A MULTILINGUISTIC ANALYSIS OF SPELLING AMONG CHILDREN WITH HEARING LOSS

Nancy Ann Quick

A dissertation submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Allied Health Sciences in the School of Medicine.

Chapel Hill
2017

Approved by:

Melody Harrison

Karen Erickson

Elizabeth Crais

Penelope Hatch

Cara McComish

ABSTRACT

Nancy Ann Quick: A Multilinguistic Analysis of Spelling among Children with Hearing Loss
(Under the direction of Melody Harrison and Karen Erickson)

The purpose of these studies was to utilize a novel multilinguistic analysis of spelling in the writing samples of children. The first study evaluated the clinical utility of a multilinguistic spelling assessment, the POMplexity for Roots and Affixes, for identifying different profiles among four spellers. The clinical implications of the resulting distributions of phonological, orthographic, and morphological spelling errors were then described.

The second study assessed the spelling of words produced in writing samples of 188 children who are hard of hearing (CHH) and 93 children with normal hearing (CNH). Unexpectedly, compared to CNH, the CHH produced fewer misspelled words. The CHH demonstrated some areas of linguistic weakness (e.g., fewer phonologically plausible errors, more consonant errors, more omitted affixes), as well as areas of linguistic strength (e.g., fewer vowel errors). When comparing different levels of aided audibility among CHH, poorer aided audibility was associated with more single sound errors (e.g. omissions, additions), and fewer multiple sound errors.

The third study evaluated the spelling of 23 children with cochlear implants (CIs). The spelling performance of the subset of nine children who received a CI by 24 months was compared with age-matched CNH and CHH. Compared to CNH, children with CIs demonstrated a similar proportion of misspelled words but a different distribution of errors. The errors produced by children with CIs suggested areas of linguistic weakness (e.g. fewer

phonologically plausible errors) and areas of linguistic strength (e.g., fewer misspelled roots in multimorphemic words, fewer vowel errors) relative to peers with typical hearing. Compared to CHH, children with CIs demonstrated a similar proportion of misspelled words as well as a similar distribution of errors.

The results of these studies suggest that the novel multilinguistic spelling assessment has the sensitivity to detect important differences in spelling performance of individual and groups of children. Furthermore, the findings suggest that children with hearing loss who have benefitted from early intervention and use a spoken language approach demonstrate similar, if not better, spelling accuracy than CNH, while demonstrating differences in the degree to which they utilize phonological, orthographic, and morphological awareness to inform their spelling.

In memory of my father, Steven Charles Quick, who modeled and instilled the passion for lifelong learning, the honor of seeking truth, and the joy of discovery.

ACKNOWLEDGEMENTS

If you want to go fast, go alone. If you want to go far, go together.
African Proverb

Although completing a dissertation is considered by many to be a solitary endeavor, my experience was more akin to a tribal journey. Secure in the sense of belonging from having found my "tribe", I discovered beauty, joy and fulfillment in this process, and went farther than I ever imagined. The journey would never have begun if my advisor, Dr. Melody Harrison had not said "yes". Your willingness to take a chance on me, a non-traditional student with a wild and eclectic resume, ignited a heretofore unparalleled process within me of self discovery that unveiled life purpose and destiny. Thank you for shaping my clinical thought processes into critical thought processes, so that my expertise as a clinician was transformed into a rich and valuable resource for me as a developing researcher. The journey would not have continued without my co-advisor Dr. Karen Erickson. You opened the door to your Center through a Research Assistantship, invited me to see the beauty of your world in significant cognitive disability, discovered the key to my learning was bridging the known to the unknown, and then provided invaluable mentorship. You are a teacher of teachers. Thank you for verbalizing my potential long before I was aware of it, and then coupling those affirmations with growth opportunities that permitted self actualization. I am also grateful for the rest of my incredible Dissertation Committee Members. Dr. Betsy Crais, thank you for providing valuable consultation while supporting my diverse explorations, which were a necessary precursor for me to find my way. Dr. Penny Hatch, we initially bonded over our shared affinity for words, but the richness of your clinical insight and the kindness of your spirit made your invitation to be a "forever colleague" absolutely irresistible. Dr. Cara McComish, thank you for reaching out with that first warm invitation to lunch, and then connecting me with individuals, opportunities and resources that allowed me to follow in some of your footsteps, and completely shaped my doctoral student experience for the better.

The lofty goal of increasing understanding regarding language and literacy outcomes among children with hearing loss would have been unattainable without the willingness of individuals to volunteer their resources, connections and time to participate in my research. I am incredibly grateful to the directors and principals who graciously opened the doors of their organizations, as well as to the families and children that gave of their time to participate in the studies. Due to confidentiality considerations, I am unable to acknowledge you by name, but thank you to each and every one of you.

The cohort of colleagues and fellow students that morphed into lifelong friendships have served as sources of inspiration, encouragement, and celebration. I would like to extend my gratitude to my colleagues at the Center for Literacy and Disability Studies who create a synergistic, supportive, and fun environment, enabling me to love the place where I work while doing the work that I love; Karen, Penny, Lori, Claire, Lisa, Skip, Allison, Pamela and Kathryn, you are all amazing women that inspire me to do better and be better. Tom, my AR buddy, I consider myself so fortunate to have had a comrade in arms in the field of hearing loss that could serve as my sounding board. Marziye, at the intersection of east meeting west, I not only found a colleague and friend, but a sister. My doctoral journey was enriched by our never ending discussions of the beauty and intricacies of language, our celebrations of each other's milestones, and the multitude of ways you expressed your kindness and love.

Outside of the university environment, I am blessed to have more amazing supporters than any one human being possibly deserves. Beatrice Redmond you saw and spoke things over my life, and then prayed, loved and supported me until I walked in them! You are a gift for which I am eternally grateful. To the rest of my extended Raleigh family by choice, including Delon, Azizi, Lennice, Kalihah, and Chris: You have cheered and prayed me through so many seasons, and have been a continual reminder of His faithfulness and love. To my dear friends Kathy, Lea, Cindy, Marlene and Connie: Thank you for listening to the details ad nauseam, bringing needed levity, celebrating my successes, and loving me despite my foibles.

Finally, my beloved family, you provided the needed centering. You all pledged your support after I first shared my intention of pursuing a PhD in a telephone call from Ghana, and have celebrated every milestone along the way. Mom, you sent care packages, provided plane tickets for therapeutic family time, and left no lag time between notification of a celebratory moment and a Facebook post. My "best brother" Scott, thank you for all of the time you spend asking thoughtful questions to connect with me and better understand my world of research that is so far from your own. My sister-n-love Christina, our Tuesday calls became a weekly highlight and lifeline as we shared the ordinary as well as the extraordinary details of life that enable us to "do life together" from afar. Mom, Scott, and Christina, I love you.

Most of all I want to honor my Creator, who by Divine Design put abilities and passions within, and then in His perfect timing, lovingly led me to the places and people that would cause them to be revealed, developed, and expressed. Master Weaver, I love you from the depths of my heart.

In closing, I would like to acknowledge and thank Drs. J. Bruce Tomblin and Mary Pat Moeller for their support and access to data from the Outcomes of School-Age Children who are

Hard of Hearing (NIDCD 2 R01DC009560) used in chapter 3, A Multilinguistic Analysis of Spelling among Children who are Hard of Hearing, and chapter 4, A Multilinguistic Analysis of Spelling among Children with Cochlear Implants. I would also like to acknowledge funding for this research was provided by the Plural Publishing Research Award from the Council of Academic Programs in Communication Sciences and Disorders and the Paul Hardin Dissertation Fellowship from The Royster Society of Fellows of The Graduate School at the University of North Carolina at Chapel Hill.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

CHH	children who are hard of hearing
CI	cochlear implant
CNH	children with normal hearing
dB HL	decibels Hearing Level
OSACHH	Outcomes of School-Age Children who are Hard of Hearing

CHAPTER 1: INTRODUCTION

The ubiquitous instructional approach of pairing weekly word lists with a "Friday Test" reflects the common misunderstanding that spelling is merely a rote skill (Graham et al., 2008). This misperception is also likely to have influenced the limited clinical or research interest in spelling among speech-language pathologists. However, a growing body of evidence suggests that spelling is not developed through memorization, but rather through the integration of multiple sources of linguistic awareness that mature over time (Apel & Masterson, 2001; Devonshire & Fluck, 2010; Garcia, Abbott, & Berninger, 2010; Masterson & Apel, 2010a, 2010b; Rittle-Johnson & Siegler, 1999). This new evidence supports the understanding that the ability to spell is one of the language processes that speech-language pathologists, who have expertise in multiple facets of language development, are uniquely positioned to address among children with communication disorders, including children with hearing loss (American Speech-Language-Hearing Association [ASHA], 2001, 2010). In order to address spelling as a language skill among children with communication disorders, and more particularly, to understand the relationship between restricted auditory access to oral language and the development of spelling, clinicians require informative spelling tools, such as multilinguistic approaches to assessment.

