sign language with their child, they must learn the language at the same time that they are providing input for their child. It is therefore reasonable to expect that outcomes for bimodal bilingual children born to Deaf parents would differ from those reported for children in total communication programs.

Additionally, schools that use total communication vary in the nature of the sign language used, with some using artificial, manually encoded English systems, while others use American Sign Language, a full, natural language with a grammar that differs from spoken English (e.g., Klima & Bellugi, 1979). Previous research in this area has not specified the exact type of system used in the total communication educational programs child participants attended and/or

combined children with different types of sign input, and it is possible that different varieties of sign input would lead to different language outcomes.

Morphological Development in Children with CIs

Few studies have focused on the English morphological development of children with CIs, but of those that have, all have found morphological deficits. In samples of elicited speech targeting English tense morphemes, children with CIs produced these morphemes less accurately than comparison groups with typical hearing, even when groups were matched on hearing age (i.e., time since cochlear implantation) rather than chronological age (Guo et al., 2013; Guo & Spencer, 2017). Error types were similar in both groups, with morphemes more likely to be omitted than incorrectly produced (ibid). Similar deficits have been found in other languages with more complex morphology than English (e.g. Hallé & Duchesne, 2015).

Some researchers have also investigated the influence of the perceptual properties of each grammatical morpheme on its acquisition. This line of research is motivated by the Surface Account of Specific Language Impairment/Developmental Language Disorder (e.g., Leonard, 1989), which hypothesizes that morphemes which are more difficult to perceive are more likely to be omitted. For example, the English progressive morpheme *-ing* is syllabic (i.e., longer in duration), more perceptually salient and therefore less likely to be omitted than a morpheme like the 3rd person present *-s*, which is a nonsyllabic consonant (i.e., shorter in duration) of higher pitch but lower amplitude. Even though children with CIs may show an overall different pattern of performance than children with SLI/DLD (Hoog et al., 2016), any difficulties with morphemes of low perceptual salience could be exacerbated in children with CIs, who might struggle to perceive sounds of short duration and low amplitude.

Thus far results from children with CIs have been somewhat mixed, with some authors finding that perceptual salience plays a role for children with CIs (Spencer, Tye-Murray, & Tomblin, 1998; Svirsky et al. 2002; Werfel, 2018) and others not (Ruder, 2004). However, in this population, performance on tests of speech perception are often positively correlated with later accuracy in morphological production (Guo et al., 2013; Guo & Spencer, 2017; Spencer et al., 1998), which lends additional support to the theory that perceptual salience is integral for acquisition of spoken language morphology by children with hearing loss.

Morphological Development in Bilinguals Learning Two Spoken Languages

Children with typical hearing exposed to two or more spoken languages are often less accurate in their morphological production when compared to monolinguals (e.g., Nicholls, Eadie & Reilly, 2011; Nicoladis, Song & Marentette, 2012). However, it is important to consider more specific properties of the language-learning environment for bilinguals because some researchers have found that bilingual children are as accurate as monolinguals if they receive at least 50% of their input in the language being assessed (Paradis, Nicoladis, Crago & Genesee, 2011; Thordardottir, 2014). Those children who experience delayed exposure to their second language until school-age are likely to exhibit more pronounced deficits (e.g., Paradis, 2006). Additional factors, such as the typological characteristics of a bilingual's two languages, have also been found to be important. For example, the English morphological development of children who are also exposed to a morphologically rich language, such as Spanish, has been found to outpace that of children exposed to a language with a less elaborate morphological system, such as Mandarin Chinese (ibid).

English Morphological Development in ASL-English Bilinguals

American Sign Language is similar to Mandarin in that it has few, if any obligatory grammatical morphemes parallel in function to English grammatical morphemes (Sandler & Lillo-Martin, 2006). For example, verb tense is often expressed via adverbial modification (e.g., yesterday, today, tomorrow) and only a subset of verbs exhibits person agreement. Verbal aspect can be expressed through modifications of sign movement rather than the addition of concatenative morphology. There is a class of predicative signs that is generally analyzed as having a highly complex morphological composition, the classifier signs, but these have no direct analogue to English morphology. Plurality of nouns can be indicated by repetitions of sign movement, but such marking is found on only a few signs. All of these typological properties suggest that the concurrent acquisition of ASL likely does not facilitate the acquisition of spoken English morphology specifically in the way that acquiring a morphologically rich spoken language does.

Studies analyzing morphological accuracy in the spoken English of ASL-English bilinguals with typical hearing have generally found higher error rates in these bilinguals compared to similarly-aged monolinguals (Johnson, Watkins, & Rice, 1992; Schiff & Ventry, 1976, but see Goodwin, Davidson & Lillo-Martin, 2017 for a counter-example). Additionally, bimodal bilinguals differ from speech-speech bilinguals (i.e., those acquiring two spoken languages) in that both of their languages can be produced simultaneously, a phenomenon often referred to as code-blending (Emmorey, Borinstein, Thompson & Gollan, 2008). When assessing morphological accuracy in bimodal bilinguals, it is important to consider the mode of language production because English morphology tends to be omitted more frequently in code-blended utterances (Petroj, Guerrera & Davidson, 2014; Petroj, 2017).

