Ear selection and pediatric cochlear implants: A preliminary examination of speech production outcomes

Peter Flipsen Jr.*

Department of Communication Sciences and Disorders, and Education of the Deaf, Idaho State University, 921 S. 8th Avenue Mail Stop 8116, Pocatello, ID 83209-8116, United States

Received 25 June 2008; received in revised form 30 July 2008; accepted 3 August 2008
Available online 10 September 2008

Summary

Objective: The goal of the current study was to examine whether ear selection (left versus right) for cochlear implantation results in significant differences in speech production outcomes.

Methods: Ten children with right-ear implants were compared to five children with left-ear implants on intelligibility of speech produced in single words, sentences, and conversation as well as on accuracy of speech sounds produced during administration of a single word articulation test and in conversational speech.

Results: The children with right-ear implants performed significantly better than those with left-ear implants but only on the single word tasks. No significant differences were observed at the sentence or conversational speech levels.

Conclusion: Findings are discussed relative to the possibility that the obtained ear of implantation differences (if real) may disappear over time. Such a conclusion is quite tentative however given the small sample size in the current study. Such a limitation may also explain why no differences were obtained for the connected speech measures. Further study of ear selection outcomes is clearly indicated.

© 2008 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Despite recent trends toward bilateral implantation and some early evidence of the relative benefits of two implants [1], many pediatric candidates for cochlear implants continue to receive only a single implant. A question that has received only limited attention is whether the ear selected for implantation (i.e., right ear versus left ear) makes any difference to the development of speech and language. In cases where both ears are viable candidates for implantation, such information clearly has the potential to influence the choice. In cases where there are...
known constraints against using a particular ear, information about outcomes has the potential to inform patients, parents, surgeons, rehabilitation professionals and educators about expectations following implantation.

A number of perspectives are usually considered when making ear selection decisions. From a medical perspective surgeons are always concerned about possible structural impediments to electrode insertion such as cochlear ossification or congenital malformations of the cochlea. They are also concerned about relative infection risks such as cases in which the patient has an active case of OM in one ear or the other. From an audiological perspective there are questions about dealing with unequal hearing thresholds; implant teams appear to vary in their preference for implanting either the better-hearing or worse-hearing ear. In addition, documentation of auditory neuropathy in one ear or the other may influence ear selection. Then there is the speech and language perspective which is particularly relevant for pediatric cochlear implantation. All other factors being equal, a strong preference to provide maximum stimulation of the language-dominant hemisphere likely motivates recommendations for implantation in the contralateral ear. With very young children, identifying the language dominant hemisphere is problematic, however, because speech and language have yet to emerge making dominance very difficult to ascertain. Typically handedness, usually evident (though not firmly established) before the first birthday, is used as a proxy for language dominance; such an approach is clearly not fool-proof however, particularly for left-handed patients [2]. A potentially higher incidence of left-handedness among hearing-impaired individuals [3] only serves to amplify the problem. A final but somewhat lesser perspective on ear selection is maximizing manipulation of the device itself by the patient which may be facilitated by implantation on the side of the dominant hand [4].

Studies to date have tended to indicate few if any differences relative to ear selection; the focus of the few studies that have been conducted has however largely been on adults and has only included responses to speech or other auditory input (i.e., there has been little or no study of children and/or speech production). Although studies of adults reflect the impact of the modified auditory input from cochlear implants to both a mature neurological system and a mature language system, comparing findings from such studies with studies of children (such as the current one) may eventually allow us to isolate the impact of development from the impact of that modified input.