Linguistic Underpinnings of Spelling

Spelling has traditionally been viewed as a rote, mechanical skill (Graham et al., 2008). More recently theorists have argued that spelling involves the non-linear development and integration of phonological, orthographic, and morphological linguistic awareness, which increase in coordinated efficiency over time (Apel & Masterson, 2001; Bahr, Silliman, Berninger, & Dow, 2012; Berninger, Abott, et al., 2006; Masterson & Apel, 2010a, 2010b; Wolter & Squires, 2013). Phonological awareness, the knowledge of how to segment and manipulate sounds in words, promotes successful sound to letter correspondences (Bourassa & Treiman, 2001). Orthographic awareness, including stored mental representations of grapheme sequences as well as knowledge of orthographic patterns, facilitates statistical learning by identifying patterns and coding them as units in spelling (Apel, 2011; Deacon, Conrad, & Pacton, 2008; Wolter & Apel, 2010). Morphological awareness, which includes the ability to reflect, analyze, and manipulate morphemes (Apel, 2014), also facilitates the statistical learning of patterns and the systematic storage of these patterns into the mental lexicon (Berninger, Raskind, Richards, Abbott, & Stock, 2008; Carlisle, 1988; Deacon, 2008; Nagy, Berninger, & Abbott, 2006). Over time, children are increasingly able to utilize these domains of linguistic awareness to varying degrees as they spell written words.

Each area of linguistic awareness that contributes to spelling poses potential problems for children with hearing loss. First, despite advances in hearing technologies, issues with audibility, low pass filtering and spectral degradation result in reduced or limited access to oral language input with a subsequent reduction in cumulative linguistic experiences (Moeller & Tomblin, 2015). For some children with hearing loss, this access-related language impoverishment results in delays in linguistic areas that contribute to spelling, such as phonological awareness (Ambrose, Fey, & Eisenberg, 2012; Briscoe, Bishop, & Norbury, 2001), orthographic awareness (Harris & Terlektsi, 2011; Most, Aram, & Andorn, 2006), and morphological awareness (Halle & Duchesne, 2015; Koehlinger, Van Horne, & Moeller, 2013). Based on the interconnectedness of oral language and written language, deficiencies in oral language noted in many children with hearing loss are presumed to influence their development of literacy, including reading, writing, and spelling (Antia, Reed, & Kreimeyer, 2005; Harris, 2015).

Spelling among Children with Hearing Loss

Given the difficulties children with hearing loss have in the linguistic domains that support spelling, it is not surprising that most studies have documented spelling deficits among this population (Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Kyle & Harris, 2006; Park, Lombardino, & Ritter, 2013; Sutcliffe, Dowker, & Campbell, 1999). The relationship between these foundational linguistic skills and spelling performance among children with hearing loss may be explained by the lexical quality hypothesis. The lexical quality hypothesis (Perfetti & Hart, 2001) proposes that the quality of one's word knowledge, as informed by multiple forms of linguistic awareness, supports literacy skills. Extending the lexical quality hypothesis to the influence of hearing loss on spelling, a degraded spectral signal and reduced linguistic access may result in deficiencies in phonology, orthography, and morphology that influence the quality of lexical representations, and the subsequent accuracy of spelling (Perfetti, 2007). These presumed underlying linguistic deficits are also likely to influence the types of spelling errors children with hearing loss produce.

Intervening in the area of spelling requires speech-language pathologists to have methods for identifying different types of spelling errors, in order to infer linguistic areas of strengths and weaknesses. Given the presumed role of multilinguistic contributions to spelling, traditional standardized spelling assessments that evaluate student responses as correct or incorrect do not provide clinicians or educators with sufficient diagnostic information to inform spelling instruction or support student improvement in spelling (Al Otaiba & Hosp, 2010; Bear et al., 2012; Sharp, Sinatra & Reynolds, 2008). Nevertheless, most spelling studies among children with hearing loss have only utilized a binary, correct/incorrect paradigm (Colombo, Arfé, & Bronte, 2012; Harris & Terlektsi, 2011; Kyle & Harris, 2006; Sutcliffe et al., 1999).

There are a few spelling studies that moved beyond correct and incorrect to more sophisticated analyses of errors, and included phonological plausibility (Aaron et al., 1998; Colombo et al., 2012; Harris & Terlektsi, 2011), orthographic transpositions (Aaron et al., 1998; Colombo et al., 2012), or multiple linguistic domain categories (Apel & Masterson, 2015; Bowers et al., 2014). However, there are limitations with generalizability of these studies to children with hearing loss being served by speech-language pathologists today. For example, the earliest of these studies included children with more profound degrees of hearing loss who utilized older hearing technology and who, because of age of identification, were likely to have had less access to oral language relative to children identified with hearing loss and fitted with improved amplification at an earlier age (Aaron et al., 1998). In addition, exclusively studying the spelling of children who use visual communication (Bowers et al., 2014) does not capture the changing demographics of children with hearing loss who primarily use spoken language. Furthermore, including multiple modalities introduces confounding factors (Apel & Masterson, 2015). While one known study focused exclusively on children with cochlear implants who utilize spoken English (Hayes, Kessler, & Treiman, 2011), the reported ages of implantation are considered late by today's standards. Additionally, little is known about spelling among the approximately seventy-five percent of children with bilateral hearing loss who experience mild to severe hearing loss (Centers for Disease Control and Prevention, 2014).

The limitations of the current body of research point to the need for more understanding regarding the ways that spelling is influenced by underlying domains of linguistic awareness among children with hearing loss. The primary purpose of the studies reported here was to use a multilinguistic spelling assessment to compare the spelling abilities of children who primarily have early-identified hearing loss and use a spoken language approach with children who have normal hearing to determine whether there are differences in the distribution of categorical spelling errors. Differences in spelling profiles of children with and without hearing loss may provide insight into the degree to which different groups utilize various linguistic domains that support spelling and provide direction for the development of targeted interventions for these populations.

Three Related Studies

Given the limited number of studies analyzing errors among children with hearing loss, the first study applied a researcher-adapted, multilinguistic spelling assessment, the POMplexity for Roots and Affixes (Quick & Erickson, 2015). The assessment tool is based on contemporary theoretical and empirical understandings that have identified the importance of phonological, orthographic and morphological awareness in informing spelling. The POMplexity for Roots and Affixes was designed to simplify a more complex multilinguistic spelling assessment, Phonological, Orthographic, and Morphological Assessment of Spelling (POMAS, Silliman, Bahr, & Peters, 2006) and improve the utility of a more limited assessment, POMplexity (Benson-Goldberg, 2014), in order to maximize its usefulness in practice by speech-language pathologists. Furthermore, the POMplexity for Roots and Affixes was designed to build upon the analytic language skills of speech-language pathologists, by providing a framework for analyzing categorical errors in the domains of phonology, orthography and morphology in a way that could guide intervention. As such, the first study confirmed the clinical applicability of the POMplexity for Roots and Affixes for assessing spelling in writing samples, identifying different spelling profiles, and guiding the determination of intervention needs among a sample of four students.

After establishing the clinical utility of the POMplexity for Roots and Affixes, it was used in the second study to compare the spelling of children who are hard of hearing (CHH) and children with normal hearing. Only one known study has examined spelling among CHH (Park et al., 2013), and it was limited to describing performance related to whole-word spelling accuracy. The current study extended this work by examining spelling accuracy among words of different morphological status and among the morphemes in those words, while comparing the distribution of categorical spelling errors in different linguistic domains. The impact of varying degrees of auditory access was also investigated by comparing the spelling performance of children with different levels of aided audibility.

Given the differences in auditory experiences between children with hearing aids and children with cochlear implants, and their potential impact on the development of spelling, the final study evaluated the spelling performance among children with different hearing technologies who primarily use spoken English. After describing the spelling profiles of the entire sample of children with cochlear implants, a subgroup of children without additional disabilities and who were implanted by 24 months were compared with matched samples of children with hearing aids and children with normal hearing. This subset of children with cochlear implants was selected to control for comorbidity and age of implantation, while trying to understand the influence of a history of profound hearing loss and cochlear implants on the linguistic domains involved in spelling. Group differences were examined in spelling accuracy among words of different morphological status, as well as the distribution of categorical spelling errors in different linguistic domains.

Together these three studies contribute additional information about spelling performance among children with hearing loss and offer important clinical guidance for the application of the multilinguistic approach to spelling assessment that is used throughout. The studies provide information about the relationship between morphological status and spelling accuracy, as well as a nuanced analysis that suggests that differences may exist in the degree to which individual and groups of children utilize various domains of linguistic awareness during the task of spelling. These results can be used to help inform spelling instruction for children with hearing loss by targeting linguistic processes that need to be strengthened or leveraging more robust linguistic processes as a bootstrapping mechanism for supporting spelling in this population. The results also provide an important basis upon which future research can build understandings of spelling among children with hearing loss.