Present Study

The aim of this study was to compare the accuracy of English morpheme use in ASL-English bimodal bilingual children with CIs (BB-CI) to that of similar bimodal bilinguals with typical hearing (BB-TH). We addressed three main issues:

1. Do BB-CIs produce English morphology as accurately as BB-THs? The BB-CIs may be less accurate than the BB-THs because this group experienced delayed exposure to spoken English and this input was filtered through a cochlear implant, which may not have conveyed the speech signal with fidelity.

2. Does relative perceptual salience explain the pattern of performance across different English morphemes for the BB-CIs and/or the BB-THs? The duration and loudness of morphemes might be more important for children listening through a cochlear implant than those with typical hearing; therefore, it is especially important to consider this factor for the BB-CIs.

3. Do BB-CIs tend to produce the same types of morphological errors as BB-THs? Previous research has found that errors of omission are more common than errors of commission in both children with typical hearing and children with CIs.

Method

Participants

Seven ASL-English bimodal bilinguals with typical hearing (BB-TH; M age[2], = 5;09 SD = 0;05, range = 5;01-6;03) and five Deaf bimodal bilinguals with a CI (BB-CI; M age = 5;05, SD =0;10, range = 4;01-6;05) participated in this study. The groups were balanced for gender, with

4 males in the BB-TH group and 3 in the BB-CI group (57% and 60% male, respectively). All participants had at least one Deaf, signing parent and acquired ASL from birth. The BB-THs were also exposed to English from birth by hearing family and friends, whereas the BB-CIs began acquiring English from similar sources once their implants were activated (*M* age = 1;10, *SD* = 0;08, range = 1;04-2;11). The BB-CIs also received speech and language therapy as recommended by their speech-language pathologists. Both groups of children were of high SES as measured by mother's education, with all but two of the hearing children's mothers possessing a bachelor's degree or higher. Both groups of children were relatively balanced bilinguals, with home language environments predominately ASL-based and school language environments predominately English-based. Individual background characteristics are summarized in Table 1.

<Insert Table 1 about here>

Table 2 provides additional information about the audiological characteristics of the BB-CI group. All of these children were prelingually deafened and received their cochlear implants before the age of two years, except for Pam, whose pre-aided hearing thresholds were lower, and her age of implantation was higher.

<Insert Table 2 about here>

Although the two groups were matched for chronological age (Mann-Whitney $U(10) =$ 13, $Z = -.73$, $p = .53$, $r = -.21$), the hearing age (i.e., time since cochlear implantation/length of exposure to spoken language) of the BB-CIs was significantly lower than that of the BB-THs

($U(10) = 0$, $Z = -2.87$, $p = .003$, $r = -.83$). All of the BB-CIs had been exposed to English for at

least one year ($M = 3;07$, $SD = 1;04.28$, range = 1;02-4;09).

The data reported here were collected as part of a larger project investigating the

language development of bimodal bilingual children. As part of this project, the children also

completed a non-standardized assessment of auditory perception (Minimal Pairs: Pronovost &

Dumbleton, 1953) and standardized assessments of speech (Goldman-Fristoe Test of

Articulation 2: Goldman & Fristoe, 2000), expressive vocabulary (Expressive Vocabulary Test:

Williams, 1997) and overall language development (Preschool Language Scales 4: Zimmerman,

Steiner & Pond, 2002). In the Minimal Pairs task, children heard two words (e.g., goat and coat)

and were asked to point to the matching picture out of an array of three pairs of pictures (e.g., a

coat and a goat, a coat and a coat, a goat and a goat). Each word pair in this task can differ by at

most a single phoneme. The standardized assessments were administered as per test instructions.

All of these tests were administered by typically hearing researchers who presented all

instructions and feedback in English. The results of these and other tests are discussed in depth in

Davidson et al. (2014) and Cruz et al. (2014).

Results from these tests are included in Table 3 to provide a broader picture of our

participants' overall speech and language development. Unfortunately, the youngest child with a

CI (pseudonym Pam) did not receive the GFTA-2, but all other children scored within the

average range on this test, suggesting that any observed difficulties with spoken English

morphological production were not caused by articulatory difficulties. Pam also did not complete

the Minimal Pairs task. Although the sample sizes are small, which limits our power to detect

differences, a Mann-Whitney U test found no significant differences between the two groups on

the Minimal Pairs Task, suggesting that the BB-CIs showed no major deficits in speech

perception in the relatively quiet testing atmosphere ($U(6) = 13$, $Z = -1.53$, $p = .16$, $r = -.46$). All but one child (pseudonym Fin) also scored within one standard deviation or higher on all the grammar and vocabulary assessments. Group comparisons for the standardized speech and language tasks also show no significant differences (Preschool Language Scales-4: $U(10) = 13$, $Z = -.73$, $p = .53$, $r = -.21$; Expressive Vocabulary Test: $U(10) = 15$, $Z = -.33$, $p = .76$, $r = -.09$; Goldman-Fristoe Test of Articulation-2: $U(9) = 9.5$, $Z = -.85$, $p = .41$, $r = -.26$)

<Insert Table 3 about here>

Procedure

The data for this study came from short videos (about 5-10 minutes) collected at "language fairs" in which bimodal bilingual children completed a series of standardized language tests and played games designed to elicit particular types of language constructions (Quadros et al., 2015). All tests were administered by researchers with typical hearing using spoken English. Some experimenters were hearing native signers and others were second-language learners of ASL, but instructions and feedback during testing was provided in English to model for children that English was the appropriate language to use in this context.

