EMPIRICAL MANUSCRIPT

Comparing the Spelling and Reading Abilities of Students With Cochlear Implants and Students With Typical Hearing

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Abstract

The purpose of this study was to determine whether students with and without hearing loss (HL) differed in their spelling abilities and, specifically, in the underlying linguistic awareness skills that support spelling ability. Furthermore, we examined whether there were differences between the two groups in the relationship between reading and spelling. We assessed the spelling, word-level reading, and reading comprehension skills of nine students with cochlear implants and nine students with typical hearing who were matched for reading age. The students' spellings were analyzed to determine whether the misspellings were due to errors with phonemic awareness, orthographic pattern or morphological awareness, or poor mental graphemic representations. The students with HL demonstrated markedly less advanced spelling abilities than the students with typical hearing. For the students with HL, the misspellings were primarily due to deficiencies in orthographic pattern and morphological awareness. Correlations between measures of spelling and both real word reading and reading comprehension were lower for the students with HL. With additional investigations using a similar approach to spelling analysis that captures the underlying causes for spelling errors, researchers will better understand the linguistic awareness abilities that students with HL bring to the task of reading and spelling.

In the past, investigators examined the spelling abilities of students with hearing loss (HL) and found those abilities to be delayed or deficient when compared to students with typical hearing (e.g., Colombo, Arfe, & Brone, 2012; Harris & Terlektsi, 2011; Kyle & Harris, 2006, 2011; Sutcliffe, Dowker, & Campbell, 1999). A drawback of these previous studies is that most have used a correct–incorrect means of scoring the children's spelling. A few (e.g., Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Harris & Terlektsi, 2011) have modified the basic correct–incorrect scoring metric to examine the influence of students' phonological knowledge on their spelling. These latter scoring systems are based on the assumption that most misspellings are due to the children's HL, given the premise that phonological knowledge is contingent on auditory input. However, spelling is a language skill (e.g., Apel, Masterson, & Brimo, 2011a) and thus is supported by several linguistic awareness abilities in addition to phonemic awareness, including orthographic pattern awareness and morphological awareness. These latter linguistic awareness skills are not necessarily tied to hearing ability. Consequently, a simple correct–incorrect scoring system, or a slightly modified one based on phonological knowledge, not only deprives researchers from fully understanding the linguistic strengths and weaknesses children with HL bring to the act of spelling but also represents a misalignment with current theory and practices of spelling (e.g., Apel, Masterson, & Wilson-Fowler, 2011b). That is, they do not capture the linguistic knowledge children may or may not use when spelling. The purpose of this study was to compare the spelling abilities of students with and without HL, matched by reading age, to determine not only whether they differed in spelling ability but also, importantly,
whether they differed in their use of the underlying linguistic awareness skills that support spelling ability. The children with HL were cochlear implant users. We also were interested in the relationships between the scores obtained from the metric used to assess spelling and the students’ reading abilities.

### Spelling Is Language

Spelling is a language ability and several linguistic awareness skills serve as its foundation (Masterson & Apel, 2013). These skills include phonemic awareness, orthographic pattern awareness, and morphological awareness. Phonemic awareness is the ability to consciously consider and manipulate speech sounds (e.g., Mann, 1986). Orthographic pattern awareness involves the ability to think about and consider the rules and patterns of orthography or how we translate speech into print (e.g., Apel et al., 2011b). Morphological awareness is an explicit understanding of prefixes and suffixes, how they are spelled, and how they are added to base words or stems (e.g., Carlisle, 1988). It also involves a conscious ability to consider the relation between base words and their inflected and derived forms. In addition to these linguistic awareness abilities, spelling also relies on the ability to construct clear and accurate mental graphic representations (MGRs), or mental images of written words, stored in long-term memory (e.g., Apel, 2011). Current theories of spelling development (e.g., repertoire theory; Apel & Masterson, 2001) suggest that children acquire and use these various linguistic awareness skills simultaneously early in development.

Typically, the most common metric used to measure spelling is to score individuals’ writing attempts as correct or incorrect. Such an approach, however, does not capture the linguistic knowledge that individuals may or may not use as they spell. For example, one individual may misspell the word jumped as JUMPT, whereas another may misspell the same word as JUPED. Using a traditional correct/incorrect scoring system, both spellers would receive the same negative score. However, each speller is demonstrating different types of linguistic awareness strengths and weaknesses, which are not captured using this type of scoring metric. In the case of the JUMPT spelling, the individual demonstrates strengths in phonemic awareness, in that all phonemes and morphemes are represented by a letter(s). The individual, however, demonstrates a weakness with morphological awareness because he seems unaware of how to represent the inflectional suffix correctly. On the other hand, in the case of the JUPED spelling, the individual demonstrates a weakness with phonemic awareness; she seems unaware that the base form of the word, jump, contains four phonemes and thus is not representing all phonemes with a letter. However, she shows a strength in morphological awareness because she has represented the past tense inflectional morpheme correctly. Using a scoring metric that is based on the multiple linguistic awareness skills that undergird spelling provides additional insight into an individual’s linguistic awareness abilities and may be more sensitive to developmental changes (e.g., Masterson & Apel, 2010a).