REFERENCES

Aaron, P. G., Keetay, V., Boyd, M., Palmatier, S., & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal*, 10, 1–22. doi:10.1023/A:1007917929226

Al Otaiba, S., Puranik, C., Rouby, A., Greulich, L., Sidler, J., & Lee, J. (2010). Predicting kindergartners' end of year spelling ability from their reading, alphabetic, vocabulary, and phonological awareness skills, and prior literacy experiences. *Learning Disability Quarterly*, *33*, 171–183. Retrieved from http://journals.sagepub.com/home/ldq

Ambrose, S. E., Fey, M. E., & Eisenberg, L. S. (2012). Phonological awareness and print knowledge of preschool children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, 55, 811–823. doi:10.1044/1092-4388(2011/11-0086)b

American Speech-Language-Hearing Association. (2001). Roles and responsibilities of speech-language pathologists with respect to reading and writing in children and adolescents [Position Statement]. Retrieved from http://www.asha.org/policy/PS2001-00104/

American Speech-Language-Hearing Association. (2010). Roles and responsibilities of speech-language pathologists in schools [Professional Issues Statement]. Retrieved from http://www.asha.org/policy/PI2010-00317/

Antia, S. D., Reed, S., & Kreimeyer, K. H. (2005). Written language of deaf and hard-of-hearing students in public schools. *Journal of Deaf Studies and Deaf Education*, 10, 244–255. doi:10.1093/deafed/eni026

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, 42, 592–603. doi:10.1044/0161-1461(2011/10-0085)

Apel, K. (2014). A comprehensive definition of morphological awareness. *Topics in Language Disorders*, 34, 197–209. doi:10.1097/TLD.0000000000000019

Apel, K., & Masterson, J. J. (2001). Theory-guided spelling assessment and intervention: A case study. *Language, Speech, and Hearing Services in the Schools*, 32, 182–195. doi:10.1044/0161-1461(2001/017)

Apel, K., & Masterson, J. J. (2015). Comparing the spelling and reading abilities of students with cochlear implants and students with typical hearing. *Journal of Deaf Studies and Deaf Education*, 20, 125–135. doi:10.1093/deafed/env002

Bahr, R. H., Silliman, E. R., Berninger, V. W., & Dow, M. (2012). Linguistic Pattern Analysis of Misspellings of Typically Developing Writers in Grades 1 - 9. *Journal of Speech, Language, and Hearing Research*, 55, 1587–1599. doi:10.1044/1092-4388(2012/10-0335)b

Bear, A. A. G. (2012). Technology, Learning, and Individual Differences. *Journal of Adult Education*, *41*, 27. Retrieved from http://mpaea.org/?page=publications

Berninger, V. W., Abott, R. D., Thomson, J., Wagner, R. K., Swanson, H. L., Wijsman, E. M., & Raskind, W. (2006). Modeling phonological core deficits within a working memory architecture in children and adults with developmental dyslexia. *Scientific Studies of Reading*, 10, 165–198. doi:10.1207/s1532799xssr1002

Berninger, V. W., Raskind, W., Richards, T. L., Abbott, R., & Stock, P. (2008). A multidisciplinary approach to understanding developmental dyslexia within working-memory architecture: genotypes, phenotypes, brain, and instruction. *Developmental Neuropsychology*, 33, 707–744. doi:10.1080/87565640802418662

Bourassa, D. C., & Treiman, R. (2001). Spelling development and disability: The importance of linguistic factors. *Language, Speech, and Hearing Services in Schools*, 32, 172–181. doi:10.1044/0161-1461(2001/016)

Bowers, L. M., McCarthy, J., Schwarz, I., Dostal, H., & Wolbers, K. (2014). Examination of the spelling skills of middle school students who are deaf and hard of hearing. *The Volta Review*, 114, 29–56. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Briscoe, J., Bishop, D. V. M., & Norbury, C. F. (2001). Phonological processing, language, and literacy: A comparison of children with mild-to-moderate sensorineural hearing loss and those with specific language impairment. *Journal of Child Psychology and Psychiatry*, 42, 329–340. doi:10.1111/1469-7610.00726

Carlisle, J. F. (1988). Knowledge of derivational morphology and spelling ability in fourth, sixth, and eighth graders. *Applied Psycholinguistics*, 9, 247–266. doi:10.1017/S0142716400007839

Centers for Disease Control and Prevention. (2014). 2014 Summary of laterality, type and severity of identified hearing losses: By ear. Retrieved February 4, 2017, from https://www.cdc.gov/ncbddd/hearingloss/ehdi-data2014.html

Colombo, L., Arfé, B., & Bronte, T. (2012). The influence of phonological mechanisms in written spelling of profoundly deaf children. *Reading and Writing*, 25, 2021–2038. doi:10.1007/s11145-011-9343-6

Deacon, S. H. (2008). The metric matters: Determining the extent of children's knowledge of morphological spelling regularities. *Developmental Science*, 11, 396–406. doi:10.1111/j.1467-7687.2008.00684.x

Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian Psychology*, 49, 118–124. doi:10.1037/0708-5591.49.2.118

Devonshire, V., & Fluck, M. (2010). Spelling development: Fine-tuning strategy-use and capitalising on the connections between words. *Learning and Instruction*, 20, 361–371. doi:10.1016/j.learninstruc.2009.02.025

Garcia, N. P., Abbott, R. D., & Berninger, V. W. (2010). Predicting poor, average, and superior spellers in grades 1 to 6 from phonological, orthographic, and morphological, spelling, or reading composites. *Written Language & Literacy*, 13, 61–98. doi:10.1075/wll.13.1.03gar

Graham, S., Morphy, P., Harris, K. R., Fink-Chorzempa, B., Saddler, B., Moran, S., & Mason, L. (2008). Teaching spelling in the primary grades: A national survey of instructional practices and adaptations. *American Educational Research Journal*, 45, 796–825. doi:10.3102/0002831208319722

Halle, F., & Duchesne, L. (2015). Morphosyntactic skills in deaf children with cochlear implants: A systematic review. *Canadian Journal of Speech-Language Pathology and Audiology*, 39, 260–297.

Harris, M. (2015). The impact of new technologies on the literacy attainment of deaf children. *Topics in Early Childhood Special Education*, 35, 120–132. doi:10.1097/TLD.0000000000000052

Harris, M., & Terlektsi, E. (2011). Reading and spelling abilities of deaf adolescents with cochlear implants and hearing aids. *Journal of Deaf Studies and Deaf Education*, 16, 24–34. doi:10.1093/deafed/enq031

Hayes, H., Kessler, B., & Treiman, R. (2011). Spelling of deaf children who use cochlear implants. *Scientific Studies of Reading*, 15, 522–540. doi:10.1080/10888438.2010.528480

Koehlinger, K. M., Van Horne, A. J. O., & Moeller, M. P. (2013). Grammatical outcomes of 3- and 6-year-old children who are hard of hearing. *Journal of Speech, Language, and Hearing Research*, 56, 1701–1714. doi:10.1044/1092-4388(2013/12-0188)

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education*, 11, 273–288. doi:10.1093/deafed/enj037

Masterson, J. J., & Apel, K. (2010a). Linking characteristics discovered in spelling assessment to intervention goals and methods. *Learning Disability Quarterly*, 33, 185–198. doi:10.1177/073194871003300307

Masterson, J. J., & Apel, K. (2010b). The Spelling Sensitivity Score: Noting developmental changes in spelling knowledge. *Assessment for Effective Intervention*, 36, 35–45. doi:10.1177/1534508410380039

Moeller, M. P., & Tomblin, J. B. (2015). An introduction to the outcomes of children with hearing loss study. *Ear & Hearing*, 36, 4S–13S. doi:10.1097/AUD.0000000000000210

Most, T., Aram, D., & Andorn, T. (2006). Early literacy in children with hearing loss: A comparison between two educational systems. *Volta Review*, 106, 5–28. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Nagy, W. E., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology*, 98, 134–147. doi:10.1037/0022-0663.98.1.134

Park, J., Lombardino, L. J., & Ritter, M. (2013). Phonology matters: a comprehensive investigation of reading and spelling skills of school-age children with mild to moderate sensorineural hearing loss. *American Annals of the Deaf*, 158, 20–40. doi:10.1353/aad.2013.0013

Perfetti, C. A. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading*, 11, 357–383. doi:10.1080/10888430701530730

Perfetti, C. A., & Hart, L. (2001). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), Precursors of functional literacy (pp. 189–214). Philadelphia, PA: John Benjamins Publishing Company.

Quick, N., & Erickson, K. (2015, November). *Spelling derivationally complex words: An error classification system for measuring progress and planning treatment*. Paper presented at American Speech-Language and Hearing Association Annual Convention, Denver, CO.

Rittle-Johnson, B., & Siegler, R. S. (1999). Learning to spell: Variability, choice, and change in children’s strategy use. *Child Development*, 70, 332–348. doi:10.1598/RRQ.43.3.1

Sharp, A. C., Sinatra, G. M., & Reynolds, R. E. (2008). The development of children’s orthographic knowledge: A microgenetic perspective. *Reading Research Quarterly*, *43*, 206–226. doi:10.1598/RRQ.43.3.1

Silliman, E. R., Bahr, R. H., & Peters, M. L. (2006). Spelling patterns in preadolescents with atypical language skills: phonological, morphological, and orthographic factors. *Developmental Neuropsychology*, 29, 93–123. doi:10.1207/s15326942dn2901_6

Sutcliffe, A., Dowker, A., & Campbell, R. (1999). Deaf children’s spelling: Does it show sensitivity to phonology? *Journal of Deaf Studies and Deaf Education*, 4, 111–123. doi:10.1093/deafed/4.2.111

Wolter, J. A., & Apel, K. (2010). Initial acquisition of mental graphemic representations in children with language impairment. *Journal of Speech, Language, and Hearing Research*, 53, 179–195. doi:10.1044/1092-4388(2009/07-0130)

Wolter, J. A., & Squires, K. (2013). Spelling instructional and intervention frameworks. In C. A. Stone, E. R. Silliman, B. J. Ehren, & G. P. Wallach (Eds.), Handbook of Language and Literacy, Second Edition: Development and Disorders (pp. 602–616). New York: The Guildford Press.