Examining the existing adult studies, Morris et al. [5] reported no significant differences in speech recognition performance between 38 adult patients with left-ear implants against 63 adult patients with right ear implants at 1 year post-implant. The findings were the same even when the analysis was limited to only the 67 right-handed patients. Roman et al. [6] reported no significant difference between adults with left-ear implants (n = 4) and those with right-ear implants (n = 3) on consonant discrimination thresholds. Analysis of auditory evoked potential responses by the same participants indicated similar overall response shapes, but significantly slower response latencies in those with left-ear implants. In a related study Roman et al. [7] examined auditory evoked responses to tone bursts and reported no significant difference in latency or amplitude of N1/P2 peaks between adults with left-ear (n = 4) and right-ear implants (n = 3). Deguine et al. [4] examined ear selection outcomes relative to handedness and reported no significant difference in open set word and sentence discrimination performance in 76 patients (including an unspecified number of children) regardless of whether the implant was ipsilateral or contralateral to reported handedness. Overall studies to date appear to show no significant differences relative to ear selection.

Studies of individuals with normal hearing in one ear but significant hearing loss in the other (i.e., those with significant unilateral losses) may be relevant here. This is the case because assuming a child meets the typical implantation criteria (i.e., a severe-profound bilateral hearing loss), when they receive a single cochlear implant it effectively transforms them into someone with near-normal hearing in the implanted ear but a continuing severe or profound hearing loss in the other ear. Thus, their situation is very similar to someone with a unilateral hearing loss. Of course the analogy is not a perfect one in at least two respects. First, a cochlear implant provides electric hearing rather than acoustic hearing and thus the auditory input into the “good” ear is not quite the same as the input which our auditory systems normally deal with. And second, children born with unilateral losses have the immediate benefit of normal hearing in their good ear, rather than the delay of at least 1 year usually experienced by those who receive a unilateral cochlear implant. These differences only argue however for even greater potential differences for children using a single cochlear implant. A recent review of studies of unilateral hearing loss [8] indicated mixed findings, but the author noted that up to 35% of children with significant unilateral hearing loss may need to repeat a grade in school, and up to
41% may require special educational assistance. Another study [9] reported 20% being described by their teachers as having behavior problems. Differences relative to the particular ear with the loss have also been reported. Investigators, for example, have reported that children with significant hearing losses in the right ear (analogous to having a single cochlear implant in the left ear) tend to have significantly more difficulty with verbal tasks [10,11] and greater difficulty understanding speech in noise [12] than children with left-ear losses. On the other hand, non-verbal deficits have been reported in those with left-ear losses (analogous to those with a single cochlear implant in the right ear) [11]. If confirmed in studies of unilateral cochlear implantation, such patterns of differential strengths and weaknesses relative to ear of implantation might ultimately lend support for bilateral implantation.

The possibility of differences in speech production outcomes relative to ear of implantation is based on at least two assumptions. First, it assumes a cerebral asymmetry for language which has been long established with the large majority of right-handed individuals being left-hemisphere dominant for language with dominance among left-handers being somewhat less certain [13]. Studies such as that of Vargha-Khadem and Corballis [14] have established that asymmetry for language is not present at birth, while more recent studies [15] suggest it may be at least partially established by age 5 years. Second, the possibility of ear of implantation differences also assumes (as appears to be the case) that the majority of auditory input directly stimulates the auditory cortex of the contralateral hemisphere [16]. However, even assuming lateralization for language function, it could be argued that one might expect no outcome differences relative to ear of implantation, because the ipsilateral hemisphere would receive direct input from a minority of auditory pathway fibers [16] along with indirect input through the inter-hemispheric communication provided via the corpus callosum.

The current retrospective study was an attempt to add to the extant literature in this area. Specifically, the question under investigation was whether speech production outcomes differ in children with a cochlear implant in their right ear compared to children with a cochlear implant in their left ear. Given the above discussion of cerebral asymmetry for language and lateralization of auditory input it was predicted that speech production outcomes might be superior in individuals using a cochlear implant in their right ear.