### Spelling Skills of Students With HL

One population that has received considerable attention regarding their spelling abilities are students with HL. For the most part, when investigators have examined the spelling abilities of students with HL, they have found that these students perform poorer than their chronologically matched peers (e.g., Colombo et al., 2012; Harris & Terlecki, 2011; Hayes, Kessler, & Treiman, 2011; Houston, 2009; Kyle & Harris, 2006, 2011; Sutcliffe et al., 1999) but, sometimes, similar to their reading-matched hearing peers (e.g., Hayes et al., 2011; Houston, 2009). Importantly, the prime means for scoring students’ spelling skills in these studies has been through the use of a correct–incorrect system (e.g., Kyle & Harris, 2006, 2011; Park, Lombardino, & Ritter, 2013). When researchers have attempted to go beyond correct–incorrect scoring, they typically have used systems that purport to categorize errors that are phonological or “phonetic” in nature, basing this decision on the notion that students’ HL prevents them from accessing the phonological information present in speech that might aid their spelling of words (e.g., Aaron et al., 1998; Harris & Terlecki, 2011; Hayes et al., 2011). However, these scoring metrics may not always be providing the best description of the students’ linguistic awareness skills. For example, Aaron et al. characterized the spelling errors of students with and without HL as phonologically acceptable when the misspelled word represented the target phonemes in the correct order (e.g., BLOO for blue) and as phonologically unacceptable when they did not (e.g., BUEL for blue). However, the former misspelling is an error related to a poor MGR, in that the student had requisite orthographic pattern awareness (i.e., “oo” is an allowable way to spell the long “u” sound) but did not have the correct mental image for the particular word. This information was lost (and mislabeled) by using the slightly modified, correct–incorrect scoring metric. Using their modified, correct–incorrect scoring system, Aaron et al. concluded that their older students with HL (5th-12th grade) were not better spellers than the students with typical hearing (fifth grade). Importantly, based on their form of analysis, they concluded that the students did not “use phonology” in spelling although no means of assessing the students' underlying use of phonemic awareness for spelling was used. Hayes et al. (2011) examined the spelling skills of 39 students with HL (6–12 years of age) compared to 39 peers with typical hearing. These researchers analyzed the students’ spellings in a similar manner to Aaron et al. (1998); misspellings were scored as phonologically plausible (e.g., GOSST for ghost) or phonologically implausible (e.g., GHOT or GHOSD for ghost). Again, this scoring provides minimal information regarding a student’s linguistic awareness abilities. In the case of the latter two examples, the GHOT response would suggest a problem with phonemic awareness (not representing all of the phonemes in the word because there is no spelling for the /s/ sound), whereas the second response would represent a problem with orthographic pattern awareness (not only does the letter “d” not represent the /t/ sound but it also does not occur as part of an “s” cluster or blend). The investigators concluded from their analyses that the two groups of students did not differ significantly in their error rates although the students with HL used “phonological spelling strategies” to a lesser extent than their peers with typical hearing. Given the slightly modified, correct–incorrect scoring metric, however, it is not possible to determine whether the two groups differed in the underlying linguistic awareness skills that support spelling ability.

The fact that many researchers tend to focus almost exclusively on the purported phonological inadequacies in the spelling attempts of students with HL is not entirely surprising, for a number of reasons. First, there is a long-standing line of research that suggests that spelling (and reading) development is highly contingent on strong phonemic awareness abilities (e.g., Bruck & Treiman, 1990; Lundberg, Olsson, & Wall, 1980; Sunseth, & Greig Bowers, 2002; Tangel & Blachman, 1992). Given the traditional view of the primary role that phonemic awareness plays in literacy development, it was logical that investigators would devote a great deal of their research efforts to examining the phonological capabilities of students with HL and how they...
used these skills to spell. However, more recent research points to the powerful role of multiple linguistic awareness skills in the development of spelling and other literacy skills (e.g., Apel, Wilson-Fowler, Brimo, & Perrin, 2012; Berninger, Abbott, Nagy, & Carlisle, 2010). With the recognition of multiple linguistic awareness skills contributing to spelling development, researchers should investigate the extent to which students with HL use those skills during spelling.

Second, because of the belief that spelling and other literacy skills rely heavily on phonemic awareness ability, a skill highly dependent on auditory input, researchers assume that students with HL struggle with spelling because of poor phonemic awareness abilities. Whether a traditional system of correct/incorrect is used to score students’ spellings, or a specialized system designed to “capture” deficient phonological errors is used, errors are always assumed to be phonological in nature. However, as noted above, these systems do not necessarily validly measure what they attempt to assess. Further, these narrowly defined scoring metrics do not provide information on the other linguistic awareness abilities students with HL may or may not be using when they are spelling. For example, they fail to determine the orthographic pattern awareness and morphological awareness skills students with HL may be using when spelling, as well as the students’ use, or lack of use, of MGRs. Thus, a more accurate picture of students’ linguistic awareness capabilities cannot be obtained. With a more precise picture of students’ linguistic awareness abilities, researchers would not only have a clearer understanding of students’ strengths and weaknesses, but they would also be better prepared to suggest specific instructional goals and objectives.