CHAPTER 2: EVALUATING THE LINGUISTIC CONTRIBUTIONS TO SPELLING WITHIN STUDENT WRITING SAMPLES

Introduction

School-based speech-language pathologists address the development of oral and written language among students with communication disorders, including writing processes such as spelling (American Speech-Language-Hearing Association, ASHA, 2001, 2010). The ability to spell is one essential component of writing and written language competency (Berninger, Abbott, Nagy, & Carlisle, 2010; Devonshire & Fluck, 2010). Many children with language learning disabilities or expressive phonological impairments demonstrate difficulty with spelling (Clarke-Klein & Hodson, 1995; Dockrell, Lindsay, & Connelly, 2009; Dockrell, Lindsay, Connelly, & Mackie, 2007; Nathan et al., 2004; Silliman, Bahr, & Peters, 2006). Unfortunately, many speech-language pathologists do not perceive themselves as knowledgeable about writing and spelling, and therefore self-report limited confidence in working with children that have written language disorders (Blood, Mamett, Gordon, & Blood, 2010).

One of the factors contributing to the decreased confidence among speech-language pathologists may be limited experience applying what they know about oral language to written language, specifically in the area of spelling. This article describes a criterion-referenced approach to spelling assessment, the POMplexity for Roots and Affixes, based on the POMplexity (Benson-Goldberg, 2014) and modified POMplexity (E. Silliman, personal communication, November 28, 2015). The approach builds on skills speech-language pathologists possess in the area of analyzing oral language samples and applies those skills in the area of spelling to evaluate, guide treatment, and support progress monitoring using the writing samples students produce every day in the classroom.

The Importance of Spelling

Spelling ability not only influences the correct spelling of individual words, but also other aspects of written literacy. For example, in a longitudinal study of typically developing writers, Abbott, Berninger and Fayol (2010) reported that spelling skills are related to and predictive of text composition among students in first through seventh grades. Poor spellers may need to devote more cognitive resources to spelling, which negatively influences other aspects of written composition (Hutcheon, Campbell, & Stewart, 2012; Puranik & Al Otaiba, 2012). When students lack confidence in their spelling ability, they are more likely to select less appropriate, but familiar words (Kohnen, Nickels, & Castles, 2009), or disengage from writing all together (Lowe & Bormann, 2012). Brain imaging studies suggest that poor spellers may even experience heightened stress when attempting to spell unfamiliar words (Richards, Berninger, & Fayol, 2009).

Traditional Views of Spelling

Spelling has traditionally been considered a rote mechanical skill (Bahr, Silliman, & Berninger, 2009). This perspective continues to dominate in educational settings, resulting in teachers using traditional memorization approaches to spelling instruction (Fresch, 2007). In stage models of spelling, student spelling sequentially progresses through distinct stages that are first influenced by phonological knowledge, then orthographic knowledge, and finally morphological knowledge (Bear, Invernizzi, Templeton, & Johnston, 2012; Daffern, Mackenzie, & Hemmings, 2015; Ehri, 2005; Gentry, 2012). Most standardized and non-standardized spelling assessments influenced by these stage models only evaluate student responses as correct or incorrect (Masterson & Apel, 2013a; Treiman & Bourassa, 2000), but some further analyze errors and classify spelling errors according to the specific stage of development they reflect (Bear et al., 2012; Ganske, 2000).

More Recent Views of Spelling

More recently theorists have argued that spelling development is neither stage-based or linear, rather, it reflects the simultaneous integration of multiple sources of linguistic knowledge which deepen in development over time (Apel & Masterson, 2001; Devonshire & Fluck, 2010; Garcia, Abbott, & Berninger, 2010; Masterson & Apel, 2010a, 2010b; Rittle-Johnson & Siegler, 1999). Triple Word Form Theory proposes that across all stages of development, spellers attend to and coordinate orthographic, phonological, and morphological word forms (Richards et al., 2009). Supported by brain imaging (Berninger et al., 2010; Richards, Aylward, Berninger, et al., 2006) as well as behavioral studies (Berninger, Raskind, Richards, Abbott & Stock, 2008; Garcia et al., 2010; Nagy, Berninger, & Abbott, 2006), Triple Word Form Theory proposes that changes occur in the way phonological, orthographic and morphological word forms are involved over the course of spelling development, and that intervention can influence the coordinated efficiency of these three components (Berninger et al., 2010; Richards et al., 2009).

Linguistic Contributions to Spelling

While the three areas of phonology, orthography and morphology are integrated, and each is attended to in a coordinated way during spelling, difficulties with one or more of these linguistic areas contributes to difficulties with spelling. Phonological awareness, or the ability to segment and manipulate units at the sub-syllable level, is predictive of many literacy outcomes, including spelling (Bird, Bishop, & Freeman, 1995; Bradley & Bryant, 1983; Bryant, MacLean, Bradley, & Crossland, 1990; Wood & Terrell, 1998). Phonological awareness is thought to reflect increased awareness of the internal structure of words, promoting successful phoneme to grapheme encoding required in spelling (Bourassa & Treiman, 2001). Therefore skills such as phoneme deletion (Muter & Snowling, 1997) and parsing words into phonemes (Ritchey & Speece, 2006) have been predictive of spelling outcomes, while phoneme manipulation (Strattman & Hodson, 2005) and phoneme isolation (Caravolas, Hulme, & Snowling, 2001) have explained variance in spelling achievement.

Orthographic knowledge consists of the storage and representation of spoken language in its written form (Apel, 2011). Apel suggests this knowledge includes the stored mental representations of specific grapheme sequences as well as generalized understandings of the rule-based ways orthographic patterns represent sounds. The mostly implicit awareness of rules for graphemes and grapheme combinations facilitates the use of statistical patterns in spelling, reducing or eliminating the need for memorization of individual words (Berninger, Abbott, et al., 2006; Deacon, Conrad, & Pacton, 2008). Students also draw from orthographic knowledge to produce plausible orthographic representations of unfamiliar words (Apel, 2011; Wolter & Apel, 2010). Orthographic knowledge has been found to contribute uniquely to spelling development (Walker & Hauerwas, 2006).

Morphological awareness includes the graphemic representation of morphemes, as well as the rules for affixing morphemes (Apel, 2014). Morphological relationships provide additional statistically predictable patterns, and students increasingly use this knowledge to spell derived morphological words (Berninger, Raskind, Richards, Abbott & Stock, 2008; Carlisle, 1988; Deacon, 2008). As morphological awareness promotes understanding of the relatedness between derived words, it limits the range of orthographic spelling patterns, facilitating spelling accuracy (Deacon, Kirby, & Casselman-Bell, 2009; Walker & Hauerwas, 2006; Wolter, Wood, & D'zatko, 2009). Morphological awareness also assists the systematic storage of information into the mental lexicon (Nagy et al., 2006). Morphological awareness is highly correlated with spelling ability among elementary school children (Garcia et al., 2010) and uniquely explains variance in spelling outcomes among upper elementary and middle school students (Nagy et al., 2006).

Assessing Spelling Skills

Traditional standardized spelling assessments that only evaluate student responses as correct or incorrect do not provide speech-language pathologists with sufficient diagnostic information to support student improvement in spelling (Bear et al., 2012; Sharp, Sinatra, & Reynolds, 2008). Approaches that focus on stages of spelling development provide more information (Bear et al., 2012; Ganske, 2000), but presume strengths and weaknesses in linguistic foundations based on assigned stages. More recent multilinguistic approaches acknowledge the possibility of different profiles of underlying linguistic foundations among spellers, and support the prescriptive identification of specific deficits based on hypothesis-driven analyses of misspellings (Masterson & Apel, 2010a, 2013b;).

Spelling assessments are most often administered by dictating words within a sentence context. Dictation spelling tests reliably capture a student's spelling ability (Kohnen et al., 2009) while minimizing cognitive load in composition planning and execution. Unfortunately, dictation spelling tests alone are unable to create a comprehensive profile of a student's spelling ability (Hammond, 2004). In contrast, writing samples allow spelling achievement to be evaluated in contexts that are more representative of real life literacy tasks that require planning, syntax creation, cohesion, vocabulary selection and monitoring.

A few spelling measures have been developed that can be used to assess linguistic errors of misspelled words within contextualized written compositions. The Spelling Sensitivity Score (SSS, Masterson & Apel, 2010b) divides words into elements which are defined as phonemes, juncture changes, and affixes, and then assigns a score based on the orthographic legality of the element. The authors suggest that the average element and word scores may indicate the phonologic or orthographic nature of underlying deficits, but this metric does not include separate examinations of phonological or morphological knowledge on spelling. In addition, some attempts to spell words are considered unanalyzable (e.g. two adjacent omissions) and cannot be included in analyses.

The Phonological, Orthographic, and Morphological Assessment of Spelling (POMAS, Silliman, Bahr, & Peters, 2006) is a qualitative scoring system that classifies errors into the three categories of phonology, orthography, and morphology and then further codes errors into one of 41 linguistic features associated with general American English. While the coding system documents the underlying linguistic features of each spelling attempt and how those linguistic features change over time, the approach is complex and time consuming. The POMplexity (Benson-Goldberg, 2014) and modified POMplexity (E. Silliman, personal communication, November 28, 2015) were developed as quantitative metrics to examine the misspellings of morphologically complex words, based on the qualitative descriptors identified in the POMAS. Examining spelling at the word level, the POMplexity and modified POMplexity separately rank the phonological, orthographic and morphological contributions based on the severity of the misspelling. Both of these frameworks are limited to analysis of morphologically complex words, and therefore cannot be used to examine all of the spelling errors that may occur in a writing sample.

