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A Multilingual Spelling Analysis of Children who are Hard of Hearing

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Abstract

Spelling in writing samples was compared between children who are hard of hearing (HH) ($n = 142$) and their peers with typical hearing (TH) ($n = 72$) in second and fourth grade. The same analyses were then conducted comparing groups of children who are HH with different levels of aided audibility. Compared to children with TH, children who are HH produced fewer misspelled words ($p = .041$, $d = .42$) at second grade but performed similarly in fourth grade ($p = .943$, $d = .02$). Compared to peers with TH, children who are HH demonstrated similar distributions of errors in roots but some differences in the distribution of errors for affixes. Different levels of aided audibility among children who are HH were not associated with significant differences in spelling accuracy at both grades. However, second-grade children with poorer aided audibility produced significantly more phonological omissions ($p = .005$, $r = .32$) and orthographic consonant errors for monomorphemic words ($p = .001$, $r = .37$), as well as more orthographic consonant errors for and affixes ($p = .015$, $r = .28$).

Although a growing body of literature has documented difficulties with spoken language among children with mild to severe hearing loss (Koehlinger et al., 2013; Tomblin et al., 2015a), much less is understood about their written language skills, such as spelling. Spelling is important because it supports the development of reading comprehension and written composition skills (Apel, 2009; Berninger & Fayol, 2008). The connection between profound hearing loss and spelling difficulties has been well-documented (Apel & Masterson, 2015; Bowers et al., 2016; Hayes et al., 2011). The little that is known about spelling in children with permanent mild to severe hearing loss, referred to collectively here as children who are hard of hearing (HH), suggests that they may also have difficulties (Park et al., 2013).

Contemporary, multilingual views of spelling suggest that even beginning spellers bring multiple forms of linguistic awareness to the task of spelling (Bourassa & Treiman, 2013; Wolter & Squires, 2013). One of these language-based views of spelling is reflected in Triple Word Form Theory (Berninger et al., 2006). Based on brain imaging (Richards et al., 2006) and behavioral

studies (Berninger et al., 2010), Triple Word Form Theory purports that spellers integrate phonological, orthographic, and morphological awareness from the earliest stages of development.

Phonological awareness is the awareness of and the ability to manipulate the sound structure of a language (Stahl & Murray, 1994), which contributes to successful phoneme to grapheme encoding (Bourassa & Treiman, 2013). Orthographic awareness includes the word spellings stored in long-term memory (i.e., mental graphemic representations), spelling rules for translating phonemes to graphemes (i.e., orthographic pattern knowledge), as well as positional constraints of phonemes to graphemes (i.e., orthotactic principles) (Apel, 2011). Orthographic awareness facilitates spellers' use of the quick-access route of mental graphemic representations for words that are well-constructed in memory and the use of statistical patterns when spelling unfamiliar words (Apel, 2011; Deacon et al., 2012). Morphological awareness is the graphemic representation of morphemes, including the rules for adding affixes to base words and how they change the meaning (Apel, 2014), and it provides additional

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information regarding statistically predictable patterns to facilitate systematic storage and retrieval (Berninger et al., 2008; Deacon, 2008). For example, morphological awareness facilitates recognition of words that share the same base (e.g., autograph, graphic, and orthography) (Masterson & Apel, 2010a), as well as how to represent sounds in morphemes (e.g., “c” for “magician” and “t” “connection” in complex words but “sh” in “fish” or “ss” in “mission” for single morpheme words) (Deacon et al., 2009).

All children with hearing loss receive degraded or restricted linguistic input due to the effects of sensorineural hearing loss, noise, and reverberation (Delage & Tuller, 2007). The limited access hypothesis proposes that reduced auditory access to quantity or quality of input results in a reduction in cumulative spoken language experiences, thereby limiting the potential for uptake and acquisition of language (Moeller & Tomblin, 2015). In extending this theory to spelling achievement, it is proposed that inconsistent or restricted access puts children who are HH at long-term risk for difficulties in linguistic areas undergirding spelling; children who are HH have been reported to have difficulties with phonological (Gibbs, 2004; Park & Lombardino, 2012), orthographic (Halliday & Bishop, 2005; Most et al., 2006), and morphological awareness (Koehlinger et al., 2013; Moeller et al., 2010). These deficits may have cascading effects, with some children who are HH struggling to effectively draw upon and integrate those domains when spelling words (Park et al., 2013). Given the difference in degree of reduced or degraded access among children who are HH relative to peers with typical hearing (TH) or more profound hearing loss, there may also be differences in spelling performance between these three groups.

Linguistic Influences on the Spelling Errors of Children with Hearing Loss

Despite the growing body of research regarding the multilingual contributions to spelling among children with TH, very little is known about the influence of these linguistic sources of knowledge on spelling errors among groups of children who are HH relative to children with TH. Most studies examining categories of linguistic errors have exclusively or primarily included children with profound degrees of hearing loss. These studies suggest that children with hearing loss may have weaknesses in linguistic awareness when spelling words.

Weaknesses in the domain of phonological awareness have been observed, with studies documenting that children who are deaf produce fewer phonologically plausible errors than their peers with TH (Hayes et al., 2011; Olson & Caramazza, 2004). In the domain of orthographic awareness, no significant differences in the use of transpositions have been reported (Hayes et al., 2011), but studies of children with cochlear implants have reported fewer homophone substitutions (Quick et al., 2019), more illegal orthographic errors (i.e., unallowable sequences in written English such as “mnat” or “ltp”), and more omissions (Apel & Masterson, 2015). Morphological awareness may also be weaker, as children with cochlear implants have been reported to more frequently omit affixes or spell them illegally (Apel & Masterson, 2015).

Quick and colleagues (2019) examined the spelling of children with cochlear implants ($n = 9$) and separately compared their errors to children who are HH ($n = 9$) and children with TH ($n = 9$) using a multilingual analytic framework. When compared to children with TH, early implanted children with cochlear implants who use spoken language produced significantly fewer orthographic and morphological errors of certain types,

which suggests that children with cochlear implants may use orthographic and morphological information due to strengths in visuo-graphic skills in order to compensate for difficulties in phonological coding that result from restrictions in auditory access. When compared to children who are HH, there were no significant differences in the errors made by children with cochlear implants in this small sample, suggesting that children with any degree of “unaided” hearing loss may use similar linguistic strategies when attempting to spell unknown or less familiar words.

Spelling Error Analysis Approaches and Contexts

Spelling Error Analysis Approaches

There are several spelling error analytic approaches that are informed by a multilingual understanding of spelling, including Multiple Linguistic Coding (MLC; Apel & Masterson, 2001; Bowers et al., 2014), Spelling Sensitivity Score (SSS; Masterson & Apel, 2010b), The Phonological, Orthographic, and Morphological Assessment of Spelling (Bahr et al., 2012; Silliman et al., 2006), POMplexity (Bahr et al., 2020; Benson-Goldberg, 2014), and POMplexity for Roots and Affixes (Quick & Erickson, 2018; Quick et al., 2019). All of these tools infer children’s linguistic knowledge or strategies from their spelling errors (Devonshire & Fluck, 2010), but they vary in their approach. The present study uses the POMplexity for Roots and Affixes, and the rationale for selecting this tool for children who are HH follows.

The POMplexity for Roots and Affixes is based on Triple Word Form Theory (Richards et al., 2009), as are other analytic approaches (e.g., POMAS, POMplexity) and spelling assessments (e.g., Daffern et al., 2015). As spelling errors can involve the application or misapplication of multiple domains of language (Silliman et al., 2006), several approaches allow multiple error codes (e.g., MLC, POMplexity, POMAS). The POMplexity for Roots and Affixes is the only error analysis approach that concurrently describes the phonological, orthographic, and morphological linguistic features for each morpheme of a misspelled word. Given that children who are HH may have weaknesses in all three domains, this unique feature of the POMplexity for Roots and Affixes allows for patterns of strengths and weaknesses to be compared across linguistic domains (Quick & Erickson, 2018).

The unit of analysis varies among multilingual approaches to spelling error analysis. Several approaches code errors at the word level (e.g., MLC, POMAS, POMplexity), while the SSS parses words into three units of analysis, including phonemes, junctures, and affixes. The POMplexity for Roots and Affixes uses the morpheme as the unit of analysis for both roots and affixes. This approach is theoretically based on research that suggests that complex words are organized morphemically in the mental lexicon (Richards et al., 2006; Taft & Nguyen-Hoan, 2010), and that the mental lexicon segmentation into bases and affixes may further support segmentation into sound and letter sequences (Richards et al., 2006). Given that the present study uses writing samples rather than a controlled list of words, this framework allows for uniformity of analysis across morphologically simple and complex words.