### Spelling Sensitivity System

As a means to capture students’ use, or nonuse, of phonemic, orthographic, and morphological awareness, as well as their MGR abilities, during spelling, Masterson and Apel (2010a, 2013) developed the Spelling Sensitivity System (SSS). This scoring system assigns point values to students’ spellings based on whether each element (i.e., a letter/digraph representing a phoneme or the set of letters representing a morpheme) in a target word is spelled correctly or represents an error due to deficiency in MGR knowledge, orthographic or morphological awareness, or phonemic awareness. Masterson and Apel (2010a) have demonstrated that the SSS has specific advantages over the traditional correct–incorrect scoring system, such as providing increased sensitivity to both developmental changes in spelling across an academic year in kindergarten children and specific increases in linguistic knowledge across grades for kindergarten through fifth grade students. Further, Williams and Masterson (2010) found that the SSS revealed linguistic strengths in non-mainstream English speakers that would have been overlooked with a traditional scoring system.

The SSS can be used to analyze spellings of students of all backgrounds, including those with HL. With a clear and complete picture of the linguistic awareness strengths and weaknesses students with HL apply to spelling, researchers will have a better understanding of the factors that may lead to differences in spelling abilities between these students and their peers with typical hearing. Further, education professionals will be better prepared to meet the academic needs of students with HL. When these professionals understand which linguistic awareness abilities contribute to weaknesses in spelling, they will be better prepared to fine-tune their instructional activities to optimize their students’ learning.

In summary, the purpose of this study was to compare the spelling skills of students with and without HL, using the SSS (Masterson & Apel, 2010a, 2013), which yields scoring metrics that reflect the several linguistic awareness skills used to spell words. We were interested in determining not only whether the two groups of students differed in their spelling abilities but also whether they differed in the underlying linguistic awareness skills used to spell words. We were particularly interested in whether the spelling errors of the students with HL were primarily the result of deficient phonemic awareness abilities, as most researchers have supported in the past (e.g., Aaron et al., 1998; Harris & Terlektsi, 2011; Hayes et al., 2011), or whether their errors might be attributed to other linguistic awareness abilities. We chose to target students with HL who were cochlear implant users because larger numbers of children are being implanted each year (e.g., 38,000 children in the United States as of December 2012; National Institute of Child Health and Human Development, 2014). Further, cochlear implants allow children with HL to hear spoken language, making it easier to acquire the connections between speech sounds and their written equivalents (e.g., Hayes et al., 2011). Additionally, there have been few studies of the spelling abilities of students with cochlear implants.

As a secondary aim, we sought to determine whether the scores from the SSS would be associated with the students’ reading abilities. In the past, some researchers have reported moderate to strong relations between the single-word reading and spelling skills of students with HL (e.g., rs ranging from .56 to .88; Harris & Terlektsi, 2011; Kyle & Harris, 2006, 2011). It may be that this association differs depending on the metric used, given that a system based on the multiple linguistic model would provide a wider range of scoring than a simple correct–incorrect model.

### Method

#### Participants

To participate in this study, all students were required to have a signed parental consent form approved by the sponsoring university. Students with HL were recruited from a university speech and hearing center that served clients of all ages and socioeconomic levels, providing services on a sliding fee scale as needed. The students with HL were required to have a congenital, severe to profound HL in at least one ear and to have received a cochlear implant within the first 3 years of life. Students with typical hearing were recruited from a research participant pool maintained by the first author and colleagues. The students without HL had no history of a hearing, speech,
language, or other learning deficit, as reported by the parents. Participant demographic information is provided in Table 1.

Nine students with HL were recruited for the study. The mean age for these students was 8:11 (standard deviation [SD] = 1:10). The group consisted of four females, five Caucasians, and four African-Americans. The children were born with severe (N = 8) or profound (N = 5) HLs and all received at least one if not two (N = 5) cochlear implants before the age of 3. At the time of the study, five students were able to detect sounds within the 10–20 db range; the remaining four children presented with mild HLs. Prior to implantation, the students ranged in their communication modes: three used speech, one used sign language only (signed English), two used a combination of signed English and speech, and four either used no formal system or produced babbling because they were implanted early in life (within the first 12–15 months). At the time of the study, seven used speech as their main mode of communication and three used total communication (speech and signed English). Five of the students were mainstreamed in public education classrooms, four were partially mainstreamed and partially in self-contained classrooms for students with HL, and one was home-schooled.

Nine students with typical hearing also were recruited and matched to the group with HL on sex, race, and reading level. The mean age for the students in the control group was 7:2 (SD = 1:4). This group consisted of four females, four Caucasians, three African-Americans, and two Asian-Americans. All students were enrolled in public education classrooms.