In contrast, the Multi-linguistic Coding System includes a linguistic analysis of errors in the domains of phonology, orthography, mental graphemic representation, morphology, and semantics (Bowers, McCarthy, Schwarz, Dostal & Wolbers, 2014). Words are the unit of analysis, and each misspelled word can be coded for one or more linguistic errors. One of the limitations of this assessment is that there are no references or guidelines provided for evaluating criteria such as pronunciation or legality, and error categories are vaguely defined.

There is clearly a need for an approach to analyzing spelling errors that is efficient enough for busy clinicians to use across all morphological word types, but with sufficient guidelines and specificity for supporting reliability. It is also important that the spelling assessment sufficiently captures the full range of spelling errors students make when writing, in order to provide prescriptive information regarding the underlying linguistic contributions of phonology, orthography, and morphology.

POMplexity for Roots and Affixes: A New Approach to Spelling Assessment

The POMplexity for Roots and Affixes (Quick & Erickson, 2015) is a modification of the POMplexity (Benson-Goldberg, 2014) and modified POMplexity (E. Silliman, personal communication, November 28, 2015) intended to address the need to efficiently analyze both monomorphemic and multimorphemic words. The POMplexity and modified POMplexity both require analysis of each phoneme and grapheme, but this new adapted approach evaluates errors at the level of the morpheme. By changing the unit of analysis to morphemes, and developing criteria that can be applied to both roots and affixes, the approach permits assessment of single morpheme, compound, contracted, inflected and derivational words. At the level of the morpheme, misspellings are coded into subcategories within each linguistic domain, eliminating the need for more complex computations at phonemic or graphemic sublevels and making the approach more useful in clinical settings.

The POMplexity for Roots and Affixes separately analyzes each root or affix and then allows for the identification of categorical errors in the domains of phonology, orthography, and morphology. Appendix 1 provides a definition of each linguistic category and examples to accompany the criteria for phonological, orthographic and morphological errors with the POMplexity for Roots and Affixes. For example, the misspelling of “burd” for “bird” would be coded as follows: (a) Phonology - plausible, (b) Orthography - legal vowel error, and (c) Morphology - non-morpheme substitution. Frequency counts for each categorical error within each linguistic area are calculated. The tool provides flexibility in analyzing patterns of spelling errors of roots and affixes. For example, frequency distributions can be calculated based on all morphemes, categories of morphemes (e.g., roots, affixes), or specific types of morphemes (e.g. inflectional morphemes). In order to control for differences in the number of misspelled words across sampling contexts, the total frequency count can be divided by the total number of errors, or by the total number of morphemes in the analysis, in order to produce a standardized metric for use in identifying changes in the relative contribution of each error type over time.

One of the weaknesses of previous studies is the vagueness of definition for phonological plausibility and orthographic legality. In POMplexity for Roots and Affixes, phonological plausibility and orthographic legality are determined according to the criteria outlined by Olson and Caramazza (2004). Specifically, phonological plausibility is determined by first identifying phoneme to grapheme(s) correspondences within the morpheme of a misspelled word. The 36,000-word Merriam-Webster Elementary Dictionary (2014) is then searched to identify the grapheme or grapheme sequence in similar positions in any word that would permit the misspelling to be produced like the target. The phonological judgments are phoneme sensitive rather than context sensitive as outlined by Olson and Caramazza. Therefore “stoped” is considered phonologically plausible even though, contextually, doubling the consonant is required to maintain a short vowel in the medial position of a word.

In order to examine orthographic legality, words are first parsed into word-initial consonants or vowels (e.g., *t*op, *a*bout), word-medial onsets (e.g., a*b*out), word medial-vowels (e.g., ab*ou*t), word-medial codas (e.g., ha*r*mony), and word-final consonants or vowels (e.g., abou*t*). When examples of orthographic letter or letter sequences in these categories found in the misspelled words can be identified among words in the Merriam-Webster Elementary Dictionary, the response is considered legal (e.g., “rite” for “right”; “plant” for “planet”).

Morphological plausibility is ascribed when the morphograph (i.e., written representation of morpheme) contains minor orthographic errors that suggest awareness of the target morpheme. These errors include spacing errors (“some where” for “somewhere”) and transpositions (“toegther” for “together”), as well as alternative orthographic representations of the target morpheme. Alternative orthographic representations include the range of spelling patterns for a target morpheme that occur in root, inflected and derived word forms. For example, the spelling patterns of “motive” and “motiv” are alternative orthographic representations of the same target morpheme (motive; motivating). Therefore “motiveating” for “motivating” is considered morphologically plausible. Similarly, the spelling patterns of “stop” and “stopp” are alternative orthographic representations of the same target morpheme (stop; stopping), and therefore “stoping” for “stopping” is considered morphologically plausible. A score sheet for the entire process is provided in Appendix B.

Applying POMplexity for Roots and Affixes to Assessment

To demonstrate the utility of the POMplexity for Roots and Affixes, we randomly selected the writing samples of four 5th grade students who participated in a larger study of writing (Erickson, Geist, & Hatch, in press). The students completed the Story Construction subtest of the Test of Written Language 3 (Hammill & Larsen, 1996) as a pre- and post-test measure in the larger study. Students were instructed to write a story in response to a picture from a prehistoric period. The pre-test writing samples were transcribed and each word was coded as being either a single morpheme, compound (e.g., single unit of two words), inflected (free standing root or base with an affix that changes the tense, person, or number such as "girl*s*" or "walk*ed*") or derived (e.g., free standing root or base with one or more affixes that change the meaning or grammatical class of the base word such as "*un*happy" or "grow*th*"). Next misspelled words for each student were analyzed for phonological, orthographic, and morphological errors using the POMplexity for Roots and Affixes in order to provide specific examples of the application of the approach. The scoring of misspelled words for each student is provided in Appendix C.

Participants

Participants from the larger study were selected for the current study on the basis of having writing samples that appeared to represent diversity in the number and types of spelling errors. The selected participants included four males from two separate fifth grade classrooms ranging in age from 10 to 11 years. They represented diverse backgrounds, and half were eligible for free price or reduced lunch. One student had a diagnosis of high functioning autism, and was fully mainstreamed in the general education classroom. Participant demographics are reported in Table 2.1.

Table 2.1 Participant Demographics

Student	Chronological Age	Ethnicity	Free/Reduced Lunch	Disability
1	10;3	Hispanic	Yes	-
2	10;3	white	No	-
3	11;2	black	Yes	-
4	10;0	white	No	Autism

The student writing samples varied in length and in the number of spelling errors. Students 1 and 2 wrote compositions of similar length and had 10 or fewer errors. Students 3 and 4 wrote the longest and shortest compositions, respectively, yet demonstrated a similar total number of errors (n = 25-28). Across all four students, the compositions had a mean of 93 total words in length, with an average of 24% of words being misspelled. The writing sample of student 1 had a high percentage of single morpheme words with the majority of misspellings occurring among single morpheme words. Student 2 used the greatest number of morphologically complex words, and had no errors with single morpheme words. Student 3's writing sample contained no derivationally complex words and his errors were distributed across single morpheme, compound and inflected words. Student 4 had the greatest percentage of misspelled words (60%), and all words that were not single morphemes were misspelled. The total number of words and errors for each of the students are reported below in Table 2.2.

Monomorphemic Level of Analysis

Using the POMplexity for Roots and Affixes, the first analysis examined the distribution of categorical errors among the roots of misspelled words that were monomorphemic. In addition to single morpheme words, this grouping included the parsed morphemes of compound and contracted words. Compound words and contracted words were included in the

Table 2.2 Total Number of Words and Total Number of Misspelled Words across Morphological Word Types

		Distribution of Errors			
	Total Words	Derived	Inflected	Compound	Single
Student 1	94 (10)	1(0)	9 (2)	2 (2)	82 (7)
Student 2	92 (5)	3 (2)	14 (2)	5 (1)	70 (0)
Student 3	141 (25)	-	14 (9)	9 (4)	118 (12)
Student 4	47 (28)	-	5 (5)	1 (1)	41 (22)

monomorphemic analysis as they are composed of two single morpheme words that form a single word unit. Compound words do not include changes in pronunciation or spelling when combined (e.g. nobody, somewhere), but contracted words include an apostrophe that marks the changes in pronunciation and spelling of the second morpheme (e.g., can't, don't).

Among monomorphemic roots, student 2 demonstrated little difficulty as he only had one misspelled morpheme. The remaining students had 11 to 25 misspelled monomorphemic roots. When examining phonology, all of student 1's misspellings were either phonologically correct or plausible. In contrast, students 3 and 4 made one or more phonological errors in approximately 33-50% of the monomorphemic words they wrote. Student 3 tended to use substitutions or omissions while student 4 tended to use substitutions or additions. In the area of orthography, the errors of student 1 were fairly evenly divided between minor errors of spacing or transpositions, and legal grapheme errors of vowels. The orthographic scoring of student 3's monomorphemic words was fairly evenly distributed across correct, minor, legal and illegal categories, but the majority of errors involved legal grapheme errors of consonants. Student 4 demonstrated the greatest difficulty with orthography, as he had no minor errors and the majority of his errors involved both vowels and consonants. In the area of morphology, nearly one half of the errors student 1 made were morphologically plausible as they primarily involved spacing errors among compound words. The errors student 3 made reflected awareness of morphographs, as there were frequent substitutions of homophones, other morphemes, and alternative orthographic representations of the target morpheme. The errors student 4 made primarily included non-morpheme substitutions, indicating more limited morphographic awareness. The frequency counts and percentages of categorical errors for monomorphemic roots are reported in Table 2.3.