2. Method

2.1. Participants

Participants were recruited from Child Hearing Services at the University of Tennessee using procedures approved by the local Institutional Review Board. Potential participants had to have at least a severe (i.e., >70 dB HL) bilateral hearing loss and no other handicapping conditions. They had to have been using their implants for at least 12 months prior to testing and been capable of producing at least two word utterances in conversation with an unfamiliar examiner. A total of 17 participants completed the protocol; one was excluded from the current study because she had been fitted with a second implant (i.e., she was now a bilateral user) 5 months prior to testing. A second participant was excluded when it was revealed that she had experienced a partial device failure and had been using a replacement implant for the 12 months prior to testing. Details on the 15 participants included in the current study are highlighted in Table 1. The sample included 11 females and 4 males; the somewhat skewed gender distribution was likely an artifact of a convenience sample. Male and female participants did not differ significantly from each other on implantation age, age at testing, amount of implant experience or pre-implantation pure-tone average (Mann-Whitney ps > .05). Note that the sample included a pair of identical female twins (participants #4 and #5). Nine of the participants used an Advanced Bionics device, and six used a Cochlear Corporation device.

As indicated in Table 1, age of implantation ranged from 1.8 to 8.4 (Mean = 3.11, S.D. = 2.3). At the time of testing the participants ranged in age from 5.1 to 11.1 (Mean = 8.3, S.D. = 1.10) and their amount of implant experience ranged from 1.0 to 7.10 (Mean = 4.3, S.D. = 2.5). Pre-implantation pure-tone average thresholds obtained from patient records ranged from 70 to 103 dB HL in the better ear (Mean = 84.3, S.D. = 10.3).

For purposes of the current study, comparisons were made between the ten right-ear device users (7 females; 3 males) and the five left-ear devices users (4 females; 1 male). A series of Mann-Whitney tests revealed that the two groups did not differ significantly on age of implantation, age at testing, amount of implant experience, or pre-implantation pure tone average (p > .05). Each group included equal proportional representation from the two device manufacturers. Note that this was a retrospective study and was not originally designed to look at ear selection; thus, information on the reasons for ear selection was not available for these
children. As indicated in Table 1, 14/15 participants were determined to be right-handed based on parent report. The possible exception was participant 7, for whom handedness information was unavailable because she moved from the area shortly after testing.

2.2. Test procedures

All testing was conducted in fall 2005 by a single, trained, female graduate student examiner. All testing for each participant was conducted during a single 60–90 min session in a single-wall sound treated booth. All productions were recorded onto digital audio tape using an external microphone attached to the hand of a puppet sitting on the table approximately two feet from the participant.