The two groups of students were matched on the Sight Word Efficiency (SWE) subtest of the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999). Specifically, each student with typical hearing was matched to a student with HL based on age equivalency reading score (AE) within 6 months. The average AE score for the HL group was 7.3 months (SD = 1.6), and the average AE score for the hearing group was 7.4 (SD = 1.1). There was no significant difference between these scores, t(13) = 0.22, p = .83; d = .10.

**Measures**

The participants were administered six assessments measuring the following abilities: nonverbal cognition, speech perception, word-level reading and reading comprehension, and spelling. All the assessments were administered individually. Testing was conducted either in the participant’s home or in the university speech and hearing center.

**Nonverbal cognition**

To assess nonverbal cognitive abilities, the participants were administered the Pattern Reasoning subtest of the Kaufman Assessment Battery for Children-II (Kauffman & Kaufman, 2004). The Pattern Reasoning subtest requires students to view a series of pictures or shapes that form a logical pattern but has one item missing and then choose, from amid an array of four to six items, the correct missing item. According to the authors’ manual, internal consistency is .88.

**Speech detection**

The Ling Six Sound Test (Ling & Ling, 1978) was administered to document students’ ability to hear and discriminate speech. The task was chosen because the six sounds (/a/ as in art, /u/ as in who, /i/ as in eat, /m/, “sh,” and /s/) represent low-, mid-, and high-frequency speech sounds and the ability to detect these sounds suggest an ability to detect all speech sounds. The examiner produced each sound at a normal speaking volume behind or beside the student to ensure that the student could not view the examiner’s lips. Students were required to detect a minimum of five of the six sounds on first presentation. All students met criterion.

**Reading**

The students’ word-level reading and reading comprehension skills were assessed. To measure their word-level reading abilities, two subtests of the TOWRE were administered: the SWE subtest, which measures the students’ ability to read real words, and the Phonetic Decoding Efficiency (PDE) subtest, which measures the students’ ability to decode pseudowords. On both subtests, the students were required to read as many words/pseudowords as possible within 45 s. According to the authors’ manual, alternate form reliability is .96. The TOWRE is a measure frequently used with elementary school age children and has been administered to students with HL in previous investigations (e.g., Park et al., 2013, Von Mentzer et al., 2014). As mentioned above, the SWE also served as the mechanism for matching the students with HL and the students with typical hearing.

Reading comprehension was assessed using the Test of Silent Reading Efficiency and Comprehension (TOSREC: Wagner, Torgesen, Rashotte, & Pearson, 2010). With the TOSREC, the students read sentences silently and then mark either yes or no on an answer sheet to indicate whether the sentence is true or false. According to the authors’ manual, alternate form reliability is .91.

**Spelling**

The students’ spelling abilities were assessed using two different metrics. One measure used was the Test of Written Spelling-4 (TWS-4; Larsen, Hammill, & Moats, 1999). Standard procedures were followed when administering this single word, dictation task with the exception that the students with HL were required to repeat the word after the examiner had said the word the second time. If the word the student verbalized appeared to be incorrect, the examiner repeated the word again and requested the student to repeat the word once more. The student then was asked to spell the word. Standard procedures for scoring (correct vs. incorrect) were followed. Raw scores and standard scores were calculated based on standard instructions. The authors’ reported test-retest reliability coefficient for this test is .96.

We also administered a second word list to assess the students’ spelling skills. Students spelled a graded word list consisting of 40–50 words based on his/her grade level as measured by performance on the SWE subtest of the TOWRE. That is, if a student obtained an age equivalency score of second grade, third month on the SWE, then the student was administered the second grade spelling list. Like the TWS-4, each word was presented first, then in a sentence, and then again as a word. Additionally, the procedure for requiring the student to repeat the word after the examiner was followed as well. Items for the graded word

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**Table 1.** Sex and race information for participants in each group

<table>
<thead>
<tr>
<th></th>
<th>Hearing loss</th>
<th>Typical hearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Females</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mean age</td>
<td>8.9</td>
<td>7.1</td>
</tr>
<tr>
<td>White</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>African-American</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

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scores represent the types and amount of underlying sources of linguistic awareness evident in the participant’s spellings. The SSS-E allows credit for individual elements within a word, so it is most sensitive to the types of linguistic knowledge used in the spellings. The SSS-W represents the level of linguistic knowledge reflected in the spelling of the overall word. Whereas it is less sensitive than the SSS-E, it is more indicative of linguistic knowledge than simple correct–incorrect scoring.

Procedures

All measures were administered over two sessions within 2 weeks by graduate students in communication science and disorders trained by the first author. The entire battery took approximately 90 min.

Reliability

Inter-rater agreement on scoring for all measures was calculated on 15% of the sample. Reliability across all the tasks for the sample ranged from 97% to 100%.