Interpreting Monomorphemic Scores. The variations in scores across the domains of phonology, orthography, and morphology suggest that the three students who struggled with spelling monomorphemic words would benefit from spelling instruction that focused on strengthening different underlying linguistic skills. For example, most of the errors student 1 made involved either phonologically plausible misspellings of polysyllabic words or spacing errors with compound words. Therefore student 1 would benefit from intervention that increased his orthographic awareness among these particular word types. The multiple phonological errors made by students 3 and 4 indicate a need for increased phonological awareness. In addition, student 3 would benefit from morpheme-based instruction that assists him in differentiating between morphographs that have similar phonological or orthographic skeletons, while student 4 requires intervention that assists him in the spelling of morphographs using legal orthographic selections.

Table 2.3 Frequency Counts and Percentage of Categorical Errors for Roots of Monomorphemic Words

		Student 1	Student 2	Student 3	Student 4
Phonology	Correct	-	1 (50.0%)	2 (9.5%)	-
	Plausible	11 (100%)	1 (50.0%)	6 (28.6%)	12 (48.0%)
	Substitution	-	-	5 (23.8%)	6 (24.0%)
	Omission	-	-	4 (19.0%)	-
	Addition	-	-	-	4 (16.0%)
	Multiple	-	-	4 (19.0%)	3 (12.0%)
Orthography	Correct	6 (54.5%)	1 (50.0%)	2 (9.5%)	-
	Minor	5 (45.4%)	-	6 (28.6%)	-
	Vowel	-	-	2 (9.5%)	12 (48.0%)
	Consonant	-	1 (50.0%)	7 (33.3%)	2 (8.0%)
	V + C	-	-	2 (9.5%)	9 (36.0%)
	Illegal	-	-	2 (9.5%)	2 (8.0%)
Morphology	Correct	-	1 (50.0%)	2 (9.5%)	-
	Plausible	5 (45.4%)	-	5 (23.8%)	-
	Homophone	1 (9.1%)	1 (50.0%)	2 (9.5%)	1 (4.0%)
	Morpheme	1 (9.1%)	-	4 (19.0%)	4 (16.0%)
	Non-morpheme	4 (36.4%)	-	8 (38.1%)	20 (80.0%)
	Omitted	-	-	-	-

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Multimorphemic Level of Analysis

The next analysis examined the frequency distributions of categorical errors among misspelled multimorphemic words. Inflected and derived words were included in the multimorphemic analysis because they are both comprised of a root and one or more affixes. These multimorphemic words are more complex due to the possibility of pronunciation or spelling changes with the addition of affixes (e.g., *run – running* or *magic - magician*). In this sample, none of the multimorphemic words contained more than 2 morphemes, and 90% (n = 20) of the misspelled multimorphemic words involved inflected words. The roots and affixes were separately examined because relative to roots, affixes are composed of a limited set of morphemes (e.g. inflectional affixes include past tense *–ed*, past participle *-en*, plural *-s* or *-es* plural, third person singular -s, possessive *'s*, and progressive *-ing*).

In examining the roots of multimorphemic words, student 1 demonstrated little difficulty because he had only two errors and both were phonologically plausible, orthographically legal, and indicated awareness of the target morpheme. The three misspelled roots of student 2 were morphologically plausible, but included single phonological errors due to legal grapheme errors of either vowels or consonants. For student 3, although more than half of the roots of his misspelled multimorphemic words were spelled correctly, all of the errors included non-morpheme substitutions that were most often the result of an omission. Student 4 also used non-morpheme substitutions in his misspelled multimorphemic words, but he tended to have multiple phonological errors due to multiple legal and illegal grapheme errors. The frequency counts and percentages of categorical errors for roots of multimorphemic words are reported in Table 2.4.

Different distributions of categorical spelling errors were noted in the affixes of misspelled multimorphemic words. Student 1 demonstrated no affix errors in his misspelled multimorphemic words. Approximately 2/3 of the multimorphemic words misspelled by students 2, 3, and 4 had issues with affixes. Most of the affixes student 2 misspelled were phonologically plausible errors with vowels in derived words. For student 3, all affix errors in his misspelled multimorphemic words included omitted inflectional morphemes. Student 4 used morpheme and non-morpheme substitutions for affixes that often contained multiple phonological errors due to difficulties with the representation of consonants. The frequency counts and percentages of categorical errors for multimorphemic affixes are reported in Table 2.5.

Interpreting Multimorphemic Scores. Student 1 demonstrated limited difficulty with the roots of multimorphemic words but would benefit from instruction that focused on inclusion of obligatory inflectional morphemes. Student 2 demonstrated little difficulty with inflected words but would benefit from morpheme-based instruction that increased awareness of the morphographs of the most common derivational affixes (e.g., “ious”, “ous”). Student 3 would benefit from intervention that focused on increasing phonological awareness of sonorant consonants such as “n” and “r”, as well as morpheme-based instruction that targeted the inclusion of the past tense “ed”. Student 4 demonstrates the need for intervention that increases his phonological awareness across a wide range of vowels and consonants, his knowledge of legal orthographic representations, and his ability to represent morphographs of the limited set of inflectional morphemes (e.g., “ing”), as well as the size and diversity of his vocabulary.

Table 2.4 Frequency Counts and Percentage of Categorical Errors for Roots of Multimorphemic Words

		Student 1	Student 2	Student 3	Student 4
Phonology	Correct	-	1 (25.0%)	6 (60.0%)	-
	Plausible	2 (100%)	1 (25.0%)	-	1 (20.0%)
	Substitution	-	1 (25.0%)	-	1 (20.0%)
	Omission	-	-	2 (20.0%)	-
	Addition	-	1 (25.0%)	-	-
	Multiple	-	-	2 (20.0%)	3 (60.0%)
Orthography	Correct	-	1 (25.0%)	6 (60.0%)	-
	Minor	-	-	-	-
	Vowel	2 (100%)	1 (25.0%)	-	1 (20.0%)
	Consonant	-	2 (50.0%)	2 (20.0%)	-
	V + C	-	-	1 (10.0%)	2 (40.0%)
	Illegal	-	-	1 (10.0%)	2 (40.0%)
Morphology	Correct	-	1 (25.0%)	6 (60.0%)	-
	Plausible	2 (100%)	3 (75.0%)	-	-
	Homophone	-	-	-	-
	Morpheme	-	-	-	5 (100%)
	Non-morpheme	-	-	4 (40.0%)	-
	Omitted	-	-	-	-

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Table 2.5 Frequency Counts and Percentage of Categorical Errors for Inflected and Derived Affixes

		Student 1	Student 2	Student 3	Student 4
Phonology	Correct	2 (100%)	2 (40.0%)	4 (40.0%)	2 (40.0%)
	Plausible	-	2 (40.0%)	-	1 (20.0%)
	Substitution	-	-	-	-
	Omission	-	-	-	-
	Addition	-	-	-	-
	Multiple	-	-	-	2 (40.0%)
	Omitted	-	1 (20.0%)	6 (60.0%)	-
Orthography	Correct	2 (100%)	2 (40.0%)	4 (40.0%)	2 (40.0%)
	Minor	-	-	-	-
	Vowel	-	2 (40.0%)	-	1 (20.0%)
	Consonant	-	-	-	-
	V + C	-	-	-	2 (40.0%)
	Illegal	-	-	-	-
	Omitted	-	1 (20.0%)	6 (60.0%)	-
Morphology	Correct	2 (100%)	2 (40.0%)	4 (40.0%)	2 (40.0%)
	Plausible	-	-	-	-
	Homophone	-	-	-	-
	Morpheme	-	2 (40.0%)	-	1 (20.0%)
	Non-morpheme	-	-	-	1 (20.0%)
	Omitted	-	1 (20.0%)	6 (60.0%)	1 (20.0%)

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Discussion

The POMplexity for Roots and Affixes offers insight into the phonological, orthographic, and linguistic skills that appear to interfere with a student's spelling success, enabling a prescriptive approach to spelling assessment and intervention. Although some students produced comparable written compositions with regards to length or the number of spelling errors, different profiles emerged regarding the type and severity of underlying linguistic deficits. Student 1 demonstrated less severe errors as all misspelled words were phonologically plausible, orthographically legal and morphologically plausible. Student 1 is primarily struggling with the orthographic representation of polysyllabic monomorphemic words and inflected words that require spelling changes (e.g., running, stopping). Student 2 demonstrated no difficulty with single morpheme words, but struggled with representing the pronunciation and spelling changes associated with complex derived words. Student 3 demonstrated strong morphographic awareness, but did not correctly represent morphemes based on meaning and inconsistently included inflectional morphemes. Student 4 demonstrated the most severe categorical errors across all types of word morphology, and displayed issues with phonological, orthographic, and morphological awareness. The diversity in spelling profiles among these four students suggests that each may require different types of intervention to improve each student's spelling success while writing.