Two general approaches to speech production outcomes were taken for the current study. The first involved measurement of message intelligibility or the percentage of words produced that could be understood by normal hearing listeners. This was measured using output at the single-word level using the 50 item Children’s Speech Intelligibility Measure or CSIM [17], at the sentence level using the 10 item Beginners’ Intelligibility Test or BIT [18], and in conversational speech involving interaction about topics of general interest; a target of including at least 90 different words was set for the conversational samples because such samples have been shown to include a representative sample of all English phonemes and syllable shapes [19]. 14/17 samples met the target. Samples also included a minimum of 10 min of interaction but were terminated after approximately 20 min to avoid fatigue.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Implant manufacturer</th>
<th>Implanted ear</th>
<th>Handedness (parent report)</th>
<th>Age $^a$ of implantation</th>
<th>Age $^a$ at testing</th>
<th>Implant experience $^a$</th>
<th>Pre-implant PTA $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>Advanced Bionics</td>
<td>Right</td>
<td>Right</td>
<td>3.6</td>
<td>5.7</td>
<td>2.1</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Right</td>
<td>Right</td>
<td>2.0</td>
<td>5.1</td>
<td>3.0</td>
<td>78</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>Advanced Bionics</td>
<td>Left</td>
<td>Right</td>
<td>2.3</td>
<td>7.7</td>
<td>5.3</td>
<td>80</td>
</tr>
<tr>
<td>4 $^c$</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Left</td>
<td>Right</td>
<td>6.1</td>
<td>7.1</td>
<td>1.0</td>
<td>82</td>
</tr>
<tr>
<td>5 $^c$</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Left</td>
<td>Right</td>
<td>6.1</td>
<td>7.1</td>
<td>1.0</td>
<td>73</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Left</td>
<td>Right</td>
<td>8.4</td>
<td>9.10</td>
<td>1.6</td>
<td>78</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>Advanced Bionics</td>
<td>Right</td>
<td>Unknown</td>
<td>5.8</td>
<td>11.1</td>
<td>5.5</td>
<td>80</td>
</tr>
<tr>
<td>9 $^d$</td>
<td>Female</td>
<td>Advanced Bionics</td>
<td>Right</td>
<td>Right</td>
<td>8.0</td>
<td>9.10</td>
<td>1.10</td>
<td>95</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Right</td>
<td>Right</td>
<td>2.0</td>
<td>6.8</td>
<td>4.8</td>
<td>90</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>Cochlear Corp</td>
<td>Right</td>
<td>Right</td>
<td>3.6</td>
<td>6.10</td>
<td>3.4</td>
<td>70</td>
</tr>
<tr>
<td>13</td>
<td>Female</td>
<td>Advanced Bionics</td>
<td>Right</td>
<td>Right</td>
<td>2.4</td>
<td>9.7</td>
<td>7.3</td>
<td>95</td>
</tr>
<tr>
<td>14</td>
<td>Female</td>
<td>Advanced Bionics</td>
<td>Right</td>
<td>Right</td>
<td>2.7</td>
<td>8.11</td>
<td>6.4</td>
<td>103</td>
</tr>
<tr>
<td>15</td>
<td>Female</td>
<td>Cochlear Corp</td>
<td>Right</td>
<td>Right</td>
<td>2.0</td>
<td>9.10</td>
<td>7.10</td>
<td>98</td>
</tr>
<tr>
<td>16</td>
<td>Female</td>
<td>Advanced Bionics</td>
<td>Left</td>
<td>Right</td>
<td>3.0</td>
<td>10.6</td>
<td>7.6</td>
<td>83</td>
</tr>
<tr>
<td>17</td>
<td>Male</td>
<td>Cochlear Corp</td>
<td>Right</td>
<td>Right</td>
<td>1.8</td>
<td>7.9</td>
<td>6.1</td>
<td>90</td>
</tr>
</tbody>
</table>

Mean (S.D.) 3.11 (2.3) 8.3 (1.10) 4.3 (2.5) 84.3 (10.3)

$^a$ Expressed in years; months.
$^b$ Pure tone average (dB HL) in the better ear.
$^c$ Identical twins.
$^d$ GFTA-2 data missing.
effects. Final samples included between 57 and 225 utterances (Mean = 102.4; S.D. = 39.7). The second general approach to measuring speech production outcomes involved examination of the accuracy of individual speech sounds. This was measured at the single-word level using the Goldman-Fristoe Test of Articulation — Second Edition or GFTA-2 [20] and in conversational speech using the same samples described above. The tests were administered in the following order: conversational speech, GFTA-2, CSIM, BIT. The GFTA-2 and CSIM were administered according to their respective test manuals. For the BIT, one of the four different sets of 10 sentences was randomly assigned to each participant. It is noteworthy that both the CSIM and BIT were presented as imitative tasks.

2.3. Scoring and analysis

Following recording the samples were transferred to a laptop computer and each task for each child was stored as a separate computer file. Note that during this process a tape problem was discovered which rendered the GFTA-2 data for one participant (#9) unusable. Comparisons for the GFTA-2 were thus based on 14 participants (9 right-ear implants versus 5 left-ear implants). The CSIM and BIT files were further subdivided into separate files for each test item using Computerized Speech Lab (CSL Model 4400). Prior to scoring, all files within each task were amplitude-normalized to average amplitude across all items within that task using the software program Cool-Edit Pro.