Results

The primary aim of this descriptive study was to examine whether students with and without HL differed in their spelling abilities and, specifically, whether they differed in the underlying linguistic awareness skills that support spelling. A secondary aim was to determine the association between reading and spelling skills for the two student groups.

Descriptive statistics for all measures administered, using raw scores, are provided in Table 2. The two groups did not differ significantly in their nonverbal cognitive, word-level reading, or reading comprehension skills (all \( p \) values > .05 and small to moderate effect sizes).

Differences in Spelling Abilities and the Underlying Linguistic Awareness Skills That Support Spelling Ability

**TWS-4 scores**

The mean raw score (i.e., number correct) on the TWS-4 for the students with HL was 4.89 (SD = 4.08), and the average raw score for the students without HL was 9.65 (SD = 5.24). The difference in scores was significantly different, \( t(16) = 2.15, p = .05 \), and it was associated with a large effect size (\( \alpha = 1.01 \)).

**Spelling accuracy on graded word lists**

Spellings for the graded word lists were analyzed via the SSS, which yielded three metrics: (a) number of analyzable words, (b) SSS-W, and (c) SSS-E. Because there were three dependent variables, a Bonferroni adjustment was made (\( .05/3 \)), resulting in an alpha level of .017.

The average number of spellings that were unanalyzable for SSS (i.e., they could not be parsed and aligned with target words) produced by the students with HL was 12.9 (approximately 30%). None of the spellings written by the students without HL were unanalyzable. Examples of misspellings, including an example of an unanalyzable spelling, are presented in Table 3.

Independent sample \( t \) tests were conducted to determine whether there were significant group differences on the spelling metrics used to represent accuracy of the analyzable spellings. The mean SSS-Word score of the students with HL (\( M = 1.27 \)) was lower than the mean SSS-Word score of the students with typical
Table 2. Scores on cognitive and literacy measures for participants in each group

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading age equivalency (in months) on TOWRE SWE</td>
<td>Hearing loss</td>
<td>87.0</td>
<td>18.7</td>
<td>0.22</td>
<td>.83</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>88.7</td>
<td>12.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-ABC-II raw score</td>
<td>Hearing loss</td>
<td>18.33</td>
<td>10.39</td>
<td>0.21</td>
<td>.835</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>17.33</td>
<td>9.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOWRE SWE raw score</td>
<td>Hearing loss</td>
<td>33.1</td>
<td>20.7</td>
<td>0.81</td>
<td>.43</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>40.7</td>
<td>18.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOWRE PDE raw score</td>
<td>Hearing loss</td>
<td>10.3</td>
<td>11.0</td>
<td>0.51</td>
<td>.62</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>13.2</td>
<td>11.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOSREC raw score</td>
<td>Hearing loss</td>
<td>12.6</td>
<td>8.3</td>
<td>0.37</td>
<td>.26</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>17.8</td>
<td>10.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWS-4 raw score (correct/incorrect)</td>
<td>Hearing loss</td>
<td>4.89</td>
<td>4.08</td>
<td>2.15</td>
<td>.05</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>9.67</td>
<td>5.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of unanalyzable spellings</td>
<td>Hearing loss</td>
<td>12.8</td>
<td>11.9</td>
<td>3.22</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spelling Sensitivity Score-Word</td>
<td>Hearing loss</td>
<td>1.27</td>
<td>0.45</td>
<td>2.12</td>
<td>.05</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>1.75</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spelling Sensitivity Score-Element</td>
<td>Hearing loss</td>
<td>2.10</td>
<td>0.35</td>
<td>2.36</td>
<td>.03</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>Typical hearing</td>
<td>2.46</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. SD = standard deviation; TOWRE = Test of Word Reading Efficiency; SWE = Sight Word Efficiency (real words); K-ABC-II = Kaufman Assessment Battery for Children-II; TWS-4 = Test of Written Spelling-4; PDE: Phonetic Decoding Efficiency (nonsense words); TOSREC: Test of Silent Reading Efficiency and Comprehension.

Table 3. Sample spellings with element scores and explanations

<table>
<thead>
<tr>
<th>Target/parsing</th>
<th>Spelling/parsing</th>
<th>Scoring and rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPEALING/a pp ea l ing</td>
<td>APPEALING/a pp ea l ing</td>
<td>All elements are spelled correctly, so each would be given a score of 3</td>
</tr>
<tr>
<td>FEED/f ee d</td>
<td>FEED/f ee d</td>
<td>The f and d are spelled correctly, so they are each given 3. The ee is spelled as ea, which is a plausible way to spell the long e sound (e.g., bed, read), so it is given two points</td>
</tr>
<tr>
<td>BANGED/b a ng ed</td>
<td>BANGED/b a ng ed</td>
<td>The b, a, and ng are spelled correctly, so they are each given a 3. The affix ed is spelled with a d. Regardless of how the sound is pronounced, it not a plausible spelling for the past tense morpheme, so it is given a 1</td>
</tr>
<tr>
<td>CATCH/c a ch</td>
<td>CH/c # h</td>
<td>The c is spelled correctly, so it is given a 3. The ch is not spelled with a plausible spelling, so it is given a 1. The a is not represented with a spelling at all, so it is given a 0</td>
</tr>
<tr>
<td>TABLE</td>
<td>ZZ</td>
<td>Unanalyzable. There is no identifiable relationship between the student’s spelling and any of the elements in the target word. The spelling is classified as unanalyzable, so no SSS codings are assigned</td>
</tr>
</tbody>
</table>