We analyzed fifty utterances of each participants' data to estimate how frequently code-blending (simultaneous production of ASL and English) occurred. In the BB-CI group, code-blended utterances were produced an average of 2.6 times out of 50 utterances (range = 0-7, SD = 3.21). In the BB-TH group, code-blended utterances were produced an average of 4.29 times out of 50 utterances (range = 0-17, SD = 5.94). This is consistent with previous research that has found code-blending to be infrequent in bimodal bilinguals when they are using the dominant

spoken language of the broader community (Lillo-Martin, Quadros, Chen Pichler & Fieldsteel, 2014). These code-blended utterances tended to consist of a complete, although possibly ungrammatical, English sentence with a single and often redundant ASL sign, such as a number or a verb. All clear English utterances, including code-blended utterances, were analyzed for morphological accuracy.

Children were administered the standardized tests and language games individually and in a randomized order. The present study analyzed language samples from two tasks: verbal morphology and narrative[3]. In the verbal morphology task, children were shown cards with four similar pictures involving characters engaged in different activities, one of which had a yellow box drawn around it. They were asked to describe the picture outlined in yellow so that an experimenter could match the picture to the same one on their card (which did not have a yellow outline). The children had to describe the pictures by telling the experimenter what the characters were doing in each one, eliciting person/number and tense/aspect agreement with singular and plural subjects. For example, a child needed to produce a sentence such as "the cows are drinking water" to distinguish a picture with three cows drinking water from an adjacent picture with a single cow drinking water. There was one training item for which the experimenter modelled the correct sentence form for the child. These cards were developed specifically for this task. All children received all eleven items in the same order.

In the narrative task, children watched animated videos or were shown a series of pictures that depicted a story. They then had to tell the story to an experimenter who had not seen the video or the pictures. The videos were short (under two minutes), unnarrated excerpts from the French television series *Minuscule –The Private Life of Insects* (Giraud & Szabo, 2006). There were two different sets of pictures used for the picture narrative task. The first set was from the

picture book *Tuesday* (Wiesner, 1991). The second set of pictures was developed specifically for this task (Quadros et. al., 2015). Each child received only one version of the narrative task, with distribution of narrative tasks based on the year of data collection. Five of seven BB-TH's received the video-based narrative task and four of five BB-CI's received a picture-based narrative. A Spearman's rank-order correlation was run to determine the relationship between morphological accuracy in the verbal morphology and narrative tasks and, by extension, whether there was evidence of an effect of task type. There was a statistically significant, strong positive correlation ($r_s(10) = .694$, $p = .012$), demonstrating that participant performance was consist across tasks, regardless of the type of narrative task used.

Transcription and Coding

All videos were transcribed by native English-speaking undergraduate research assistants using ELAN Linguistic Annotator software (Sloetjes & Wittenburg, 2008). The first author (a native English speaker) coded all transcripts for mean length of utterance (MLU) and morphological accuracy. As part of a larger study on morphological development in bimodal bilingual children, two additional coders unaware of the study's objectives but not to participant group (cochlear implants were visible or visibly absent in the videos used for analysis) independently coded nine percent of the total number of transcripts. Cohen's kappa for the first author and second coder was .83, indicating near perfect agreement. Cohen's kappa for the first author and third coder was .74, indicating substantial agreement.

MLU was calculated using standard rules for English as established by Brown (1973). All utterances not excluded as interjections, imitations, repetitions, or unintelligible were analyzed for their MLU in words (MLU_w) and morphemes (MLU_m). MLU calculations were based on a total of 50 utterances, half drawn from each task. Two children, Kim & Lyn, produced fewer

than 25 analyzable utterances (18 & 22, respectively) during the verbal morphology task;

therefore, additional utterances were drawn from the narrative task in order to reach a total of 50

utterances for these children. These two children seemed to understand the verbal morphology

task well and gave adequate, although not necessarily grammatically correct, descriptions of all

eleven verbal morphology cards with a minimal number of utterances.

Accuracy of use in obligatory contexts of verbal morphology (e.g. 3rd person present *–s,*

progressive *-ing,* past *-ed*), nominal morphology (i.e., regular plural *–s* and irregular plural) and

the definite and indefinite articles *the* and *a(n)* was analyzed for all clear utterances in both tasks.

Errors were coded as belonging to one of four categories: omission, commission, over-

regularization, and other. Omission errors were missing the target morpheme (e.g. *she run* or *two*

dog). Commission errors included morphemes that were ungrammatical in the context (e.g., *I*

runs or *one dogs*). Over-regularization errors occurred when general rules were applied to

exceptions (e.g., *she runned* or *sheeps*). Finally, errors categorized as 'other' included any error

that did not fit into a previously mentioned category, such as double past tense marking (e.g.,

walkeded, *ranned*), incorrect forms of *to be* verbs (e.g., *I is, she am, we was, he were*),

contraction of uncontractible verbs (e.g., *she's running* for *she was running*), and errors of verb

choice (e.g., *have monkeys* for *there are monkeys*). This category was only relevant for verbal

morphology. Both groups of children did sometimes use articles inappropriately (e.g., using

definite *the* for indefinite *a(n)* or using an article in a context in which an adult would not), but

coding of this depends on subtle contextual judgment and was less reliable, so these error types

were excluded for all analyses. Additionally, although no children consistently used the

indefinite article allomorph *an* before a noun that began with a vowel phoneme, we did not code

these non-adult-like forms as errors. Therefore, errors of omission were the only type possible

for articles.