For each participant, groups of three undergraduate students served as judges of the CSIM and BIT productions (45 judges for the CSIM and 45 judges for the BIT). The judges were recruited as part of a research participation requirement for an undergraduate course in psychology. Judgments were made in the same sound-treated booth that had been used to obtain the original recordings. Judges heard each item (word or sentence) twice in sound field via external computer speakers and were asked to write down what they heard. Judges sat approximately 3 feet from the speakers. Transcriptions were compared to the target items and a % words understood was calculated. A transcription format was used for scoring the CSIM rather than the usual multiple choice format to ensure consistency in judgments across the three intelligibility tasks. For the BIT, participants were not penalized for words not actually produced (e.g., for leaving out function words such as determiners). Prior to scoring a graduate student compared the productions to the targets and determined the number of words attempted. Scores were then averaged across the three judges to yield a single score per participant per task. For the conversational speech task, a second graduate student who had just completed a course in phonetics transcribed the samples both orthographically, in order to derive a % words understood value, and using narrow phonetic transcription [21], in order to derive phoneme accuracy values. The transcriber had not been present during the original testing. Following an interval of 2 months the same transcriber then also judged phoneme accuracy for the target consonant sounds from the GFTA-2 productions. The number of errors on the GFTA-2 was then calculated for each participant and standard scores were computed using the norms in the test manual. The standard scores were derived relative to both amount of implant experience and chronological age.

The two implant groups (left-ear and right-ear) were then compared on each of the measures using a significance level of $p < .05$. A lower Bonferroni-corrected value was not used because this appeared to be the first study in this area, and concerns about Type II errors were judged to be just as great as concerns about Type I errors. Exact probabilities below .05 are provided to allow the reader to judge the veracity of any conclusions reached.

3. Results

Overall values across the 15 participants for the CSIM ranged from 4.7% to 77.3% (Mean = 35.2; S.D. = 21.1). Overall values for the BIT ranged from 19.2% to 97.4% (Mean = 67.6; S.D. = 27.4). Overall values for intelligibility in conversational speech ranged from 52.7% to 97.8% (Mean = 83.5; S.D. = 15.2). Overall values for the standard scores on the GFTA-2 (relative to chronological age) ranged from 40 to 95 (Mean = 63.8; S.D. = 20.8). Relative to amount of implant experience, overall GFTA-2 standard scores ranged from 40 to 109 (Mean = 82.3; S.D. = 20.6). Overall percentage consonants correct (PCC) values from conversational speech ranged from 51.3 to 95.6 (Mean = 75.8; S.D. = 13.2). Overall percentage vowels correct (PVC) from conversational speech ranged from 79.7 to 99.2 (Mean = 93.4; S.D. = 5.3). No differences were observed on any of the outcome variables between male and female participants.

Correlations between each of the outcome variables and chronological age, age of implantation and amount of implant experience are shown in Table 2. As indicated in Table 2, the only significant correlation ($p < .05$) with chronological age was with BIT scores. As age increased, intelligibility in sentences increased. Both of the GFTA-2 variables were significantly (and negatively) correlated with
age of implantation. As age of implantation decreased, standard scores on the GFTA-2 increased. All but one of the variables (the exception being PVC) were significantly correlated with amount of implant experience. As amount of implant experience increased, performance on all of the outcome measures (except PVC) improved.

Relative to ear selection, means and standard deviations for each of the two study groups on the seven measures are shown in Table 3. As indicated, in each case values were lower for children with left ear implants compared to children with right ear implants. However, as shown in the rightmost column of Table 3, the differences were statistically significant \((p < .05)\) only at the single word level (i.e., on the CSIM and GFTA-2). Findings for the GFTA-2 were significant relative to both age of testing and amount of implant experience.

For the sake of completeness, results for the one participant for whom handedness was unknown (Participant 7; right ear implant) were examined relative to the rest of the participants. Her performance on each of the outcome measures did not stand out from the rest of the group overall and appeared to be consistent with the rest of the children who received right-ear implants.