hearing (M = 1.75). Although this difference was not statistically significant, (1, 16) = 2.12, p = .05, it was associated with a large effect size (d = 1.00). Similarly, the mean SSS-Element score of the students with HL (M = 2.10) was lower than the mean SSS-Word score of the students without HL (M = 2.46). Again, the difference was not statistically significant, t(1, 16) = 2.36, p = .03, but it was associated with a large effect size (d = 1.11).

Types of spellings
SSS metrics represent average scores across or within words, and it is possible that collapsing the types of spellings to determine mean scores might mask potential differences between the groups. Consequently, frequencies of each type of spelling (i.e., correct, legal, illegal, and omissions) were calculated for each group. These data, along with expected frequencies, are illustrated in Figure 1. Results indicated that there were group differences in the distribution of spelling types (χ² = 21.9, p < .0001). The students with HL produced more words characterized by omissions and illegal spellings than expected, whereas the students with typical hearing used more legal and correct spellings than expected. Expected frequencies were calculated in the chi-square analysis by multiplying each column total by each row total and dividing the result by the overall total.

Spelling of morphological elements
The SSS metrics represent a system for scoring students’ spellings. As such, there is some flexibility in how the system can be adapted to examine specific linguistic awareness abilities. For example, spellings for target elements are typically scored on a scale of 0–3, with no differentiation between base word elements and morpheme elements. To examine the influence of the students’ morphological awareness specifically, we first compared the groups’ average SSS scores for spelling juncture and affix elements. The average SSS score for junctures spelled by the HL group (1.30) was not significantly different from the average score for junctures spelled by the group with typical hearing (1.67), t(1, 103) = 1.47, p = .144. On the other hand, the average SSS score for affixes spelled by the HL group (1.46) was significantly lower than the average SSS score for affixes spelled by the group with normal hearing (1.98), t(1, 103) = 3.20, p = .002.

Next, we compared the group frequencies of each type of spelling (omitted, illegal, legal, and correct) for target junctures and affixes. The observed frequencies for each group and expected frequencies are illustrated in Figures 2 and 3. There was not a significant group difference on juncture spellings, χ²(3) = 3.09, p = .379. There was a significant group difference on affix spellings, χ²(3) = 11.07, p = .011. Children with HL tended...
to either omit affixes or spell them illegally more often than expected, whereas children with typical hearing tended to spell affixes either legally or correctly more often than expected.

Finally, we examined whether there would be group differences based on morphological complexity (i.e., monomorphemic words vs. multimorphemic words). These potential differences were explored with two 2 (group) by 2 (word status: monomorphemic, multimorphemic) analyses of variance, with the SSS-W serving as dependent variable in the first and the SSS-E as the dependent variable in the second. The interaction between group and word status was not significant for either metric (SSS-W: F(1, 634) = 0.25, p = .618; SSS-E: F(1, 634) = 0.61, p = .436). The main effect for word status was significant for both metrics (SSS-W: F(1, 634) = 87.61, p < .0001; SSS-E: F(1, 634) = 30.73, p < .0001). These findings indicate that there were no group differences in spelling words of differing morphological complexity. Instead, both groups spelled multimorphemic words with less accuracy (mean SSS-W = 0.99, mean SSS-E = 2.15) than monomorphemic words (mean SSS-W = 1.84, mean SSS-E = 2.44).

Analyses of mean and frequency differences regarding accuracy indicated that the children with HL spelled affixes less accurately than did students with typical hearing. However, both groups handled morphological complexity in a similar fashion, with words consisting of more than one morpheme misspelled more often than words consisting of a single morpheme.