Results

MLU

The BB-TH group had a mean MLU in words of 4.86 ($SD = .54$, range = 3.70-5.36) and

the BB-CIs had a mean of 4.75 ($SD = .67$, range = 4.16-5.86). For MLU in morphemes, the BB-

TH group had a mean of 5.74 ($SD = .52$, range = 4.62-6.22) and the BB-CIs had a mean of 5.54

($SD = .65$, range = 5.04-6.66). Mann-Whitney U tests showed no significant differences between

the two groups whether MLU was measured in words ($U(10) = 12$, $Z = -.89$, $p = .43$, $r = -.26$) or

morphemes ($U(10) = 11$, $Z = -1.06$, $p = .34$, $r = -.31$).

Overall Accuracy

Figure 1 depicts the overall accuracy on all morphemes for both groups. Although the

overall accuracy was higher for the BB-TH group ($M = 91.43\%$, $SD = 3.78\%$, range = 86-97%)

than the BB-CI group ($M = 84.2\%$, $SD = 8.01\%$, range = 76-92%), this difference was not

statistically significant ($U(10) = 8$, $Z = -1.55$, $p = .15$, $r = -.45$).

<Insert Figure 1 about here>

Figure 2 depicts accuracy on individual English morphemes by group. Based on Guo et al. (2013), we required a minimum of four obligatory contexts for each morpheme to be considered individually in order to decrease the effect of outliers. Only six morphemes met this minimum requirement in all children and are included in the boxplot in Figure 2 (definite article *the*, indefinite article *a*, progressive *-ing*, contractible copula, contractible auxiliary and regular plural *-s*). The morphemes in this figure are generally arranged from most to least salient, with those that are pronounced as independent words listed first, then those that are syllabic, followed by those that are (usually) nonsyllabic on the right of the figure. While the regular plural has a syllabic allomorph (*-es*), obligatory contexts for this were exceedingly rare in the data.

<Insert Figure 2 about here>

Performance for each morpheme was then compared between the groups using Bonferroni adjusted alpha levels of .008 per test (.05/6). Only the regular plural morpheme approached significance ($U(10) = 2.5$, $Z = -2.45$, $p = .01$, $r = -.71$), while differences in accuracy for the definite article ($U(10) = 15$, $Z = -.41$, $p = .76$, $r = -.12$), indefinite article ($U(10) = 12$, $Z = -.91$, $p = .43$, $r = -.26$), progressive ($U(10) = 17$, $Z = -.09$, $p = .93$, $r = -.03$), contractible copula ($U(10) = 14$, $Z = -.57$, $p = .64$, $r = -.17$), and contractible auxiliary ($U(10)=14$, $Z = -.61$ $p = .64$, $r = -.18$) did not approach statistical significance.

Table 4 provides accuracy scores for each child across all six morphemes discussed above, as well as means and standard deviations for each group. Figure 2 and Table 4 illustrate that there is a wider variation in performance in the BB-CI group.

<Insert Table 4 about here>

Perceptual Salience Hypothesis

Results from the six individual morphemes appearing in a minimum of four obligatory contexts were also used to address the prediction that perceptual salience would influence development, by comparing performance across morphemes within each group. A Friedman test showed that, for the BB-TH group, there was no significant difference in accuracy rate across morphemes ($\chi^2(5) = 3.40$, $p = .64$). For the BB-CIs, there was a significant difference in accuracy rates across morphemes ($\chi^2(5) = 13.31$, $p = .02$). Post hoc analysis with Wilcoxon signed-rank tests was conducted. In order to limit the number of comparisons, only three comparisons were made with one morpheme from each of the perceptual categories of independent word (*the*), syllabic (progressive *-ing*), and nonsyllabic (regular plural *-s*). The contractible copula was considered a category between syllabic and nonsyllabic, because it can also appear as an independent word when uncontracted. A Bonferroni adjusted alpha level of .017 was used per test (.05/3). Given this stringent alpha level and the small sample size, none of the comparisons reached statistical significance. The results were as follows for the comparisons between (1) definite article & progressive, $Z = 0.54$, $p = .59$, $r = .17$, (2) progressive & contractible copula, $Z = 1.41$, $p = .16$, $r = .45$, and (3) progressive & regular plural, $Z = 2.02$, $p = .04$, $r = .64$.

Age and Morphological Accuracy

A single sample was formed by combining the two groups of bimodal bilinguals and a Spearman's rank-order correlation was conducted to determine the relationship between morphological accuracy and chronological age. There was not a statistically significant correlation between chronological age and overall accuracy ($r_s(10) = .217$, $p = .25$). A second

Spearman's correlation was conducted to determine the relationship between hearing age and morphological accuracy. This correlation approached significance ($r_s(10) = .49, p = .052$).

Although the mean chronological ages of our two groups of participants was not significantly different, there was one participant in the BB-CI group who is quite young (i.e., Pam at age 4;01). Our small sample sizes provide limited power to detect differences between the two groups and thus insufficient power to consider age as a covariate in our analysis. Nevertheless, if Pam is removed from the analysis, the two groups still differ significantly on hearing age ($U(9) = 0, Z = -2.68, p = .006, r = -.82$), but not chronological age ($U(9) = 12, Z = -.38, p = .006, r = -.20$). Furthermore, all comparisons of our language measures remain statistically not significant with similar effect sizes (e.g., for overall accuracy, $U(9) = 8, Z = -1.14, p = .315, r = -.27$ and for regular plural -s with an adjusted p-value of .008, $U(9) = 2.5, Z = -2.18, p = .02, r = -.66$).