In the domain of phonology, POMplexity for Roots and Affixes has five categories of description, expanding upon binary approaches of phonologically plausible and implausible (i.e., plausible, substitution, addition, omission, and multiple). Given that children with hearing loss have more difficulties

with phonological awareness and produce fewer phonologically plausible misspellings (Hayes et al., 2011; Olson & Caramazza, 2004), this level of phonological description may be beneficial in capturing further information about the phonological implausibility of their misspellings. In the domain of orthography, The POMplexity for Roots and Affixes expands upon binary approaches of legal and illegal spellings, by separating legal errors into vowel, consonant and combined vowel/consonant errors. Given the acoustic differences in the frequencies and intensities of vowels and consonants and the implication for hearing loss, it was reasoned that it might be helpful to have information about the ability of children who are HH to represent each of these elements. The POMplexity for Roots and Affixes also includes more morphological descriptors by including a combination of codes from across approaches, including morphologically plausible errors (e.g., incorrect suffix modification with the MLC), homophone substitutions (e.g., POMplexity, POMAS), and omissions (e.g., MLC, SSS, POMplexity). Given the difficulties children who are HH have with morphological awareness and affixes in particular, the POMplexity for Roots and Affixes potentially enables rich insight into whether or not affixes are encoded, the quality of the phonological encoding, and whether visuographic strengths among children who are HH lead to different applications of orthographic and morphological knowledge.

For example, if the single morpheme word “peace” is misspelled “piece,” it would be scored as follows: (a) phonology—plausible, (b) orthography—legal vowel error, and (c) morphology—homophone substitution. Together these errors suggest that the speller is attempting to integrate all forms of linguistic awareness in this word, although imperfectly. If the two-morpheme word “walked” was misspelled “walktt,” it would first be assessed for accuracy at the level of the morpheme. The root “walk” would be scored as correct and the affix “ed” would be scored as incorrect. Then the misspelled affix would be described with three linguistic codes: phonologically plausible, illegal orthographic error, and non-morpheme substitution. Together these errors suggest that phonological awareness is informing this spelling, but that there are weaknesses in both orthographic and morphological awareness. Appendix A1 provides additional examples of phonological, orthographic, and morphological errors for both roots and affixes, and further details regarding administration and scoring can be found in Quick and Erickson (2018). Appendix A2 provides scoring examples of misspelled words.

Spelling Assessment Contexts

Spelling assessments are most often administered by dictating words within a sentence context. Dictated word spelling tasks are effective for evaluating children’s spelling skills relative to specific aspects of the spelling system (Kohnen et al., 2009). In writing samples, children can select the words they write and potentially avoid “difficult” words (Apel & Masterson, 2001), which may reduce the number of misspelled words compared to dictation tasks. However, the words children choose to write while generating writing samples must be spelled while simultaneously engaging in linguistic planning, execution, cohesion, and monitoring. Therefore, writing samples are valuable in addition to controlled tasks for developing a comprehensive profile of spelling ability (Hammond, 2004). Writing samples can offer unique insight into a speller’s accuracy and integration of linguistic knowledge when spelling words during tasks that are more representative of real-life literacy.

A few studies of spelling among children with hearing loss have examined spelling in writing samples. Straley et al. (2016) reported that the most common spelling errors of children with cochlear implants included incorrect spellings with all sounds represented and incorrect spellings with not all sounds represented. Children’s spelling performance in stories was also highly related to their performance in single word tasks. Bowers et al. (2016) reported that the types of spelling errors made by middle school students who are deaf and HH remained stable over the course of a year. There was a high percentage of phonological awareness errors, a smaller percentage of orthographic pattern awareness errors, and a small number of mental graphemic errors.

Auditory Access and Spelling

A more nuanced understanding of the role of auditory access may assist in identifying which children may be at increased risk for spelling challenges. Traditionally, the degree of unaided hearing has been used to investigate the influence of auditory access on language skills. For example, Unaided Pure Tone Averages (500 Hz, 1KHz, 2 KHz, 4 KHz) were reported to be negatively correlated with spelling performance among children with mild to moderate hearing loss (Park et al., 2013). However, if one assumes consistent hearing aid use, then it is of interest whether well-fit hearing aids moderate this threat, as has been reported with other language skills (Tomblin et al., 2015a). In that case, aided audibility measures that assess the level of access to the speech spectrum provided by hearing aids may provide more information. In fact, better aided audibility has been associated with better global language outcomes, grammatical abilities, and rates of language growth among children who are HH (Koehlinger et al., 2013; Tomblin et al., 2015a). Thus, it is logical to assume that better aided audibility would be associated with improved spelling.

Summary and Purpose

According to Triple Word Form Theory, spelling builds on multiple domains of linguistic awareness, such as phonological, orthographic, and morphological awareness. Additional studies are needed to determine if children who are HH demonstrate difficulties spelling and whether those difficulties can be attributed to potential difficulties integrating specific forms of linguistic knowledge in ways similar to, or different from, those with more profound degrees of hearing loss. Previous studies have examined the spelling accuracy of children who are HH compared to peers with TH in word tasks (Park et al., 2013), or the spelling errors of children who are HH have been compared to peers with CIs in writing samples (Quick et al., 2019), but the sample sizes were small. While the influence of unaided hearing has been examined (Park et al., 2013), no studies have investigated if differences in the levels of auditory access influences spelling performance. The primary purpose of this study was to examine these assumptions by comparing the spelling errors in writing samples of children who are HH to children with TH, using a multilingual analysis framework that will be used to infer linguistic knowledge informing spelling in these groups. The research questions were as follows:

1. Do children who are HH differ from children with TH in the percentage of total spelling errors they produce at second or fourth grade?

2. Do children who are HH differ from children with TH in the distribution of categorical spelling errors at second or fourth grade?
3. Do children who are HH with different levels of aided audibility differ in the percentage of total spelling errors or in the distribution of categorical spelling errors at second or fourth grade?

Given the limited access hypothesis, it is anticipated that children who are HH will have a higher percentage of spelling errors than their peers with TH, and children who are HH with poorer aided audibility will have a higher percentage of spelling errors than children who are HH with better aided audibility. Based on the existing spelling literature among students with more profound degrees of hearing loss, it is expected that children who are HH will have significantly more errors with more weaknesses across linguistic domains than children with TH, and children who are HH with poorer aided audibility will have significantly more errors with more weaknesses across linguistic domains than children who are HH with better aided audibility.

Methods

Participants

The 214 participants in this study included 142 children who are HH and 72 children with TH. All were assessed from 2013 to 2016 as part of a larger, ongoing, multisite longitudinal study, Outcomes of School-Age Children who are Hard of Hearing (OSACHH). Data were collected from participants during their second and/or fourth grade years. For the 134 participants who were assessed at both grades, data from one grade was randomly selected for use in the current study, resulting in 141 second graders (88 who are HH) and 73 fourth graders (54 who are HH). Participants were reported to have no significant motor or cognitive disabilities (Tomblin et al., 2015b), and English was the primary language of at least one parent. The participants ranged in age from 7.74 to 11.08 years, with an average age of 9.14 ($SD = .96$). The participants with TH passed a hearing screening at either 15 or 20 dB HL at octave frequencies from 250 to 8,000 Hz, whereas wearing insert earphones or supra-aural headphones.

The 142 participants who are HH had bilateral sensorineural or permanent conductive hearing loss and used spoken English. Audiometric thresholds for participants who are HH were obtained using conventional audiometry or conventional with video reinforcement and insert earphones or supra-aural headphones. The mean 4-frequency better-ear pure tone average (BE-PTA) for the participants who are HH ranged from 11.25 dB HL through 90 dB HL ($M = 46.07$, $SD = 15.08$). Among the children who are HH, 35.9% ($n = 51$) had a mild hearing loss, 39.4% ($n = 56$) a moderate hearing loss, and 20.4% ($n = 29$) a moderately severe hearing loss, and 4.2% ($n = 6$) a severe hearing loss. All but six of the participants who are HH wore hearing aids at the time of data collection. Among participants who are HH with reported data ($n = 132$), the mean age of identification was 10.6 months ($SD 18.7$) and the mean age at which they were fitted with hearing aids was 20.8 months ($SD 21.3$). Selected demographics of the participants are reported in Table 1. Importantly, there were no significant differences in maternal education across subgroups at second [$\chi^2(3) = 3.702$, $p = .295$] or fourth [$\chi^2(3) = 2.707$, $p = .439$] grade.