It has been argued that different types of intervention are warranted based on specific underlying linguistic deficits that emerge from a spelling profile analysis (Masterson & Apel, 2010a). Students who have more errors with the representation of roots or affixes among morphologically complex words are likely to benefit from vocabulary development that highlights the semantic relatedness of words, morphemic instruction that focuses on prefixes and suffixes, or both. Students who demonstrate illegal orthography are likely to benefit from increased time in independent reading of relatively easy text to facilitate abstraction of probabilistic spelling patterns, while students that demonstrate patterns of orthographic errors representing particular sound sequences might benefit from direct instruction in those specific representations of sound. Students who demonstrate more severe phonological errors may require more direct instruction in phonological awareness to improve segmentation and blending, while students who consistently misspell a sound with a letter that cannot represent that sound may need direct phonetic instruction for improved phoneme to grapheme encoding.

The POMplexity for Roots and Affixes provides a simple and efficient framework for analyzing underlying linguistic deficits contributing to student misspellings. Administration time is limited, as speech-language pathologists can collaborate with teachers in collecting student-generated writing samples from regularly occurring classroom assignments. The clearly defined ranking scale of this criterion-referenced tool minimizes the time required to score and analyze student spelling. The results can be used to help speech-language pathologists understand patterns of errors and know how to look for changes in those patterns over time. The POMplexity for Roots and Affixes provides a simple framework of analysis that clinicians can use to educate teachers about the linguistic contributions to spelling development. Student profiles can further be used to develop a collaborative approach to intervention that maximizes the expertise and resources of various educational team members in areas such as phonics instruction, vocabulary instruction, morphemic instruction, writing practice, and identification of appropriate reading materials. If similar writing sample contexts are utilized for pre and post assessment of spelling, the impact of targeted intervention can also be evaluated.

The POMplexity for Roots and Affixes is also flexible as an assessment tool. This criterion-referenced measure can be used in a variety of contexts, including: student-generated writing samples; formal or informal spelling dictation; and standardized tests of writing at the word, sentence, or discourse level. As this spelling assessment can be used with mono- and multiple-morphemic words, student spelling can be monitored across all stages of writing development. The inherently longer developmental course of morphological awareness places increased constraints on spelling accuracy, as upper elementary and adolescent students transition into using more morphologically complex words. Nevertheless, the POMplexity for Roots and Affixes can assist speech-language pathologists in supporting these students who are increasingly expected to incorporate these complex words into their writing with each grade level.

Limitations

One of the limitations of this tool is the inability to interpret the quantitative metric independent of linguistic analysis. As with other quantitative metrics of language, the scores cannot be interpreted in the absence of the larger linguistic framework of the student's language sample. Higher misspelling scores are not necessarily equated with a "poorer speller", in the same way a higher Mean Length of Utterance is not necessarily indicative of more advanced syntax. It is conceivable that a younger speller who primarily uses monomorphemic words could receive similar percentages of more severe categorical errors as an older speller who is embedding morphologically complex words in more advanced syntax. Nevertheless, with their extensive training in oral language sample analysis, speech-language pathologists are particularly well suited to using their phonological, orthographic and morphological expertise to evaluate and interpret students' spelling errors. This spelling framework enables speech-language pathologists to develop more comprehensive and targeted literacy intervention for meeting the individual needs of students with written language disorders.

Summary

Given that it is in the scope of practice of school-based speech-language pathologists to address both the oral and written language needs of the students they serve, it is important that they have access to tools to support their intervention efforts. The POMplexity for Roots and Affixes is an efficient spelling assessment tool that clinicians can use to assess and monitor student spelling skills and progress over time. Importantly, the POMplexity for Roots and Affixes provides speech-language pathologists with a diagnostic and prescriptive means of analyzing the linguistic contributions to errors students make when spelling. While speech-language pathologists often report that they lack knowledge about written language (Blood et al., 2010), the POMplexity for Roots and Affixes draws upon their knowledge of oral language and oral language assessment and intervention as a means of addressing spelling.

REFERENCES

Abbott, R. D., Berninger, V. W., & Fayol, M. (2010). Longitudinal relationships of levels of language in writing and between writing and reading in grades 1 to 7. *Journal of Educational Psychology*, *102*, 281–298. doi:10.1037/a0019318

American Speech-Language-Hearing Association. (2001). Roles and responsibilities of speech-language pathologists with respect to reading and writing in children and adolescents [Position Statement]. Retrieved from http://www.asha.org/policy/PS2001-00104/

American Speech-Language-Hearing Association. (2010). Roles and responsibilities of speech-language pathologists in schools [Professional Issues Statement]. Retrieved from http://www.asha.org/policy/PI2010-00317/

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, *42*, 592–603. doi:10.1044/0161-1461(2011/10-0085)

Apel, K. (2014). A comprehensive definition of morphological awareness. *Topics in Language Disorders*, *34*, 197–209. doi:10.1097/TLD.0000000000000019

Apel, K., & Masterson, J. J. (2001). Theory-guided spelling assessment and intervention: A case study. *Language, Speech, and Hearing Services in the Schools*, *32*, 182–195. doi:10.1044/0161-1461(2001/017)

Bahr, R. H., Silliman, E. R., & Berninger, V. W. (2009). What spelling errors have to tell about vocabulary learning. In C. Woods & V. Connolly (Eds.), *Contemporary perspectives on reading and spelling* (pp. 109–129). New York: Routlege.

Bear, D. R., Invernizzi, M., Templeton, S., & Johnston, F. (2012). *Words their way: Word study for phonics, vocabulary, and spelling instruction (5th ed.)*. Upper Saddle River, NJ: Pearson Education.

Benson-Goldberg, S. (2014). *Spelling of derivationally complex words: The role of phonological, orthographic, and morphological features* (master's thesis). University of South Florida. Retrieved from Scholar Commons at the University of South Florida

Berninger, V. W., Abbott, R. D., Jones, J., Wolf, B. J., Gould, L., Anderson-Youngstrom, M., … Apel, K. (2006). Early development of language by hand: Composing, reading, listening, and speaking connections; three letter-writing modes; and fast mapping in spelling. *Developmental Neuropsychology*, *29*, 61–92. doi:10.1207/s15326942dn2901_5

Berninger, V. W., Abbott, R. D., Nagy, W., & Carlisle, J. (2010). Growth in phonological, orthographic, and morphological awareness in grades 1 to 6. *Journal of Psycholinguistic Research*, *39*, 141–63. doi:10.1007/s10936-009-9130-6

Berninger, V. W., Raskind, W., Richards, T. L., Abbott, R., & Stock, P. (2008). A multidisciplinary approach to understanding developmental dyslexia within working-memory architecture: Genotypes, phenotypes, brain, and instruction. *Developmental*

Neuropsychology, *33*, 707–744. doi:10.1080/87565640802418662

Bird, J., Bishop, D. V. M., & Freeman, N. H. (1995). Phonological awareness and literacy development in children with expressive phonological impairments. *Journal of Speech and Hearing Research*, *38*, 446–462. doi:10.1044/jshr.3802.446

Blood, G. W., Mamett, C., Gordon, R., & Blood, I. M. (2010). Written language Disorders: Speech language pathologists' training, knowledge and confidence. *Language Speech and Hearing Services in Schools*, *41*, 32–161. doi:10.1044/0161-1461(2009/09-0032)

Bourassa, D. C., & Treiman, R. (2001). Spelling development and disability: The importance of linguistic factors. *Language, Speech, and Hearing Services in Schools*, *32*, 172–181. doi:10.1044/0161-1461(2001/016)

Bowers, L. M., McCarthy, J., Schwarz, I., Dostal, H., & Wolbers, K. (2014). Examination of the spelling skills of middle school students who are deaf and hard of hearing. *The Volta Review*, *114*, 29–56. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature*, *301*, 419–421. doi:10.1038/301419a0

Bryant, P. E., MacLean, M., Bradley, L., & Crossland, J. (1990). Rhyme and alliteration, phoneme detection, and learning to read. *Developmental Psychology*, *26*, 429–438. doi:10.1037/0012-1649.26.3.429

Caravolas, M., Hulme, C., & Snowling, M. (2001). The foundations of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language*, *45*, 751–774. doi:10.1006/jmla.2000.2785

Carlisle, J. F. (1988). Knowledge of derivational morphology and spelling ability in fourth, sixth, and eighth graders. *Applied Psycholinguistics*, *9*, 247–266. doi:10.1017/S0142716400007839

Clarke-Klein, S., & Hodson, B. W. (1995). A phonologically based analysis of misspellings by third graders with disordered-phonology histories. *Journal of Speech and Hearing Research*, *38*, 839–49. doi:10.1044/jshr.3804.839

Daffern, T., Mackenzie, N. M., & Hemmings, B. (2015). The development of a spelling assessment tool informed by Triple Word Form Theory. *Australian Journal of Language and Literacy*, *38*, 72–83. Retrieved from http://www.alea.edu.au/resources/australian-journal-of-language-and-literacy-ajll-2/australian-journal-of-language-and-literacy-ajll

Deacon, S. H. (2008). The metric matters: Determining the extent of children's knowledge of morphological spelling regularities. *Developmental Science*, *11*, 396–406. doi:10.1111/j.1467-7687.2008.00684.x

Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian*

Psychology, *49*, 118–124. doi:10.1037/0708-5591.49.2.118

Deacon, S. H., Kirby, J. R., & Casselman-Bell, M. (2009). How robust is the contribution of morphological awareness to general spelling outcomes? *Reading Psychology*, *30*, 301–318. doi:10.1080/02702710802412057

Devonshire, V., & Fluck, M. (2010). Spelling development: Fine-tuning strategy-use and capitalising on the connections between words. *Learning and Instruction*, *20*, 361–371. doi:10.1016/j.learninstruc.2009.02.025

Dockrell, J. E., Lindsay, G., & Connelly, V. (2009). The impact of specific language impairment on adolescents'written text. *Exceptional Children*, *75*, 427–446. doi:10.1177/001440290907500403

Dockrell, J. E., Lindsay, G., Connelly, V., & Mackie, C. (2007). Constraints in the production of written text in children with specific language impairments. *Exceptional Children*, *73*, 147–164. doi:10.1177/001440290707300202

Ehri, L. C. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of Reading*, *9*, 167–188. doi:10.1207/s1532799xssr0902_4

Erickson, K., Geist, L., & Hatch, P. (in press). Impact of self-regulated strategy instruction integrated with SOLO® Literacy Suite. *Assistive Technology Outcomes and Benefits*.