## 4. Discussion

Findings from this small preliminary study suggest that ear of implantation may make a difference for speech production outcomes at least insofar as single word measures were concerned. Children with implants in their left ears performed significantly less well on single word intelligibility (CSIM) and standard scores on the single word productions of the GFTA-2. Significant differences were not observed for sentence level intelligibility (BIT), intelligibility in conversation, or accuracy of consonant and vowel production during conversational speech.

The current findings only partly confirm the earlier prediction of better performance by the children with right-ear implants. The significant differences were all in the direction predicted. As well, an examination of Table 3 reveals that the nonsignificant differences were also consistently in the direction predicted.

The significantly better performance for children with right ear implants (at least on single word output measures) supports the long-standing view of hemispheric asymmetry for language and the dominance of contralateral auditory pathways. Stimulation of the left hemisphere’s language centers by implants inserted into the right cochlea may offer a specific advantage to the development of spoken language for children with severe and profound hearing loss.

The differences obtained herein however are not consistent with previous studies of speech perception in adults which have generally failed to show ear selection differences \([4–7]\). Comparing the current findings with those of studies of adults with cochlear implants is problematic however as most current adult implant recipients received their implants as adults and thus typically have not had the benefit of such implants during the developmental period. On the other hand, it may be that the ear of implantation differences observed for the children in the current study may be temporary and may simply disappear as they gain more experience with their implants. Such a disappearance may reflect maturation of their auditory and language systems or the accumulation of lesser amounts of stimulation provided by ipsilateral projections of the auditory nerve and/or the indirect stimulation provided via the corpus callosum. The correlations reported in Table 2 may be informative in this regard. Note that there is a significant correlation between GFTA-2 standard scores
and amount of implant experience. Standard scores factor out chronological age differences because they scale performance relative to age expectations and thus, a significant correlation between standard scores and amount of implant experience would not normally be expected. The finding of a significant correlation herein suggests a change in the relative distance between performance of the current participants and their normal hearing age peers over time. Interestingly, separate (Spearman) correlation analysis revealed that the correlation between GFTA-2 standard scores (re: amount of implant experience) and amount of implant experience was significant for the children with left-ear implants ($r = .975$, $p = .005$) but not for the children with right-ear implants. It is worth noting that the standard scores for all of the children with right ear implants (re: amount of implant experience) were in the normal range (85—109). On the other hand, scores ranged from 40 to 81 (only one score above 70) for the children with left-ear implants; the highest score was earned by the child with the most implant experience. This appears to support the possibility that while children with left-ear implants may be initially behind age expectations, they may catch up as they gain experience with their implants. It should be pointed out however, that such a conclusion should be considered quite tentative given the cross-sectional nature of the current study, the fact that there were only five children in the left-ear implant group and that the group included a pair of identical twins. Further study is clearly indicated.

On a related note, GFTA-2 standard scores were also significantly (negatively) correlated with age of implantation (see Table 2). Combined with a significant positive correlation between GFTA-2 standard scores and amount of implant experience, this finding is as would be expected given that age of implantation was significantly correlated ($r = -.693$, $p = .004$) with amount of implant experience.

The failure to observe ear selection differences for sentence-level or conversation-level measures is not consistent with typical views of hemispheric asymmetry for language. Once again the correlations in Table 2 may be informative. BIT scores were significantly correlated with chronological age. As previously, separate (Spearman) correlation analysis revealed a significant correlation for the children with left-ear implants ($r = .975$, $p = .005$), but no significant correlation for the children with right-ear implants ($p > .05$). This difference suggests that the failure to obtain left-ear versus right-ear differences in connected speech may have resulted from either the limited statistical power of the current study (i.e., small sample size) or the inherently greater variability in both the production and judgment tasks for the connected speech measures. It is of course possible that ear selection differences simply do not exist at higher levels; indeed production beyond the word level is thought to include significant contributions of the right hemisphere [22]. Once again, further study is indicated.