In the current study, 9 of the 142 participants who are HH and 9 of the 72 participants with TH were included in a previous

pilot study evaluating the spelling of participants with cochlear implants which compared their performance to participants with TH and participants who are HH (Quick et al., 2019). The current study employed the same measures, procedures, and analyses as reported by Quick and colleagues, but the current study compared a much larger group of participants who are HH with participants who have TH and compared the performance of the participants who are HH across different levels of aided audibility.

Measures

The participants' reading abilities were examined with the Gray Oral Reading Tests-5 (GORT; Wiederholt & Bryant, 1992), which was included in the test battery of the OSACHH study. The fluency score reflects the child's ability to read a passage orally and includes the child's performance on the accuracy of word decoding as well as the speed of reading. The comprehension subtest on the GORT-5 measures a child's ability to answer comprehension questions after reading a passage. Given that significant differences in reading could impact word selection and spelling performance, this measure was included to ensure that any group differences in spelling were not the result of differences in overall reading ability.

The writing samples subtest of the Woodcock-Johnson III tests of Achievement, (WJ-III; Woodcock et al., 2001) was also administered in the test battery of the OSACHH study. This subtest is designed to measure a child's ability to write words and sentences when provided a verbal and picture cue (e.g., "Write a good sentence that describes what the girl is doing."). Given the fact that basal and ceiling rules were administered according to the test manual, the writing sample content varied across participants.

POMplexity for Roots and Affixes is an error analysis approach that separately analyzes the phonological, orthographic, and morphological categorical errors of each misspelled word (Quick & Erickson, 2018). This efficient error-analytic approach has been shown to identify differences in spelling profiles of monomorphemic and multimorphemic words among children with TH (Quick & Erickson 2018), as well as children with hearing loss (Quick et al., 2019).

Procedures

The writing samples were first transcribed and analyzed using Systematic Analysis of Language Transcripts (SALT 2012 Research Version; Miller & Iglesias, 2012) in order to describe the overall quality of the writing samples using conventional SALT procedures. Given that language-based differences in writing samples could impact spelling performance, a language analysis was included to ensure that any group differences in spelling were not the result of differences in the length, grammatical complexity, or word variety between the two groups. Words that could not be identified due to handwriting or spelling errors ($n = 136/20,790$, .006%) were removed from further analysis. Each correct or misspelled word was coded as monomorphemic (e.g., "bird," "umbrella"), compound/contracted (e.g., "baseball," "can't"), inflected (e.g., "shopping," "girls"), or derived (e.g., "healthy," "thankful").

The U-Score reported in the Educators' Word Frequency Guide (Zeno et al., 1995), an indicator of both the frequency and dispersion of the word in primary and secondary academic textbooks, was determined for each word. This measure was included as a proxy for level of difficulty of words that children

Table 1. Demographics of participants and their families as a percentage of the sample in each grade

Grade	Characteristic ^a		HH	TH
			n (%)	n (%)
Second	Gender	Male	46 (32.6)	25 (17.7)
		Female	42 (29.8)	28 (19.9)
	Mother's education	High School	12 (8.7)	11 (8.0)
		Some college	23 (16.7)	7 (5.1)
		Bachelor	26 (18.8)	16 (11.6)
		Graduate	26 (18.8)	17 (12.3)
	Race	Asian	1 (.7)	1 (.7)
		Black	4 (2.9)	4 (2.9)
		Hispanic	1 (.7)	0 (0)
		Native American	1 (.7)	0 (0)
		Multiracial/other	6 (4.4)	5 (3.6)
		White	73 (52.5)	42 (30.2)
Fourth	Gender	Male	29 (39.7)	7 (9.6)
		Female	25 (34.2)	12 (16.4)
	Mother's education	High School	10 (14.3)	1 (1.4)
		Some college	12 (17.1)	3 (4.3)
		Bachelor	17 (24.3)	8 (11.4)
		Graduate	13 (18.6)	6 (8.6)
	Race	Asian	1 (1.4)	1 (1.4)
		Black	2 (2.7)	1 (1.4)
		Hispanic	3 (4.1)	0 (0)
		Native American	0 (0)	0 (0)
		Multiracial/other	4 (5.5)	2 (2.8)
		White	44 (60.3)	15 (20.5)

^aMother's education was not reported for three children who are HH and three children with TH. Race was not reported for two children who are HH.
Note: HH = hard of hearing; TH = typical hearing.

chose to write. As more difficult words are more likely to be misspelled, it was important to ensure that any group differences in spelling were not the result group differences in the difficulty of words children chose to spell. Finally, each misspelled word was coded for spelling errors using POMplexity for Roots and Affixes (Quick & Erickson, 2018).

Scoring POMplexity for Roots and Affixes

Scoring with POMplexity for Roots and Affixes begins by identifying all misspelled words in the writing sample, parsing them into separate morphemes, and scoring each morpheme as correct or incorrect. Incorrectly spelled morphemes are analyzed three separate times in the domains of phonology, orthography, and morphology. Each misspelled morpheme is assigned one of five categorical errors in each of the three domains: (a) phonology (plausible error, single substitution, single omission, single addition, and multiple errors), (b) orthography (minor error, legal vowel error/s, legal consonant error/s, legal vowel and consonant errors, illegal error/s), and (c) morphology (plausible error, homophone substitution, morpheme substitution, non-morpheme substitution, and omission). For the purposes of analysis, morphemes were grouped into monomorphemic roots (e.g., single morpheme words, both morphemes of compound words, both morphemes of contracted words), multimorphemic roots (e.g., inflected and derived words), or affixes (e.g., inflectional affixes, prefixes, and suffixes).

Interobserver Agreement

The first author transcribed and coded all of the data. The first author trained two undergraduate secondary coders in standard

SALT conventions, and three graduate secondary coders in the POMplexity for Roots and Affixes. The first author and secondary coders were blind to the hearing status of the children. Krippendorff's alpha test (Hayes & Krippendorff, 2007) was used to estimate interobserver agreement between the first author and each of the secondary coders for all measures. After calculating Krippendorff's alpha between the first author and each trained coder, the arithmetic mean was computed across all author-coder pairs.

Interobserver agreement for the SALT measures was calculated for 39% of the samples ($n = 110$) between the first author and secondary coders. Krippendorff's alpha showed high interobserver agreement for all SALT measures (T-Units, MLU-M, NDW, NTW, TTR) ($\alpha = .93-.99$), with the exception of the subordination index (SI; $\alpha = .76$). Determining interrater agreement for the spelling analysis occurred in two stages. First, the first author and secondary coders separately coded the intended word, spelling accuracy, and morphological word type of every word in 32% ($n = 90$) of the writing samples. The mean percentage of agreement for the intended word, spelling accuracy, and morphological word type was .98 ($\alpha = .96-1.0$). Next, the first author and secondary coders separately coded each misspelled word within the same writing samples using the POMplexity for Roots and Affixes. Krippendorff's alpha was computed across all scoring domains (phonology, orthography, and morphology) and found to be high ($\alpha = .92-.94$, $M = .93$). Consensus coding was used to resolve disagreements.

Aided Audibility Groupings

Aided audibility was measured using the better-ear average Speech Intelligibility Index (SII), which describes the proportion

Figure 1. Histogram of better-ear average speech intelligibility index of children with hearing loss.

of the amplified speech spectrum that is audible to children who are HH when wearing their hearing aids. Audioscan Verifit software was used to calculate aided audibility for stimuli presented at 65 dB and based on the SII (American National Standards Institute S3.5–1997, R2007). To calculate SII, the speech spectrum was divided into frequency bands that were weighted based on each band's contribution to speech intelligibility. The weighted amounts from each band were then summed. SII is reported on a scale from 0 to 1, with 0 indicating the entire speech spectrum is inaudible and 1 denoting the entire speech spectrum as completely audible (for additional details see [McCreery et al., 2015](#)). The average SII was measured for 122 of the 142 children who are HH and is presented in [Figure 1](#). Given the complexities of the dataset and visual inspection of the negatively skewed SII data, a median split of the SII was used to create equivalent groups ([DeCoster et al., 2011](#)). The median better-ear SII ($Mdn = .822$) was used to divide this subset of children who are HH into “low” (.291–.822) and “high” (.823–.983) aided audibility groups. At second grade this resulted in 42 children with low and 34 children with high aided audibility, and at fourth grade this resulted in 19 children with low and 27 children with high aided audibility.