**Relation of Reading and Spelling Skills**

Pearson product-moment correlations were conducted to examine the association between reading and spelling skills for both student groups. For the students with HL, the number of unanalyzable words yielded strong, significant correlations with the three measures of reading (all rs above −.75; Table 4). The correlations between nonsense word reading (TOWRE PDE) and the SSS metrics were not significant with the exception of the correlation with SSS-Elements for the group with HL (r = .76). The correlations between real word reading (TOWRE SWE) and the SSS metrics were strong and significant for the children with typical hearing (rs = .83–.84), but not for the children with HL. The correlations between reading comprehension (TOSREC) and both SSS metrics were strong and significant for the children with typical hearing (rs = .76). For the children with HL, both correlations were strong. However, only the correlation between the SSS-E and the TOSREC was significant (r = .81).
As in previous studies (Colombo et al., 2012; Harris & Terlektsi, 2011; Kyle & Harris, 2006, 2011; Sutcliffe et al., 1999), the students with HL demonstrated less advanced spelling abilities than the students with typical hearing despite being matched for word-level reading abilities. Using the traditional correct–incorrect metric of spelling (TWS-4), the students with HL spelled notably fewer words correctly than their counterparts with typical hearing. Similarly, their SSS scores for both the element and word levels were lower than the participants without HL. Although none of these differences reached statistical significance based on the alpha level resulting from the Bonferroni adjustment, all were associated with large effect sizes. The difference between the TWS-4 score and the SSS scores, however, was that the correct/incorrect scoring method revealed only group differences; it did not provide any insight into the nature of the deficient spelling abilities in the students with HL. On the other hand, examination of the frequencies of each type of word spelling (omission, orthographically legal, illegal, and correct) provided information regarding relative strengths and weaknesses of the students with HL (Figure 1). As emphasized in previous research, the students with HL did have relatively more errors related to phonemic awareness limitations (20%) than the students with typical hearing (13%). However, they also had a markedly disproportionate number of misspellings that were due to limitations in their knowledge of spellings patterns for base word and morphological elements. Almost half of their misspellings were considered illegal compared to a little more than one third of the misspellings by students without HL. These findings indicate that students with HL are not only challenged by the components of literacy that are phonologically based, possibly due to their current hearing limitations and/or lack of early hearing exposure. Rather, they also struggle to develop sufficient awareness and use of sound–letter patterns in base words and modifications and spellings associated with the addition of affixes. Indeed, the majority of their errors were the latter type.

There were striking group differences in the number of spellings determined to be unanalyzable. On average, 12.9 of the spellings of the students with HL were unanalyzable, all of the spellings of their peers with typical hearing were similar enough to the targets to allow linguistic comparison. The substantial number of unanalyzable spellings was likely not due directly to the students’ hearing because most students’ current hearing capabilities were within typical limits, and all were required to repeat the word the examiner had said before writing it. Instead, the unanalyzable spellings likely were further examples of poor orthographic pattern awareness; the students had limited abilities for representing the sounds with legal orthographic representations in ways that made scoring their attempts possible.

The fact that the students with HL used appropriate orthographic pattern knowledge and MGRs in their spelling less often than the students with typical hearing is particularly striking because the groups were matched on single-word reading level. The students with HL seem to be using orthographic skills (i.e., MGR abilities, one aspect of orthographic knowledge; Apel, 2011) to a greater degree in single-word reading than in spelling. Our examination of the relationship between the students’ SSS scores and their performance on all of the measures of reading provided additional insight into this mismatch between the two literacy skills. The correlations between the measures of spelling and reading differed slightly between the two groups although both had higher correlations between the reading tasks and the SSS-E score than between the reading measures and the SSS-W score. This finding likely was due to the larger amount of variability in scores per word using the SSS-E than the SSS-W. The greatest group difference was for the correlation between the two SSS metrics and the TOWRE-SWE. For the students with typical hearing, significant and strong associations were found ($r = .83$ and $.84$) However, lower and nonsignificant relations were found for the students with HL ($r = .26$ and $.53$).

### Discussion

As in previous studies (Colombo et al., 2012; Harris & Terlektsi, 2011; Kyle & Harris, 2006, 2011; Sutcliffe et al., 1999), the students with HL were unanalyzable; all of the spellings of their peers with typical hearing were similar enough to the targets to allow linguistic comparison. The substantial number of unanalyzable spellings was likely not due directly to the students’ hearing because most students’ current hearing capabilities were within typical limits, and all were required to repeat the word the examiner had said before writing it. Instead, the unanalyzable spellings likely were further examples of poor orthographic pattern awareness; the students had limited abilities for representing the sounds with legal orthographic representations in ways that made scoring their attempts possible.

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One hypothesis for the disparate correlations between the groups and the mismatch in reading and spelling levels in the HL group may be that the TOWRE-SWE overestimates the sight word vocabulary (MGs) of the students with HL. The TOWRE-SWE, by design, is a recognition task; students must match a printed word to a stored representation of a written word (MGR). That representation does not need to be perfectly formed; it only needs to be well formed enough to match the printed word. Spelling, however, is a generation activity; it requires an individual to produce a word by relying either on a well-formed MGR or using other linguistic awareness skills (i.e., phonemic, orthographic, and/or morphological awareness). Thus, an underdeveloped mental representation (MGR) may allow an individual to recognize (read) a word but not produce (spell) it. It may be that the MGr of the students with typical hearing were well formed which allowed them to both read and spell words at a similar level of competency, thus explaining the strong associations between the TOWRE-SWE and the two SSS metrics. Conversely, the MGs of the students with HL may have been less well formed, leading to adequate performance on the TOWRE-SWE and poorer performance on the spelling task and, thus, a weaker association between the two skills. The cause for the posited less well-formed MGs is unknown. There are some data that suggest young children with HL have less developed print knowledge and concepts about written words (e.g., written word boundaries) compared to their hearing counterparts (e.g., Werfel, Lund, & Schuele, 2014). With less well-developed print knowledge and word boundaries, poorer MGs necessarily would be formed, leading to the potential for adequate word recognition but poor word generation (i.e., spelling). The less well-formed MGs also may be a result of educational practices; that is, it may be instructors emphasize more whole word reading instruction with students with HL, assuming a phonological recoding route might be less productive because of their hearing issues. Such an approach does not promote fully specified MGs because the individual grapheme/phoneme bonding does not occur, leading to an MGR that is not fully specified and robust (e.g., Ehri, 2000; Share, 2004). Regardless of the cause, our findings suggest that the students with HL were demonstrating both poor orthographic awareness and poor MGR knowledge, both aspects of orthographic knowledge (Apel, 2011).