Error Type Frequencies

Tables 5 and 6 show the raw numbers of errors and the percentages out of total errors broken down into the morpheme types of verbal and plural and separated by group (BB-TH and BB-CI). Data from articles *the/a(n)* are not displayed because only errors of omission were possible given our coding scheme. In both groups and for both morpheme types, errors of commission were quite rare. The BB-CIs omitted plural morphemes more frequently than BB-THs, who over-regularized plural about as often as they omitted plural morphemes. The raw number of errors also demonstrated that there were many more errors of plural omission within the BB-CI group.

<Insert Table 5 about here>

<Insert Table 6 about here>

Discussion

This study investigated the development of English morphology in bimodal bilingual

children with CIs (BB-CI) and did not find that they were less accurate than bimodal bilingual

children with typical hearing (BB-TH) at a statistically significant level. We focused on

morphology here because previous research has found it to be particularly difficult for children

with CIs (e.g., Guo et al. 2013; Werfel, 2018).

The BB-CIs did not differ significantly on MLU in words or in morphemes, despite the

fact that they had had access to spoken English input for a much shorter period of time than the

BB-THs. This could indicate that the two groups were at a similar stage of syntactic development

at the time of testing. The difference in overall morphemic accuracy between the two groups

only approached significance, and this trend seemed to be driven by a lower accuracy rate with

regular plurals in the BB-CI group. These results could mean that verbal morphology is a relative

strength for these BB-CIs, while plurals are a weakness. This conclusion is not yet warranted

though, because our elicitation method failed to obtain large numbers of regular past tense and

3rd person singular present morphemes, which may be particularly difficult for children with CIs

based on their low perceptual salience and/or syntactic and semantic complexity (cf., Werfel,

2018). Future research with these populations should include tasks that have been shown to

reliably elicit all morphemes of interest, including regular past tense and 3rd person present tense

morphemes. As Figures 1 and 2 illustrate, there was also wider variation in accuracy levels in the

BB-CI group, an observation that has also been made about children with cochlear implants

more generally (e.g., Niparko et al., 2010). Additionally, Spearman's correlations demonstrated that our participants' overall morphological accuracy was more closely related to hearing age (i.e., time since cochlear implantation/length of exposure to spoken English) than chronological age.

The relatively lower performance by the BB-CI participants on plurals could be attributable to their low perceptual salience. For children with typical hearing, numerous studies of monolingual development have found that it is one of the earliest acquired grammatical morphemes, with many children mastering it by 36 months of age or younger (Brown, 1973; de Villiers & de Villiers, 1973; Lahey et al., 1992). Even children with Specific Language Impairment/Developmental Language Disorder also acquire plurals and other nominal morphology earlier than tense/aspect morphology (e.g., Paradis, 2010). If the relatively lower perceptual salience of plurals affects very young children with typical hearing, other factors, such as higher input frequency or lower semantic complexity seem to outweigh this given the early age of acquisition. On the other hand, monolingual children with hearing loss do show evidence of difficulty with plurals (e.g., Werfel, 2018). Overall, then, it is likely that the lower performance of the BB-CI participants on plurals, as for monolingual children with hearing loss, is due to the morphemes' lower perceptual salience rather than the children's bilingual status.

As has been found in research with monolinguals and speech-speech bilinguals, omission errors occur much more frequently than errors of commission. There was also a tendency for the BB-TH group to over-regularize irregular verbs and nouns more than the BB-CIs, but future research using a task specifically eliciting inflections of irregular verbs and nouns would be necessary to determine if true group differences exist. Counter-intuitively, more over-regularization errors could be indicative of more sophisticated morphological understanding. For

example, Nicholls et al. (2011) found that bilinguals were more accurate with irregular noun

plural than monolinguals while also being simultaneously less accurate inflecting regular noun

plurals. This was presumably because the monolinguals had mastered the regular English plural

morpheme and begun overapplying it to exceptions, while the bilinguals had memorized

individual irregular forms, but had not yet mastered the regular plural morpheme. In this study,

such a discrepancy in knowledge is plausible given that the BB-TH group had received more

spoken input than the BB-CIs, who had a significantly lower hearing age. Yet both the regular

past tense and plural morphemes are also of low perceptual salience, so it is difficult to

disentangle the effects of delayed exposure from the possibility that these morphemes were not

well-represented through the CI.

One limitation in this study is the small sample sizes, which reflects the fact that it

remains relatively uncommon for culturally Deaf parents to choose cochlear implants for their

children with hearing impairments (e.g., Mitchiner & Sass-Lehrer, 2011). Unfortunately, this fact

also means that our study is underpowered and only a quite large effect size (i.e., $r \geq .73$ or

Cohen's $d \geq 2.13$) would lead to statistically significant differences. To provide some context for

this, Werfel (2018) found that children with hearing loss (using hearing aids and/or CIs) were

less accurate than age-matched and language-matched peers in the production of various English

morphemes, with effect sizes ranging from $r = .33-.58$ (originally reported as Cohen's $d = .69-$

1.43). One of our results, overall accuracy across all morphemes, fell within this range ($r = .45$, d

$= 1.00$) and another result, accuracy for regular plural, had an even larger effect size ($r = .71$, $d =$

1.99). This suggests that we may have found statistically significant differences in these

comparisons with larger groups or if our stimuli had elicited more types of morphemes that other

researchers have found to be especially difficult for children with CIs (e.g., 3rd person singular

present or regular past tense, as in Werfel, 2018). On the other hand, all other comparisons had

much smaller effect sizes (r = .03-.31, d = .05-.53), except for group differences in mean length

of utterance in morphemes, which had an effect size of r = .31 (d = .64). This is consistent with

the fact that the BB-CIs tended to omit plural morphemes more frequently than the BB-THs,

leading to a smaller MLUm.