Relative Percentage Calculations

Frequency counts of categorical errors among each morpheme group (monomorphemic roots, multimorphemic roots, affixes) were calculated and then standardized by the total number of misspelled words within each morpheme group to be represented as percentages.

Statistical Comparisons and Significance

Statistical analyses were completed using IBM SPSS Statistics version 24.0 for Mac. Although sample sizes were unequal,

all data were retained. Independent samples *t* tests were used to examine group equivalence. Mann-Whitney tests were employed to examine group comparisons of the proportion of categorical errors within each linguistic domain due to the fact that the approach is robust when data deviate substantially from normality, include multiple outliers, and result in unequal sample sizes ([Mann & Whitney, 1947](#)). As this is the first analysis of categorical spelling errors among participants who are HH, all results that achieved a .050 significance level in the absence of adjustments for multiple testing were preserved because the current study is exploratory and the use of adjustments increases the possibility of overlooking important and meaningful results ([Rothman, 1990](#)). However, results that survived a Holm–Bonferroni Sequential Correction for multiple comparisons are separately noted in the narrative and tables so that future studies can evaluate the scientific strength of all results. Given that the POMplexity for Roots and Affixes uses multiple categorical codes across three categorical domains, the nature of the data did not allow the statistical analysis to account for multiple codings across linguistic domains. Therefore, the results of the analyses should be considered with this limitation in mind.

Results

Descriptive Statistics of Entire Sample

A total of 20,790 words were analyzed, including 1,873 misspelled words. Individual writing samples ranged from 3 to 313 words ($Mdn = 94$), whereas the number of errors ranged from 0 to 41 ($Mdn = 7$). On average, the participants' writing samples were comprised of the following distribution of morphological word types: 88% monomorphemic words (e.g., bat), 2% compound

Table 2. Percentage of categorical errors in each morpheme group according to domain, grade, and hearing status

Domain	Error	Hearing Status	Second grade			Fourth grade		
			Monomorph	Multimorph	Affixes ^a	Monomorph	Multimorph	Affixes ^b
Phonology	Plausible	HH	56.4	55.6	41.5	65.8	69.5	41.3
		NH	60.5	60.3	56.4	68.8	73.5	62.1
	Substitution	HH	19.5	11.8	5.3	15.8	9.9	10.7
		NH	19.4	12.6	13.3	15.8	9.6	9.1
	Omission	HH	15.2	15.0	5.6	11.2	13.8	10.1
		NH	11.0	13.0	5.2	12.8	4.9	0
	Addition	HH	2.9	5.2	3.1	1.5	2.7	0
		NH	5.0	4.1	0	0	10.4	0
	Multiple	HH	6.1	12.5	44.5	5.8	4.2	37.8
		NH	4.1	10.1	25.3	8.4	1.6	28.8
Orthography	Minor	HH	25.3	5.7	13.9	44.4	12.9	21.1
		NH	25.7	3.8	13.3	37.2	5.2	27.3
	Vowel	HH	34.2	24.5	29.0	23.1	42.5	16.7
		NH	31.5	35.6	36.0	39.3	41.4	25.8
	Consonant	HH	23.6	42.2	4.9	23.9	37.2	19.6
		NH	23.7	33.9	14.3	20.2	28.2	9.1
	V&C	HH	13.1	23.0	7.7	6.7	5.3	4.8
		NH	12.9	22.3	13.4	3.0	23.1	0
	Illegal	HH	3.8	4.6	11.7	1.8	2.1	16.8
		NH	6.2	4.5	10.9	.3	2.1	22.7
Morphology	Plausible	HH	19.0	16.4	9.8	29.2	31.2	6.5
		NH	16.1	14.3	10.9	23.1	6.8	9.1
	Homophone	HH	13.8	.5	11.8	19.7	.3	17.6
		NH	15.3	.1	12.5	19.3	0	27.3
	Morpheme	HH	17.6	5.8	15.3	19.1	.8	16.7
		NH	14.7	4.0	26.7	20.9	3.3	16.7
	Non-morpheme	HH	49.4	77.0	19.6	31.4	67.6	21.4
		NH	54.0	80.3	26.1	36.8	89.9	9.1
	Omitted	HH	–	–	43.4	–	–	37.8
		NH	–	–	23.7	–	–	37.9

Note. Monomorph = monomorphemic roots; Multimorph = multimorphemic roots; V&C = vowel and consonant error; HH = hard of hearing; TH = typical hearing. ^{a,b}The percent of categorical errors does not equal 100% in phonology and orthography because omitted affixes were excluded from phonological and orthographic analysis.

words (e.g., baseball), 9% inflected words (e.g., running), and 1% derived words (e.g., player). In examining spelling accuracy, the participants averaged 93% accuracy on monomorphemic words, 63% accuracy on compound words, 64% accuracy on inflected words, and 50% accuracy on derived words.

Based on frequency of occurrence, a similar ranking order of categorical errors was observed across morpheme categories, regardless of hearing status (see Table 2). The most frequent categorical errors in phonology included plausible errors, while additions and multiple phonological errors rarely occurred. In the domain of orthography, legal orthographic errors accounted for nearly 2/3 of all errors, while minor or illegal orthographic errors were less frequent. The most frequent morphological error, accounting for approximately half of the monomorphemic and multimorphemic root errors, were non-morpheme substitutions. Among affixes, the two groups differed in the rank order of categorical errors. Omitted morphemes comprised the most frequent morphological error among participants who are HH, but only the third most frequent for participants with TH.

Comparison of Participants Who are HH and Who Have TH

Prior to comparing groups, the equivalence of reading ability, quality of writing samples, and the frequency and dispersion

of words written were examined between participants who are and are not HH. As reported in Table 3, independent samples *t* tests were used to compare the GORT comprehension and fluency scores, multiple lexical and syntactic measures of the writing samples generated by SALT, and the average U-score of the words in the writing samples. Participants who are HH and participants with TH demonstrated similar performance across all measures, and at the second and fourth grade there were no significant group differences as measured by *t* tests. These indicators of group equivalence strengthen the conclusions that any differences in the distributions of categorical spelling errors associated with hearing status reported in the current investigation are not related to differences in reading ability, the overall quality of the writing samples, or the frequency and dispersion of the words that participants included in their samples.

For second graders, the mean percentage of spelling errors across all words was significantly lower among participants who are HH ($M = .12 \pm .09$) than among participants with TH ($M = .16 \pm .13$) [$t(139) = -2.062, p = .041, d = .42$]. For fourth graders, the mean percentage of spelling errors across all words was not significantly different between participants who are HH ($M = .06 \pm .06$) and participants with TH ($M = .06 \pm .04$) [$t(71) = -2.062, p = .943, d = .02$].

As reported in Table 4, Mann–Whitney analyses were used to compare the percentage of categorical spelling errors made

Table 3. Measures of reading, as well as lexical and syntactical quantity and quality of writing samples according to hearing status and grade

		HH ^a		TH		df	t	Sig	d
		M	SD	M	SD				
Second grade									
Measure									
GORT	Fluency	97.75	13.06	95.28	12.99	138	.204	.838	.19
	Comp	95.23	12.73	96.42	12.42	138	-.539	.591	.09
SALT	T-units	14.31	4.25	15.02	5.37	139	-.871	.385	.15
	MLU-M	5.79	1.79	5.74	1.76	139	.125	.900	.03
	NDW	53.55	23.40	56.38	27.52	139	-.651	.516	.11
	NTW	79.58	39.36	83.68	46.28	139	-.560	.576	.10
	TTR	.69	.07	.70	.07	139	-.225	.823	.14
	SI	1.01	.25	1.02	.31	139	-.334	.739	.04
U-score		11,278	2,551	10,430	2,368	139	1.962	.052	.34
Fourth grade									
Measure									
GORT	Fluency	93.40	12.04	95.53	11.89	70	-.664	.509	.18
	Comp	94.25	12.50	99.21	13.36	70	-1.459	.149	.39
SALT	T-units	17.50	5.59	17.37	4.5	71	.092	.927	.02
	MLU-M	7.87	2.03	7.75	1.76	71	.234	.816	.06
	NDW	83.76	31.52	83.74	25.48	71	.003	.998	.00
	NTW	129.41	55.99	124.05	44.55	71	.376	.708	.10
	TTR	.66	.05	.69	.06	71	-1.902	.061	.57
	SI	1.13	.15	1.11	.14	71	.325	.746	.14
U-score		10,986	1,785	10,370	1,438	71	1.354	.180	.36

^aGORT was not administered to one second grade child who is HH and one fourth grade child who is HH.