The current study suffers from a number of limitations that restrict our ability to generalize its findings. First, as mentioned previously, the small sample (in particular for the left-ear group) greatly limits the validity of the findings. As well, although no gender differences were observed, the somewhat skewed gender distribution of the group may have also impacted the findings in some unknown way. Reasons for ear selection (particularly for those with left-ear implants) were unknown in the current study, and thus the group overall (or either of the ear groups) may not be fully representative of the population of

### Table 2: Outcome variable Children with left-ear implants ($n = 5$) Children with right-ear implants ($n = 10$) Mann—Whitney $p$-value

<table>
<thead>
<tr>
<th>Intelligibility (% understood)</th>
<th>Children with left-ear implants ($n = 5$)</th>
<th>Children with right-ear implants ($n = 10$)</th>
<th>Mann—Whitney $p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single words (CSIM)</td>
<td>19.5 (9.2)</td>
<td>43.0 (21.1)</td>
<td>.0433</td>
</tr>
<tr>
<td>Sentences (BIT)</td>
<td>49.8 (24.6)</td>
<td>76.5 (25.2)</td>
<td>ns</td>
</tr>
<tr>
<td>Conversational speech</td>
<td>72.8 (13.9)</td>
<td>88.8 (13.4)</td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phoneme accuracy</th>
<th>Children with left-ear implants ($n = 5$)</th>
<th>Children with right-ear implants ($n = 10$)</th>
<th>Mann—Whitney $p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single words</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFTA-2 (re: age)</td>
<td>47.2 (12.6)</td>
<td>73.0 (18.8)</td>
<td>.0278</td>
</tr>
<tr>
<td>GFTA-2 (re: Imp. Exp.)</td>
<td>60.0 (15.9)</td>
<td>94.7 (8.8)</td>
<td>.0034</td>
</tr>
<tr>
<td>Conversational speech</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage Consonants Correct (PCC)</td>
<td>66.7 (11.4)</td>
<td>80.3 (12.1)</td>
<td>ns</td>
</tr>
<tr>
<td>Percentage Vowels Correct (PVC)</td>
<td>91.7 (3.9)</td>
<td>94.3 (5.9)</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns, not statistically significant ($p > .05$).

a Cell entries are means (and standard deviations).

b Standard scores.
children with cochlear implants. The fact that ear selection was inconsistent with reported handedness for the children in the left-ear group only serves to magnify this possibility as such decisions may have reflected underlying issues for those children that affected their progress with speech production disproportionately. This also raises the question of indexing handedness which is widely understood to vary by degree [2]. Handedness information for the current participants was obtained by parent report only. Finally, the sample of children in the current study only included one child implanted before age 2 years. It is not clear how the inclusion of children who received their implants at a much younger age might have affected the outcomes obtained.

Despite these limitations, the current findings at least open the door to the possibility of ear selection differences which deserve additional exploration. Although it is currently difficult to determine which hemisphere is dominant for language in very young children, confirming that outcomes differences exist relative to ear of implantation would have serious implications for single versus bilateral implantation as well as for ear selection.

Acknowledgments

Portions of these findings were previously reported as a presentation at Idaho State University Kasiska College of Health Professions Research Day in April 2008. Many thanks to the children who participated and their parents. Thanks especially to Rhonda Parker for participant testing, Joel Blaiss for transcription of the conversational speech samples and scoring of the GFTA-2, and to Fadwa Khwaileh for coordinating the scoring of the CSIM and BIT tasks. Thanks also to the student judges of the CSIM and BIT. Finally thanks to the following for their assistance and valuable input: Julie Beeler, Velvet Buehler, Molly Erickson, Mark Hedrick, Marge Hudson, Kim Jenkins, Ann Michael, Kristin Negilski, Emily Noss, Tammy Pass, Ilsa Schwarz, Tony Seikel, and Josara Wallber.

References