Another limiting factor is that both groups of children in this study were of relatively

high SES. While this might be representative of the children with CIs who are born to Deaf

parents, such a sample does not accurately reflect the larger population of children with CIs

(Chang et al. 2010). This difference is noteworthy because higher SES has been consistently

linked to better language outcomes in both children with typical hearing (e.g., Rowe, 2008) and

children with CIs (e.g., Geers et al., 2003). Regardless, our groups were well-matched for SES,

meaning that any differences between the two groups were unlikely to be related to this factor.

While it is unlikely that transfer from ASL in the domain of morphology facilitates

acquisition of these morphemes in English, it is possible that other aspects of the linguistic

environment of bimodal bilingual children with CIs could enhance their ability to detect English

morphological elements in their input. Future comparisons with well-matched monolingual

English-speaking children with CIs could help determine whether early ASL exposure is

beneficial for later spoken English morphological development in this population. Furthermore,

as noted earlier, it is unclear to what extent the sign input these children received from their Deaf

parents would resemble that produced by hearing parents of children with CIs. The nature of the

sign input provided by Deaf and hearing parents remains to be studied.

Our results suggest that large amounts of fluent ASL input from birth does not impede

subsequent spoken language development. While there was some evidence that our group of

bimodal bilingual children with CIs had difficulties with the regular plural morpheme, this result

is consistent with studies of monolingual children with CIs (e.g., Werfel, 2018). Our participants

with CIs also demonstrated relative strengths on the same morphemes that Werfel's (2018)

monolingual children with hearing loss produced with high accuracy (e.g., present progressive -

ing and articles *the/a*). These similarities between monolingual and bimodal bilingual children

with hearing loss suggests that hearing acuity and the perceptual salience of English morphemes

are critical factors for both groups. In separate research, we are investigating the possibility that

some aspects of morphological accuracy might be affected by bilingual transfer from ASL. If so,

this is expected to affect both groups of bimodal bilingual participants relatively equally. Future

studies should incorporate comparison groups of monolinguals with typical hearing and with CIs

to directly test whether ASL-English bimodal bilinguals exhibit any bilingualism effects in their

spoken language, as has been found in speech-speech bilinguals.

In summary, we found little evidence that the spoken English of five-year-old Deaf

children with exposure to a natural sign language from birth differed significantly from that of

their bimodal bilingual peers with typical hearing despite significantly delayed exposure to

spoken English. As in monolingual children with CIs, the perceptual salience of specific

morphemes seemed to drive trends toward group differences in our two groups of bimodal

bilinguals. Finally, we stress the importance of comparing bilingual children to other bilinguals

rather than to monolinguals when assessing overall language development in order to control for

bilingualism effects. We recognize that the population we studied is quite special, since the

participants experienced no delay or disturbance in the quality of linguistic input from birth.

Nevertheless, this population is important for determining the potential outcomes for bimodal

bilingual children with CIs and optimal input conditions. Further study with this population may

help to reveal any limitations under these conditions (such as the lower accuracy we observed

with plurals), as well as specific aspects of the linguistic environment that could facilitate

English morphological development and which might be applicable to a wider range of children.