Note. HH = hard of hearing; TH = typical hearing; Comp = comprehension; MLU-M = mean length of utterance in morphemes; MLU-W = mean length of utterance in words; NDW = number of different words; NTW = number of total words; TTR = type token ratio; SI = subordination index; GORT = Gray Oral Reading Test; SALT = Systematic Analysis of Language Transcripts.

by participants who are and are not HH at second grade. There were no significant differences in the percentage of categorical errors based on hearing status for monomorphemic roots. For multimorphemic roots, only the percentage of orthographic vowel errors was significantly lower among participants who are HH compared to their peers with TH. However, for affixes, the percentages of multiple phonological errors, orthographic illegal errors, and morphological omissions were significantly higher among participants who are HH compared to participants with TH. None of the second grade results survived corrections for multiple comparisons.

Among fourth graders, there were also no significant differences in spelling errors for monomorphemic roots based on hearing status (see Table 5). For multimorphemic roots, the percentage of orthographic vowel/consonant errors and the percentage of non-morpheme substitutions among participants who are HH was significantly lower than participants with TH for monomorphemic roots, and the differences approached a medium effect size. For affixes, the percentage of phonologically plausible errors, orthographic vowel errors, and orthographic vowel/consonant errors among participants who are HH was significantly lower than participants with TH. These between group differences were of small effect size, with the exception of phonologically plausible errors, which approached a medium effect size. None of the fourth grade results survived corrections for multiple comparisons.

Comparison by Audibility Status

Group equivalence was examined between participants who are HH with low and high aided audibility, at both grades. As reported in Table 6, independent samples t tests indicated

no significant differences for reading ability, overall quality of writing samples, or U-scores at both second and fourth grades. No significant differences across groups strengthens the conclusions that any differences in the percentages of categorical spelling errors associated with audibility status are not related to reading ability, quality of writing samples, or the frequency and dispersion of words participants chose to write.

Among second graders, the mean percentage of spelling errors among all words was not significantly different between the 42 participants with low aided audibility ($M = .12 \pm .08$) and the 34 participants with high aided audibility ($M = .12 \pm .10$) [$t(74) = -.301, p = .764, d = .07$]. Among fourth graders, the mean percentage of spelling errors was not significantly different between the 19 participants with low aided audibility ($M = .06 \pm .07$) and the 27 participants with high aided audibility ($M = .05 \pm .03$) [$t(44) = 1.052, p = .298, d = .31$].

As reported in Table 7, Mann-Whitney analyses were used to compare the percentage of categorical spelling errors made by second-grade participants who are HH in low or high audibility groups. For monomorphemic roots, participants with low aided audibility had significantly higher percentages of phonological omissions and orthographic consonant errors in monomorphemic roots than participants with high aided audibility, and the difference was a medium effect size. Both of these results survived adjustments for multiple comparisons. For multimorphemic roots, there were no significant between group differences. For affixes, participants with low aided audibility had a significantly higher percentage of orthographic consonant errors than participants with high aided audibility, and the difference approached a medium effect size. Among fourth graders, there were no significant differences in the percentage of categorical errors for roots or affixes. The specific statistics for the analysis

Table 4. Nonparametric comparisons (Mann-Whitney and associated two-tailed asymptotic significance) of categorical spelling errors based on hearing status at second grade

	U	HH mean Rank/(Mdn)	TH mean Rank/(Mdn)	z	p	r
Monomorphemic roots						
Phonology						
Plausible	2,285.0	65.79 (.636)	7.11 (.667)	.632	.527	.05
Substitution	2,263.0	66.06 (.143)	69.70 (.167)	.586	.586	.05
Omission	1,758.0	72.30 (.125)	6.17 (.053)	-1.837	.066	.16
Addition	2,245.0	66.28 (.000)	69.37 (.000)	.610	.542	.05
Multiple	1,952.5	69.90 (.000)	63.84 (.000)	-1.091	0.275	.09
Orthography						
Minor	2,161.0	67.32 (.200)	67.77 (.167)	.067	.946	.01
Vowel	2,020.0	69.06 (.333)	65.11 (.333)	-.578	.563	.05
Consonant	2,116.0	67.88 (.200)	66.92 (.167)	-.140	.888	.01
V&C	2,067.0	68.48 (.059)	66.00 (.059)	-.384	.701	.03
Illegal	2,279.5	65.86 (.000)	7.01 (.000)	.783	.433	.07
Morphology						
Plausible	2,011.0	69.17 (.117)	64.94 (.000)	-.657	.511	.06
Homophone	2,166.0	67.26 (.000)	67.87 (.000)	.096	.924	.01
Morpheme	1,816.0	71.58 (.143)	61.26 (.063)	-1.557	.120	.13
Non-Morpheme	2,293.5	65.69 (.500)	70.27 (.529)	.671	.502	.06
Multimorphemic roots						
Phonology						
Plausible	2,217.5	60.07 (.500)	70.26 (.500)	1.536	.124	.13
Substitution	2,048.5	62.24 (.000)	66.81 (.000)	.849	.396	.07
Omission	1,948.5	63.52 (.000)	64.77 (.000)	.229	.819	.02
Addition	1,844.5	64.85 (.000)	62.24 (.000)	-.626	.531	.05
Multiple	1,835.5	64.97 (.000)	62.46 (.000)	-.491	.624	.04
Orthography						
Minor	1,938.5	63.65 (.000)	64.56 (.000)	.251	.802	.02
Vowel	2,313.5	58.84 (.000)	72.21 (.250)	2.124	.034*	.18
Consonant	1,839.0	64.92 (.333)	62.53 (.250)	-.366	.714	.03
V&C	2,012.5	62.70 (.000)	66.07 (.182)	.547	.584	.05
Illegal	1,927.5	63.79 (.000)	64.34 (.000)	.146	.884	.01
Morphology						
Plausible	1,899.5	64.15 (.000)	63.77 (.000)	-.069	.945	.01
Homophone	1,965.5	63.30 (.000)	65.11 (.000)	1.026	.305	.09
Morpheme	1,873.0	64.49 (.000)	63.22 (.000)	-.318	.750	.03
Non-Morpheme	2,225.5	59.97 (.500)	70.42 (.667)	1.585	.113	.13
Affixes						
Phonology						
Plausible	2,093.0	61.67 (.000)	67.71 (.000)	1.062	.288	.09
Substitution	2,097.5	61.61 (.000)	67.81 (.000)	1.894	.058	.16
Omission	1,930.5	63.75 (.000)	64.40 (.000)	.244	.807	.02
Addition	1,837.5	64.94 (.000)	62.50 (.000)	-1.384	.166	.12
Multiple	1,577.0	68.28 (.000)	57.18 (.000)	-2.063	.039*	.17
Orthography						
Minor	2,234.0	72.11 (.000)	69.15 (.000)	-.608	.543	.05
Vowel	2,294.0	71.43 (.000)	70.28 (.000)	-.193	.847	.02
Consonant	2,397.0	70.26 (.000)	72.23 (.000)	.410	.682	.03
V&C	2,314.0	71.20 (.000)	70.66 (.000)	-.112	.911	.01
Illegal	1,902.5	75.88 (.000)	62.90 (.000)	-2.154	.031*	.18
Morphology						
Plausible	1,875.5	64.46 (.000)	63.28 (.000)	-.346	.729	.03
Homophone	1,927.0	63.79 (.000)	64.33 (.000)	.156	.876	.01
Morpheme	2,037.0	62.38 (.000)	66.57 (.000)	.930	.353	.08
Non-Morpheme	2,007.0	62.77 (.000)	65.96 (.000)	.685	.493	.06
Omission	1,573.5	68.33 (.000)	57.11 (.000)	-2.125	.034*	.18

Note. HH = hard of hearing; TH = typical hearing; V&C = vowel and consonant error. * $p < .050$ level.