Our study was the first to examine the relation of spelling to reading comprehension in students with HL. For the students with HL, as well as the students with typical hearing, there was a strong and significant correlation between spelling (SSS-E) and reading comprehension. It may be that the specific use of the SSS to measure spelling, which captures students’ overall linguistic awareness abilities, is what led to the strong association between spelling performance and reading comprehension. That is, the SSS captured a level of linguistic ability that also is important for comprehension of text. For example, past researchers have acknowledged the importance of morphological awareness in reading comprehension (e.g., Apel et al., 2012; Carlisle, 2000; Deacon & Kirby, 2004; Kirby et al., 2012). Likewise, strong MGR abilities lead to fluency in reading, which frees up cognitive resources for comprehension of the text (e.g., Apel, 2011). Thus, the SSS appears to be a suitable measure for determining associations of spelling with students’ word- and text-level reading skills.

On our experimental spelling task, the students with typical hearing spelled approximately 40% of the words correctly; the students with HL spelled 34% of the words correctly. Although one could argue that 60% to almost 70% of the words were challenging to the two student groups, we believe the task was useful for allowing us to examine the linguistic awareness strengths and weaknesses the students brought to the act of spelling. Additionally, using the SSS, particularly the SSS-E, we were able to document more than just whether the students were spelling whole words correctly or incorrectly; rather, we were able to establish levels of accuracy at the element level. Finally, the SSS allowed us identify group similarities and differences in spelling words that consisted of more than one morpheme. The groups were similar in their spelling of juncture changes and they both spelled monomorphic words better than they spelled multimorphemic words. However, the group with HL had relatively greater difficulty with spelling affixes than did the group with typical hearing.

Initial Educational Implications

Our findings are preliminary and require replication. However, some initial educational implications of our findings are worth noting. First, our results suggest that students with HL likely need additional instruction in orthographic pattern knowledge. Unfortunately, in most cases, students in the United States, whether they have typical hearing or HL, are “taught” spelling via the “Friday Test” approach (e.g., Graham et al., 2008). Requiring students to memorize words, without any directed, specific, and guided instruction on the orthographic patterns that govern written language, does not encourage learning of those rules and patterns (e.g., Graham & Harris, 2005; Scott, 2000). Instead, educators working with students with HL should consider taking a multilingual approach to educating their students about written language (e.g., Bell, Cron, Jones, & Borneman, 2013; Masterson & Apel, 2010b; Wolter, 2009). With this approach, students are taught all of the linguistic awareness skills (phonemic awareness, orthographic pattern awareness, and morphological awareness) so that they have the tools needed to spell all words. This multilingual approach has shown to impact word-level reading as well (e.g., Wolter, 2009).

Limitations and Suggestions for Future Research

Our spelling analysis allowed us to go beyond identifying that students with HL demonstrate less advanced spelling skills compared to their peers matched; indeed, we were able to identify that the majority of their errors were due to difficulties with orthographic pattern and morphological awareness. Our findings are tempered by several factors. First, our sample was small. Spelling samples from additional students with HL would help confirm the findings from our study. Second, we chose to investigate the spellings of students with HL who had received at least one cochlear implant. This choice was made because of the increasing prevalence of cochlear implants in children with HL. It may be that our results would have differed in children who used other types of amplification (e.g., traditional hearing aids) or those who used no means of amplification. Finally, all of our children were relatively young (mean age of students with HL was 8.9). It may be that a different pattern of results would occur with slightly older students who had additional life and educational experiences.

In summary, our findings suggest that students with HL who were recipients of cochlear implants, though matched for reading age to peers with typical hearing, demonstrate less well-developed spelling abilities than their counterparts. These spelling difficulties appear to be largely due to difficulties in orthographic pattern and morphological awareness. The spelling abilities of the students with HL are related to their
pseudoword word-level reading and reading comprehension skills. In the future, with additional investigations using a similar approach to spelling analysis that captures the underlying causes for spelling errors, researchers will better understand the linguistic awareness abilities that students with HL bring to the task of reading and spelling.

Conflicts of Interest
No conflicts of interest were reported.

References