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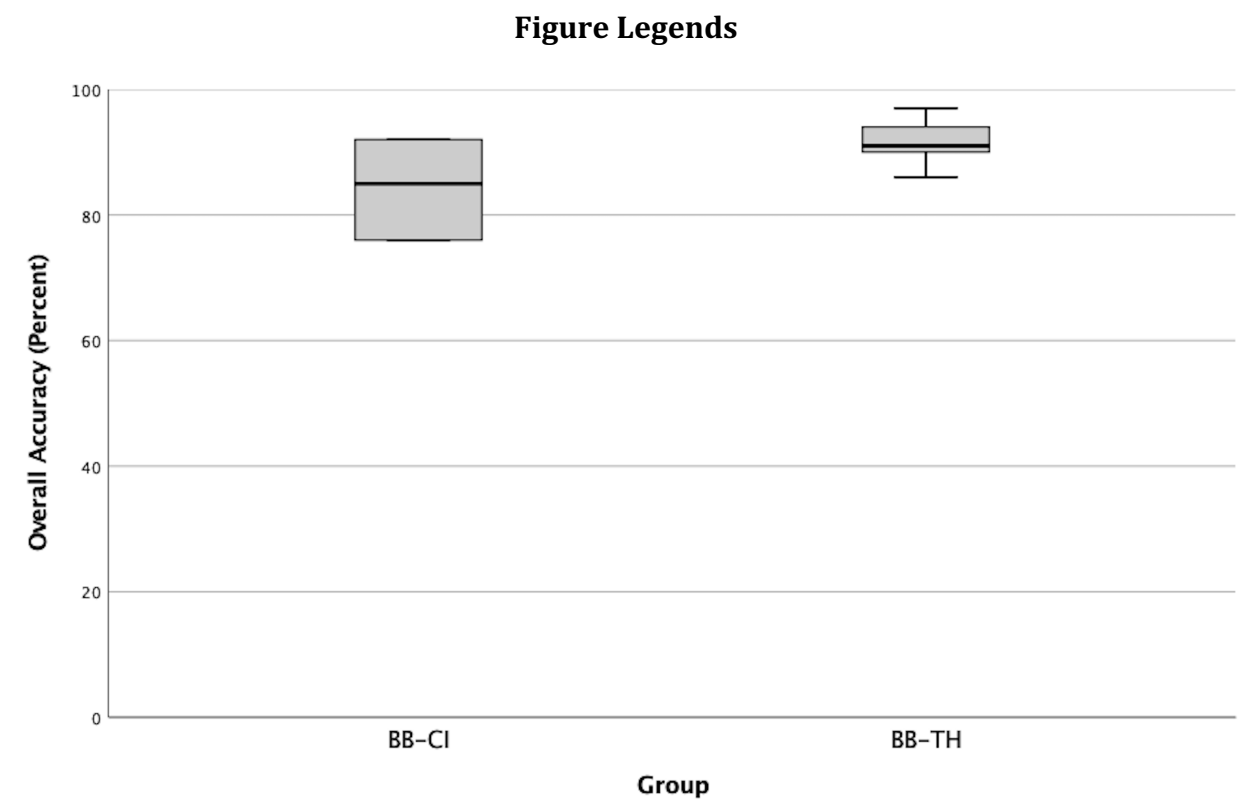   (PLS-4) English edition*. San Antonio, TX: The Psychological Corporation.

Figure Legends

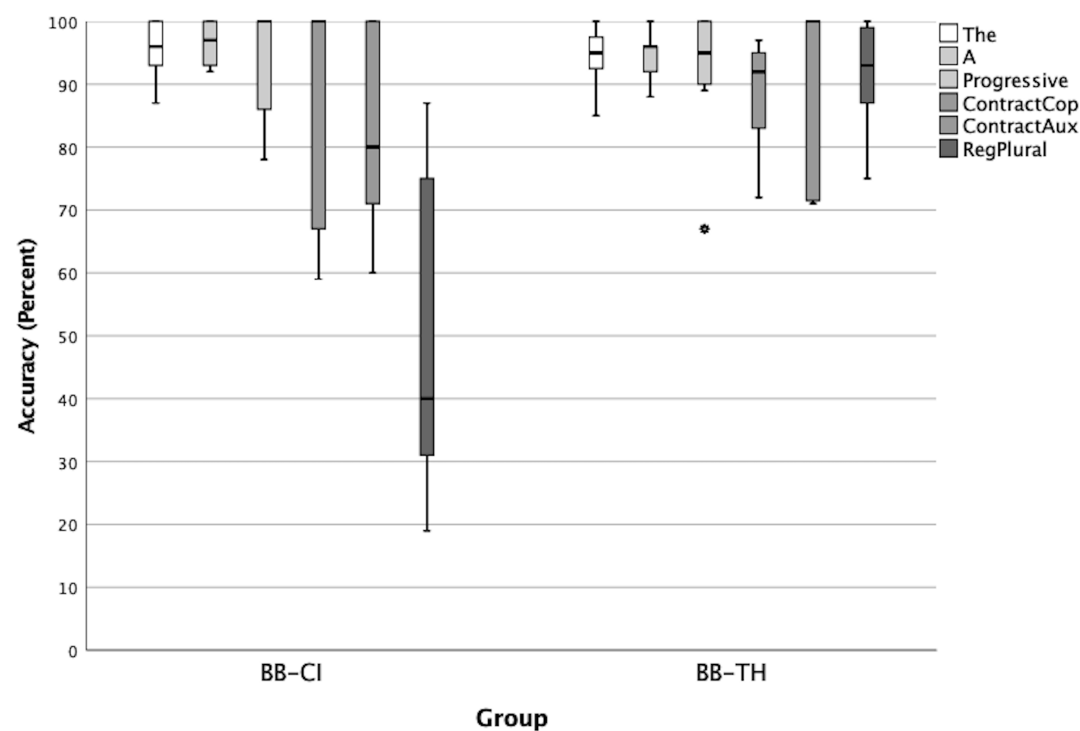Figure 1. Overall Morphological Accuracy by Group

Figure 2. Group Accuracy by Morpheme in Order of Perceptual Salience

Table 1. Participant Background Characteristics

Pseudonym	Group	Chronological Age at Testing	Hearing Age at Testing	Maternal Education	Language Use at Home (%ASL/Eng/mix)	Language Use at School (%ASL/Eng/mix)
Ben	BB-TH	6;00	6;00	16+	50/30/20	0/100/0
Kim	BB-TH	5;02	5;02	16+	90/0/10	0/50/0*
Lex	BB-TH	5;10	5;10	16+	50/20/30	60/0/40
Lyn	BB-TH	6;03	6;03	12	75/10/15	0/100/0
Tom	BB-TH	6;00	6;00	16+	80/10/10	0/100/0
Val	BB-TH	5;02	5;02	16+	-	-
Zig	BB-TH	6;01	6;01	13	50/0/50	0/100/0
Mean (SD)		**5;09 (0;05)**	**5;09 (0;05)**			
Fin	BB-CI	5;08	4;01	16	50/0/50	0/50/50
Gia	BB-CI	5;07	4;00	16+	75/5/20	0/100/0
Max	BB-CI	6;05	4;09	16	65/20/15	0/100/0
Nik	BB-CI	5;06	4;02	16+	-	-
Pam	BB-CI	4;01	1;02	16	60/30/10	0/100/0
Mean (SD)		**5;05 (0;10)**	**3;08 (1;05)**			