Table 5. Nonparametric comparisons (Mann–Whitney and associated two-tailed asymptotic significance) of categorical spelling errors based on hearing status at fourth grade

	<i>U</i>	HH mean Rank/(<i>Mdn</i>)	TH mean Rank/(<i>Mdn</i>)	<i>z</i>	<i>p</i>	<i>r</i>
Monomorphemic roots						
Phonology						
Plausible	388.5	33.41 (.667)	31.85 (.714)	−.294	.768	.04
Substitution	411.0	32.94 (.000)	33.18 (.000)	.049	.961	.01
Omission	453.0	32.06 (.000)	35.65 (.000)	.767	.443	.10
Addition	374.0	33.71 (.000)	31.00 (.000)	−1.218	.223	.15
Multiple	357.0	34.06 (.000)	30.00 (.000)	−1.059	.290	.13
Orthography						
Minor	332.5	34.57 (.414)	28.56 (.333)	−1.139	.255	.14
Vowel	511.0	30.85 (.160)	39.06 (.286)	1.580	.114	.20
Consonant	404.5	33.07 (.167)	32.79 (.200)	−.055	.957	.01
V&C	371.5	33.76 (.000)	30.85 (.000)	−.738	.460	.09
Illegal	396.0	33.25 (.000)	32.39 (.000)	−.388	.698	.05
Morphology						
Plausible	377.5	33.64 (.193)	31.21 (.167)	−.471	.638	.06
Homophone	418.0	32.79 (.080)	33.59 (.143)	.156	.876	.02
Morpheme	483.0	31.44 (.038)	37.41 (.235)	1.174	.241	.15
Non-Morpheme	461.0	31.90 (.250)	36.12 (.333)	.800	.424	.10
Multimorphemic roots						
Phonology						
Plausible	385	33.44 (.500)	30.26 (.500)	−.633	.526	.07
Substitution	434	32.36 (.000)	32.84 (.000)	.123	.902	.01
Omission	368	33.82 (.000)	29.37 (.000)	−1.178	.239	.14
Addition	452	31.96 (.000)	33.79 (.000)	.627	.531	.07
Multiple	411	32.87 (.000)	31.63 (.000)	−.521	.602	.06
Orthography						
Minor	380	33.56 (.000)	30.00 (.000)	−1.026	.305	.12
Vowel	396	33.20 (.333)	30.84 (.167)	−.479	.632	.06
Consonant	350	34.22 (.250)	28.42 (.000)	−1.192	.233	.14
V&C	531.5	30.19 (.000)	37.97 (.000)	2.175	.030*	.25
Illegal	421.5	32.63 (.000)	32.18 (.000)	−.210	.834	.02
Morphology						
Plausible	5,112	107.50 (.000)	107.50 (.000)	.000	1.00	.00
Homophone	5,408	105.42 (.000)	111.61 (.000)	.747	.455	.09
Morpheme	5,242.5	106.58 (.000)	109.31 (.000)	.321	.748	.04
Non-morpheme	6,079	100.69 (.667)	120.93 (.667)	2.273	.023*	.27
Multimorphemic affixes						
Phonology						
Plausible	6,066	100.78 (.000)	120.75 (.000)	2.257	.024*	.26
Substitution	5,490.5	104.83 (.000)	112.76 (.000)	1.152	.249	.13
Omission	5,280.5	106.31 (.000)	109.84 (.000)	.516	.606	.06
Addition	5,071.5	107.79 (.000)	106.94 (.000)	−.180	.858	.02
Multiple	5,027	108.10 (.000)	106.32 (.000)	−.298	.766	.03
Orthography						
Minor	4,988	108.37 (.000)	105.78 (.000)	−.502	.615	.06
Vowel	5,903	101.93 (.000)	118.49 (.000)	1.985	.047*	.23
Consonant	5,106.5	107.54 (.000)	107.42 (.000)	−.013	.989	.00
V&C	5,840	102.37 (.000)	117.61 (.000)	2.013	.044*	.24
Illegal	5,162	107.15 (.000)	108.19 (.000)	.231	.817	.03
Morphology						
Plausible	422.5	32.61 (.000)	32.24 (.000)	−.175	.861	.02
Homophone	456	31.87 (.000)	34.00 (.000)	.637	.524	.07
Morpheme	425.5	32.54 (.000)	32.39 (.000)	−.047	.963	.01
Non-morpheme	366	33.87 (.000)	29.26 (.000)	−1.43	.153	.17
Omission	417.5	32.72 (.000)	31.97 (.000)	−.182	.856	.02

Note: HH = hard of hearing; TH = typical hearing; V&C = vowel and consonant error. **p* < .050 level.

Table 6. Measures of reading, as well as lexical and syntactical quantity and quality of writing samples by aided audibility level and grade

		Low M	SD	High M	SD	df	t	Sig	d
Second grade									
Measure									
GORT	Fluency	93.69	13.57	124.38	154.94	74	−1.280	.205	−.30
	Comp	92.74	13.40	123.65	155.08	74	−1.288	.202	−.30
SALT	T-units	13.83	4.15	14.74	4.50	74	.132	.895	−.21
	MLU-M	6.04	2.01	5.69	1.71	74	.807	.422	.19
	NDW	53.10	22.07	55.82	26.66	74	−.488	.627	.11
	NTW	80.21	39.68	81.50	42.70	74	−.136	.892	−.11
	TTR	.69	.08	.70	.06	74	−1.159	.250	−.03
	SI	.99	.33	1.02	.15	74	−.504	.616	−.14
	TWA	11,190	2,923	11,109	2,282	74	.132	.895	.03
U-score									
Fourth grade									
Measure									
GORT	Fluency	91.84	8.20	129.22	174.37	44	−.931	.357	−.28
	Comp	92.63	10.98	130.15	174.13	44	−.935	.355	−.28
SALT	T-units	17.16	5.53	17.07	5.60	44	.050	.960	.02
	MLU-M	7.87	2.63	8.04	1.62	44	−.266	.791	−.08
	NDW	80.74	29.51	84.93	31.11	44	−.459	.648	−.14
	NTW	125.53	54.20	130.04	53.84	44	−.279	.782	−.08
	TTR	.66	.06	.67	.05	44	−.234	.816	−.18
	SI	1.14	.17	1.13	.15	44	.074	.941	.06
	TWA	11,515	1,795	10,913	1,674	44	1.166	.250	.35
U-score									

Note. Comp = comprehension; MLU-M = mean length of utterance in morphemes; MLU-W = mean length of utterance in words; NDW = number of different words; NTW = number of total words; TTR = type token ratio; SI = subordination index; GORT = Gray Oral Reading Test; SALT = Systematic Analysis of Language Transcripts.

of between group differences for all morpheme types are not reported, but none of the 43 analyses were significant.

Discussion

One unexpected and important finding was that second-grade children and fourth-grade children who are HH demonstrated better or similar spelling accuracy relative to children with TH. Group equivalency across multiple measures suggests that differences, or the lack thereof, are not due to significant differences in the length or complexity of the writing samples or the frequency and dispersion of the words. This encouraging spelling performance of children who are HH suggests that at least some children who are HH are performing similarly to or better than their peers with TH in early to middle elementary school in writing samples. [Park et al. \(2013\)](#) reported that children with mild to moderate hearing loss performed more poorly than their peers with TH in a dictation test. Although the participants were of a similar age range to the current study, the sample size was small ($n = 21$ children who are HH), grade levels were not separately examined, and the task was different (i.e., spelling dictated words). Children may perform better in spelling during writing samples because they choose the words they include. In written compositions, poor spellers with TH are more likely to select familiar words and avoid taking vocabulary risks ([Graham et al., 1997](#); [Kohnen et al., 2009](#)). This is one important factor to consider when analyzing spelling performance in writing samples.

In addition to examining spelling accuracy, the current study was designed to investigate the production of categorical errors based on hearing status. These results were also very encouraging. Among second and fourth graders, the distribution of errors for monomorphemic (e.g., walnut) and multimorphemic roots

(e.g., love in lovely) was very similar between groups, suggesting they are integrating linguistic knowledge in similar ways when spelling less familiar roots. Nevertheless, when spelling affixes (e.g., -s, -ness), the differences in categorical errors of both the second grade and fourth grade children who are HH suggests multiple linguistic weaknesses, but the change in the distribution of errors over time also suggests growth in the integration of linguistic knowledge from second grade to fourth grade. In second grade, children who are HH had significantly higher percentages of more severe categorical errors, including affixes that were missing, orthographically illegal, and/or more multiple phonological errors than their peers with TH. These weaknesses suggest that younger children who are HH have more difficulty recognizing, storing, and encoding these more difficult to hear morphemes. By the fourth grade, children who are HH were including affixes as often as their peers with TH, but they were less often phonologically plausible. This suggests older children who are HH accumulated sufficient experiences for uptake to recognize these acoustically difficult morphemes, but that the restricted and degraded input results in incorrect or unstable phonological representations.

Given the data that shows children who are HH and those with more profound degrees of hearing loss have difficulty with grammatical morphology in spoken language at preschool and early school ages ([Halle & Duchesne, 2015](#); [Koehlinger et al., 2013](#)), it is not entirely surprising that morphological difficulties persist in the spelling of at least some school-age children who are HH. [Apel and Masterson \(2015\)](#) reported that children with cochlear implants had more omitted affixes in their spellings than peers with TH ([Apel & Masterson, 2015](#)). Affixes are more difficult to hear as they are often comprised of phonemes at higher frequencies and lower intensities ([Stelmachowicz et al., 2001, 2002](#)), and thus it may be challenging for younger children who are HH to recognize, store and spell both the phonological

Table 7. Nonparametric comparisons (Mann–Whitney and associated two-tailed asymptotic significance) of categorical spelling errors based on audibility level at second grade

Domain	Categorical error	U	High mean rank/ (Mdn)	Low mean rank/(Mdn)	z	p	r
Monomorphemic roots							
Phonology	Plausible	735.5	39.29 (.600)	33.14 (.500)	1.140	.254	.13
	Substitution	703.5	38.32 (.154)	33.99 (.118)	.923	.356	.11
	Omission	391	28.85 (.000)	42.21 (.167)	−2.811	.005**	.32
	Addition	643	36.48 (.000)	35.58 (.000)	.266	.791	.03
	Multiple	564.5	34.11 (.000)	37.64 (.000)	−.845	.398	.10
Orthography	Minor	698.5	38.17 (.250)	34.12 (.167)	.838	.402	.10
	Vowel	770	40.33 (.333)	32.24 (.250)	1.656	.098	.19
	Consonant	350	27.61 (.143)	43.29 (.250)	−3.230	.001**	.37
	V&C	542.5	33.44 (.000)	38.22 (.125)	−1.046	.296	.12
	Illegal	606	35.36 (.000)	36.55 (.000)	−.349	.727	.04
Morphology	Plausible	694	38.03 (.143)	34.24 (.038)	.819	.413	.09
	Homophone	579.5	34.56 (.000)	37.25 (.061)	−.584	.559	.07
	Morpheme	521	32.79 (.083)	38.79 (.155)	−1.263	.207	.14
	Non-morpheme	657	36.91 (.500)	35.21 (.528)	.347	.729	.04
Multimorphemic roots							
Phonology	Plausible	701.0	38.41 (.600)	29.97 (.667)	1.805	.071	.01
	Substitution	448.5	30.52 (.000)	37.19 (.000)	−1.920	.055	.00
	Omission	561.0	34.03 (.000)	33.92 (.000)	.016	.988	.09
	Addition	531.0	33.09 (.000)	34.83 (.000)	−.646	.518	.05
	Multiple	606.5	35.45 (.000)	32.67 (.000)	.781	.435	.04
Orthography	Minor	547.0	33.59 (.000)	34.37 (.000)	−.307	.758	.07
	Vowel	640.0	36.50 (.000)	31.71 (.292)	1.104	.270	.02
	Consonant	491.5	31.86 (.400)	35.96 (.333)	−.880	.379	.03
	V&C	587.0	34.84 (.000)	33.23 (.191)	.375	.707	.06
	Illegal	533.0	33.16 (.000)	34.77 (.000)	−.602	.547	.05
Morphology	Plausible	551.5	33.73 (.000)	34.24 (.000)	−.130	.897	.08
	Homophone	577.5	34.55 (.000)	33.50 (.000)	1.046	.296	.03
	Morpheme	551.5	33.73 (.000)	34.24 (.000)	−.180	.857	.08
	Non-morpheme	615.5	35.73 (1.00)	32.41 (1.00)	.713	.476	.04
Multimorphemic affixes							
Phonology	Plausible	552	33.75 (.000)	34.23 (.000)	−.124	.901	.01
	Substitution	530.5	33.08 (.000)	34.84 (.000)	−.902	.367	.10
	Omission	496	32.00 (.000)	35.83 (.000)	−1.956	.050	.22
	Addition	577.5	34.55 (.000)	33.50 (.000)	1.046	.296	.12
	Multiple	508.5	32.39 (.000)	35.47 (.000)	−.776	.438	.09
Orthography	Minor	609	35.41 (.000)	41.00 (.000)	−1.506	.132	.17
	Vowel	673.5	37.31 (.000)	39.46 (.000)	−.501	.616	.06
	Consonant	557	33.88 (.000)	42.24 (.000)	−2.430	.015*	.28
	V&C	591.5	34.90 (.000)	41.42 (.000)	−1.896	.058	.22
	Illegal	597.5	35.07 (.000)	41.27 (.000)	−1.383	.167	.16
Morphology	Plausible	599.5	35.23 (.000)	32.87 (.000)	1.001	.317	.11
	Homophone	515.5	32.61 (.000)	35.27 (.000)	−1.052	.293	.12
	Morpheme	519.5	32.73 (.000)	35.16 (.000)	−.858	.391	.10
	Non-morpheme	506	32.31 (.000)	35.54 (.000)	−1.014	.310	.12
	Omission	520.5	32.77 (.000)	35.13 (.000)	−.604	.546	.07

Note: High = high audibility; Low = low audibility; V&C = vowel and consonant error. * $p < .050$ level; **significant after applying Holm–Bonferroni sequential correction for multiple comparisons.

and orthographic representations of the endings of linguistically complex words. Nevertheless, affixes also represent a limited set of morphological markers. Therefore, as language develops and familiarity with this limited set grows, older children who are HH might be able to use visuographic skills to compensate for auditory challenges, leading to better storage and production of the orthographic representation of affixes. Yet, as stated above, the frequency and intensity characteristics of affixes still make them more difficult for older children who are HH to hear, which may lead to improved (i.e., multiple phonological errors to single phonological errors) but continuing difficulties in phonologically

encoding and then representing them during spelling relative to roots of words.

The secondary purpose of the study was to examine differences in aided audibility on spelling. No significant group differences in spelling accuracy were found at the second or fourth grade based on aided audibility. Some group differences in the distribution of errors were observed at the second grade, but none were found in the fourth grade. Thus, while the second grade children with different levels of aided audibility had comparable performance in accuracy, the differences in categorical errors of misspelled monomorphemic

roots and affixes suggest that they approach less familiar or unknown words with some differences in linguistic strategies. Nevertheless, by fourth grade these differences appeared to fade.

Among second graders, children with poorer aided audibility had significantly higher percentages of phonological omissions and orthographic consonant errors for monomorphemic roots (e.g., doctor) than children with better aided audibility, and the effect sizes were moderate. These were the only significant effect sizes that survived after applying a correction for multiple comparisons. While no differences were found for multimorphemic roots (e.g., lift in lifting), children with poorer aided audibility also had a significantly higher percentage of consonant errors for affixes (e.g., -ing, -ment). This pattern of errors supports the logical notion that decreased access to the speech spectrum leads to unstable or underspecified phonological representations, which in turn weakens the development of phoneme-to-grapheme correspondences in spelling. These orthographic errors suggest that poorer auditory access has limited impact on the statistical processing of frequently co-occurring letters, sounds, and sound-spelling correspondences that assist in implicit determination of legal spelling regularities (Kessler, 2009). Nevertheless, restricted access to the auditory linguistic signal may disrupt the efficiency of phonological encoding, which facilitates the storage of accurate mental graphemic images for words, resulting in legal yet incorrect substitutions for children with poorer aided audibility (Ehri, 1992; Share, 1995).

The level of spelling accuracy reported in the writing samples of participants in this study (87–90%) should also be considered in the context of the linguistic environments of the children. The children who are HH are from families with higher average maternal education (42.9%) compared to U.S. adults over the age of 25 (33.4%; United States Census Bureau, 2017). Higher maternal education is associated with higher socioeconomic status, which is in turn associated with a richer linguistic environment in the home. Thus, the linguistically supported findings reported here likely reflect the best possible outcomes for children who are HH.