Note: BB-TH = bimodal bilingual with typical hearing; BB-CI = bimodal bilingual with cochlear implant; Maternal Education is provided in years, with 12 = high school diploma or GED, 16 = Bachelor's Degree, and 16+ = post baccalaureate or graduate school; Language use is expressed as percent reported use of ASL, English, or mix of sign and speech; *50% Spanish input; Language use data is unavailable for Val and Nik

Table 2. Audiological Characteristics of Bimodal Bilingual Participants with Cochlear Implants

Pseudonym	Age of diagnosis	Age at 1st Implant	Age at 2nd Implant	Pre-Aided HL	Pre-Device HA use
Fin	prenatal	1;07	1;07	Profound	unknown
Gia	7 days	1;06	unknown	Profound	unknown
Max	1 month	1;08	N/A	Severe-Prof	11 weeks
Nik	unknown	1;04	3;06	unknown	unknown
Pam	9 days	2;11	N/A	Mod-Prof	7 weeks

Note: HL = Hearing Level; HA = Hearing Aid; Age at 1st/2nd Implant = Age of activation of cochlear implant

Table 3. Speech and Language Test Scores

Pseudonym	Group	PLS-4	EVT	GFTA-2	Minimal Pairs
Ben	BB-TH	117	119	110	37
Kim	BB-TH	98	114	115	28
Lex	BB-TH	108	109	112	39
Lyn	BB-TH	91	87	106	37
Tom	BB-TH	92	104	107	34
Val	BB-TH	105	96	115	37
Zig	BB-TH	92	110	90	38
Mean (SD)	**BB-TH**	**100.4 (9.9)**	**105.6 (11)**	**107.9 (8.6)**	**35.71 (3.7)**
Fin	BB-CI	79	100	100	35
Gia	BB-CI	104	108	112	30
Max	BB-CI	95	90	102	36
Nik	BB-CI	96	112	109	32
Pam	BB-CI	96	110	-	-
Mean (SD)	**BB-CI**	**94 (9.1)**	**104 (9.1)**	**105.8 (5.7)**	**33.3 (2.8)**

Note: PLS-4= Preschool Language Scale, Fourth Edition; EVT = Expressive Vocabulary Test; GFTA-2 = Goldman-Fristoe Test of Articulation 2; Standard Scores provided for the PLS-4, EVT and GFTA-2, with a mean of 100 and standard deviation of 15; Raw Scores Provided for the Minimal Pairs Task with a maximum possible of 40

Table 4. Accuracy in Percentages by Morpheme Type for Individual Participants

Pseudonym	Status	Definite Article	Indefinite Article	Progressive -ing	Contractible Copula	Contractible Auxiliary	Regular Plural
Ben	BB-TH	94	96	100	97	100	98
Kim	BB-TH	91	100	67	75	71	75
Lex	BB-TH	98	94	100	97	100	83
Lyn	BB-TH	100	88	89	92	100	93
Tom	BB-TH	97	96	100	93	72	100
Val	BB-TH	85	96	95	72	71	100
Zig	BB-TH	95	90	100	91	100	91
Mean (SD)		**94.3 (5)**	**94.3 (4.1)**	**93 (12.2)**	**88.1 (10.3)**	**87.7 (15.3)**	**91.4 (9.4)**
Fin	BB-CI	87	92	86	67	71	40
Gia	BB-CI	100	93	100	100	100	75
Max	BB-CI	93	100	100	100	100	19
Nik	BB-CI	100	100	100	100	80	87
Pam	BB-CI	96	97	78	59	60	31
Mean (SD)		**95.2 (5.5)**	**96.4 (3.8)**	**92.8 (10.3)**	**59 (37.2)**	**82.2 (17.7)**	**50.4 (29.2)**

Note: BB-TH = bimodal bilingual with typical hearing; BB-CI = bimodal bilingual with cochlear implant

Table 5. Number (Percent) of Verbal Errors Produced

	Omission	Commission	Over-regularization	Other
BB-TH	61 (58%)	5 (5%)	12 (11%)	28 (26%)
BB-CI	63 (59%)	3 (3%)	3 (3%)	38 (36%)

Note: BB-TH = bimodal bilingual with typical hearing; BB-CI = bimodal bilingual with cochlear implant

Table 6. Number (Percent) of Plural Errors Produced

	Omission	Comission	Over-regularization
BB-TH	11 (52%)	1 (5%)	9 (43%)
BB-CI	47 (85%)	6 (11%)	2 (4%)

Note: BB-TH = bimodal bilingual with typical hearing; BB-CI = bimodal bilingual with cochlear implant

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[1] "Deaf" is capitalized here to refer to individuals who are culturally and linguistically deaf and utilize sign language as their main form of communication.

[2] Ages are provided in the form y;mm, with y=year and m=month.

[3] Materials from both tasks can be retrieved from [website to be added after reviewing].