Implications

The equivalent or better spelling performance exhibited by children who are HH relative to their peers with TH was unexpected, but very encouraging. These results suggest that children who are HH, formerly described as “our forgotten children” (Davis, 1990), are now being redefined by a newly emerging generation of children who have benefitted from the legislative efforts to achieve early identification and intervention for all children with hearing loss. Nevertheless, the performance of children who are HH may have been inflated by assessing spelling within contextualized writing samples, and therefore clinicians should consider multiple assessment contexts in order to build comprehensive spelling profiles.

Another important finding of this study was that the differences in categorical errors that survived multiple comparisons with the greatest effect sizes were found for children with different levels of aided audibility, than between children who are and are not HH. This suggests that for children who are HH and not profoundly deaf, suboptimally fit hearing aids present a greater risk to the development of spelling than the presence of hearing loss itself. It is conceivable that the phonological and orthographic weaknesses noted among children with low aided audibility may result in a different spelling trajectory as

the linguistic demands associated with spelling morphologically complex words increase with each grade level.

These results provide compelling evidence for the importance of providing optimal access to the frequencies encompassed by speech that can be achieved by appropriately fit hearing aids. Vigilance in ensuring appropriate audiological follow-up is particularly relevant as more than half of children who are HH may not be optimally fit with hearing aids (McCreery et al., 2015). Assuming that the spelling benefits associated with optimally fit hearing technology are not fully realized unless they are consistently worn all waking hours, these results also suggest the need for emphasis in parent and teacher education about the importance of consistency in hearing aid use. Optimal access to the auditory-linguistic signal not only promotes the development of spoken language but spelling as well.

Differences in the distribution of errors between children with and without hearing loss and between children with different levels of aided audibility also highlight the value of multilinguistic analysis of spelling errors. A traditional assessment of spelling accuracy would have suggested limited to no differences in the spelling. In contrast, the POMplexity for Roots and Affixes identified differences in linguistic knowledge underlying spelling, as well as changes in linguistic knowledge over time. Therefore, a multilinguistic error analytic approach can be employed to design interventions that target areas of need or to evaluate the impact of intervention. For example, children who show weakness in phonological awareness may benefit from phonological awareness activities, such as phoneme segmentation, phoneme deletion, and phoneme blending (Ehri et al., 2001). Children who show weakness in orthographic awareness may benefit from phoneme-to-grapheme encoding instruction (Weiser & Mathes, 2011), orthographic pattern word sorts, word family instruction, and long-term storage activities like spelling words backwards while mentally envisioning it (Squires & Wolter, 2016). Finally, children who show weakness in morphological awareness may benefit from instruction in the semantic relatedness of words, meanings of prefixes or suffixes, word origins or self-discovery through word sorts, or word building exercises (Wolter & Squires, 2013).

The use of naturally occurring writing samples also has important clinical and educational relevance as it provides a convenient means of yielding rich data for assessing, monitoring, and supporting spelling achievement among children. Given that on average nearly one-third to one-half of multiple morpheme words were misspelled, writing samples may be particularly helpful for assessing and monitoring the spelling of morphologically complex words. It can be used with the writing samples that are produced as part of everyday writing experiences rather than requiring the administration of a particular list of words. As a result, time can be devoted to examining patterns of errors using a linguistic framework that is highly familiar to teachers of the deaf and HH as well as speech-language pathologists.

Limitations and Future Directions

Assessing spelling in writing samples provides useful information because this context mimics real-world demands; however, it also introduces a variety of limitations, including variation in sample length, lack of control over spelling targets, and the possibility that poor spellers may choose to write words that are easier to spell. In the current study, the limitations of the writing context may have resulted in less stability in the SALT scores,

spelling accuracy, and POMplexity for Roots and Affixes scores of participants who submitted short writing samples. Future studies of spelling should consider including dictation tasks as well as writing samples at the sentential and discourse levels to provide a more comprehensive profile of spelling ability among children who are HH. In addition, this study did not consider the frequency and duration of hearing aid use. Future studies should examine both the quality of amplification as well as the frequency of use to have a more complete picture of the effects of amplification on spelling ability.

Although there were many similarities in the spelling profiles of children who are HH and children with TH, potentially important information about those children who struggle with spelling may be obscured by group data. Future studies should examine whether poor spellers produce different distributions of categorical errors than average or above average spellers. More specific information about the categorical errors of poor spellers could assist in both the identification of struggling spellers, as well as the development of multilingualistic spelling intervention based on a multilingualistic theoretical model.

Conclusions

The present study represents the first in-depth quantitative analysis of spelling in writing samples of school-age children who are HH in comparison to their peers with TH. Compared to children with TH, the spelling performance of children who are HH was equal to or significantly better in accuracy. Second grade children and fourth grade children who are HH demonstrated similar distributions of categorical errors for roots relative to peers with TH, but more differences in categorical errors for affixes that represented improved integration of phonological, orthographic, and morphological knowledge over time. While children who are HH with different levels of aided audibility did not differ in spelling accuracy, closer examination of categorical spelling errors identified different phonological and orthographic error profiles among children with poorer aided audibility in second grade but not in fourth grade. These findings may add to our understanding of the strategies children who are HH use to select and spell words when writing and guide the direction of future studies in developing targeted interventions for those children who are HH that struggle with spelling.

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Appendix A1 POMplexity for Roots and Affixes exemplars for each phonological, orthographic, and morphological error codes

Phonology	Orthography	Morphology
Plausible/Syncope	Minor	Plausible
Root	Root	Root
buffilo/buffalo	china/China	runing/running
butuful/beautiful	a long/along	mysterys/mysteries
to/too	it's/its	vacaiton/vacation
Affix	Affix	Affix
belled/belt	vacaiton/vacation	reversable/reversible
mysterys/mysterious	singnig/singing	radient/radiant
walkt/walked	girls/girls'	singnig/singing
Substitution or Transposition	Legal Error: Vowel	Homophone Substitution
Root	Root	Root
brid/bird	are/our	sumwhere/somewhere
swin/swim	leve/leave	a long/along
mision/mission	captin/captain	knowbody/nobody
Affix	Affix	Affix
singong/singing	wakeng/waking	mysterys/mysterious
hopin/hoping	laborotory/laboratory	avoidence/avoidance
Omission	Legal Error: Consonant	Whole Morpheme Substitution
Root	Root	Root
suprised/surprised	suprised/surprised	an/and
dint/didn't	grandfater/grandfather	plant/planet
Affix	Affix	Affix
singng/singing	watchin/watching	probaby/probably
hatchie/hatching	walket/walked	nuculier/nuclear
Addition	Legal Error: Vowel & Consonant	Non-morpheme Substitution
Root	Root	Root
nuculier/nuclear	sewle/seal	cachty/actually
monsteris/monstrous	wad/would	bindfold/blindfold
Affix	Affix	Affix
waitded/waited	runeg/running	hadisng/hiding
hidisng/hiding	vacashun/vacation	probabny/probably
Multiple Phonological	Illegal Grapheme Error	Omitted Morpheme
Root	Root	Root
bllsing/balancing	drrown/drown	base_/baseball
seeing/singing	bulld/build	he_/he's
Affix	Affix	Affix
singngn/singing	singng/singing	walk_/walked
hatchiem/hatching	walktt/walked	hop_/hoping

Appendix B1 Sample coding of misspelled words

Target word	Misspelled word	Root /Affix	Phonological code	Orthographic code	Morphological code
straight	strait	root	plausible/syncope	legal consonant	homophone sub
happiness	happyness	root affix	plausible/syncope N/A	legal vowel N/A	plausible N/A
quiet	quiyt	root	plausible/syncope	illegal	non-morpheme sub
chick	cick	root	substitution/transposition	legal consonant	non-morpheme sub
garage	groge	root	omission	legal vowel	non-morpheme sub
with	whith	root	plausible/syncope	legal consonant	non-morpheme sub
vacation	vactin	root affix	substitution/transposition	legal vowel legal vowel	non-morpheme sub
			substitution/transpo- sition	vowel	morpheme sub
dangerous	dangorous	root affix	plausible/syncope N/A	legal vowel N/A	non-morpheme sub
snakes	snake's	Root affix	N/A	N/A minor	N/A
needs	ne	Root affix	plausible/syncope omission multiple	legal V & C illegal	N/A plausible
plane	plan	root	plausible/syncope	legal vowel	non-morpheme sub
too	to	root	plausible/syncope	legal vowel	omission
walking	waliking	Root affix	addition N/A	legal vowel N/A	morpheme sub
bird	brib	root	multiple	legal V & C	homophone sub
					non-morpheme sub

Note: N/A = not applicable; V&C = vowel and consonant.