Fresch, M. J. (2007). Teachers' concerns about spelling instruction: A national survey. *Reading Psychology*, *28*, 301–330. doi:10.1080/02702710701545510

Ganske, K. (2000). *Word journeys: Assessment-guided phonics, spelling, and vocabulary instruction*. New York: The Guilford Press.

Garcia, N. P., Abbott, R. D., & Berninger, V. W. (2010). Predicting poor, average, and superior spellers in grades 1 to 6 from phonological, orthographic, and morphological, spelling, or reading composites. *Written Language & Literacy*, *13*, 61–98. doi:10.1075/wll.13.1.03gar

Gentry, J. R. (2012). An analysis of developmental spelling in GNYS AT WRK. In D. Wyse (Ed.), *Literacy Teaching and Education (Vol. 3)* (pp. 344–357). London: Sage Publications.

Hammill, D., & Larsen, S. (1996). *Test of Written Language (3rd ed.)*. Austin, TX: Pro-Ed.

Hammond, L. (2004). Getting the right balance: Effective classroom spelling instruction. *Australian Journal of Learning Disabilities*, *9*, 11–18. doi:10.1080/19404150409546769

Hutcheon, G., Campbell, M., & Stewart, J. (2012). Spelling instruction through etymology - A method of developing spelling lists for older students. *Australian Journal of Educational and Developmental Psychology*, *12*, 60–70. Retrieved from https://www.newcastle.edu.au/about-uon/governance-and-leadership/faculties-and-schools/faculty-of-education-and-arts/school-of-education/school-research/ajedp/previous-issues

Kohnen, S., Nickels, L., & Castles, A. (2009). Assessing spelling skills and strategies: A critique of available resources. *Australian Journal of Learning Difficulties*, *14*, 113–150. doi:10.1080/19404150902783450

Lowe, K., & Bormann, F. (2012). U-Can write: Working with struggling writers. *Literacy Learning: The Middle Years*, *20*, 22–28.

Masterson, J. J., & Apel, K. (2010a). Linking characteristics discovered in spelling assessment to intervention goals and methods. *Learning Disability Quarterly*, *33*, 185–198. doi:10.1177/073194871003300307

Masterson, J. J., & Apel, K. (2010b). The Spelling Sensitivity Score: Noting developmental changes in spelling knowledge. *Assessment for Effective Intervention*, *36*, 35–45. doi:10.1177/1534508410380039

Masterson, J. J., & Apel, K. (2013a). Monitoring progress in spelling improvement. *Perspectives on Language Learning and Education*, *20*, 144–152. doi:10.1044/lle20.4.144

Masterson, J. J., & Apel, K. (2013b). Spelling assessment frameworks. In C. A. Stone, E. R. Silliman, B. J. Ehren, & G. P. Wallach (Eds.), *Handbook of language and literacy, Second edition: Development and disorders* (pp. 584–601). New York: The Guildford Press.

Merriam-Webster Elementary Dictionary. (2014). Springfield, MA: Merriam Webster Inc.

Muter, V., & Snowling, M. (1997). Grammar and phonology predict spelling in middle childhood. *Reading and Writing*, *9*, 407–425. doi:10.1023/A:1007947129554

Nagy, W. E., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology*, *98*, 134–147. doi:10.1037/0022-0663.98.1.134

Nathan, E., Stackhouse, J., Goulandris, N., Snowling, M. J., Nathan, L., Stackhouse, J., … Snowling, M. J. (2004). The development of early literacy skills among children with speech difficulties: A test of the “critical age hypothesis”. *Journal of Speech, Language, and Hearing Research*, *47*, 377–91. doi:10.1044/1092-4388(2004/031)

Olson, A. C., & Caramazza, A. (2004). Orthographic structure and deaf spelling errors: Syllables, letter frequency, and speech. *The Quarterly Journal of Experimental Psychology Section A*, *57*, 385–417. doi:10.1080/02724980343000396

Puranik, C. S., & Al Otaiba, S. (2012). Examining the contribution of handwriting and spelling to written expression in kindergarten children. *Reading and Writing*, *25*, 1523–1546. doi:10.1007/s11145-011-9331-x

Quick, N., & Erickson, K. (2015, November). Spelling derivationally complex words: An error classification system for measuring progress and planning treatment. Paper presented *American Speech-Language and Hearing Association Annual Convention*, Denver, CO.

Richards, T. L., Aylward, E. H., Berninger, V. W., Field, K. M., Grimme, A. C., Richards, A. L., & Nagy, W. (2006). Individual fMRI activation in orthographic mapping and morpheme mapping after orthographic or morphological spelling treatment in child dyslexics. *Journal of Neurolinguistics*, *19*, 56–86. doi:10.1016/j.jneuroling.2005.07.003

Richards, T. L., Berninger, V. W., & Fayol, M. (2009). fMRI activation differences between 11-year-old good and poor spellers' access in working memory to temporary and long-term orthographic representations. *Ournal of Neurolinguistics*, *22*, 327–353. doi:10.1016/j.jneuroling.2008.11.002

Ritchey, K., & Speece, D. (2006). From letter names to word reading: The nascent role of sublexical fluency. *Contemporary Educational Psychology*, *31*, 301–327. doi:10.1016/j.jneuroling.2008.11.002

Rittle-Johnson, B., & Siegler, R. S. (1999). Learning to spell: Variability, choice, and change in children's strategy use. *Child Development*, *70*, 332–348. doi:10.1598/RRQ.43.3.1

Sharp, A. C., Sinatra, G. M., & Reynolds, R. E. (2008). The development of children's orthographic knowledge: A microgenetic perspective. *Reading Research Quarterly*, *43*, 206–226. doi:10.1598/RRQ.43.3.1

Silliman, E. R., Bahr, R. H., & Peters, M. L. (2006). Spelling patterns in preadolescents with atypical language skills: phonological, morphological, and orthographic factors. *Developmental Neuropsychology*, *29*, 93–123. doi:10.1207/s15326942dn2901_6

Strattman, K., & Hodson, B. (2005). Variables that influence decoding and spelling in beginning readers. *Child Language Teaching and Therapy*, *21*, 165–190. doi:10.1191/0265659005ct287oa

Treiman, R., & Bourassa, D. C. (2000). The development of spelling skill. *Topics in Language Disorders*, *20*, 1–18. doi:10.1191/0265659005ct287oa

Walker, J., & Hauerwas, L. B. (2006). Development of phonological, morphological, and orthographic knowledge in young spellers: The case of inflected verbs. *Reading and Writing*, *19*, 819–843. doi:10.1007/s11145-006-9006-1

Wolter, J. A., & Apel, K. (2010). Initial acquisition of mental graphemic representations in children with language impairment. *Journal of Speech, Language, and Hearing Research*, *53*, 179–195. doi:10.1044/1092-4388(2009/07-0130)

Wolter, J. A., Wood, A., & D'zatko, K. W. (2009). The influence of morphological awareness on the literacy development of first-grade children. *Language, Speech, and Hearing Services in Schools*, *40*, 286–298. doi:10.1044/0161-1461(2009/08-0001)

Wood, C., & Terrell, C. (1998). Preschool phonological awareness and subsequent literacy development. *Educational Psychology*, *18*, 253–274. doi:10.1080/0144341980180301

CHAPTER 3: A MULTILINGUISTIC ANALYSIS OF SPELLING AMONG CHILDREN WHO ARE HARD OF HEARING

Introduction

Children with hearing loss were not traditionally considered to be at risk for spelling difficulty due to misconceptions that spelling is reliant upon visual memory, a domain of relative strength (Hoemann, Andrews, Florian, Hoemann, & Jensema, 1976). Nevertheless recent studies document that children with various degrees of hearing loss demonstrate difficulty with spelling, despite earlier identification and advances in hearing technologies (Apel & Masterson, 2015; Park, Lombardino, & Ritter, 2013). This is not surprising given that contemporary understandings of spelling suggest that it requires the sophisticated integration of multiple linguistic skills including phonological, orthographic, and morphological awareness (Apel & Masterson, 2001; Devonshire & Fluck, 2010; Garcia, Abbott, & Berninger, 2010; Masterson & Apel, 2010a, 2010b; Rittle-Johnson & Siegler, 1999). The impact of profound hearing loss on these linguistic skills is well documented (Ambrose, Fey & Eisenberg, 2012; Halle & Duchesne, 2015; Harris & Terlektsi, 2011), and there is evidence that even mild to moderately severe sensorineural hearing loss negatively impacts performance in linguistic areas that inform spelling, such as phonological (Ambrose, Unflat Berry, Walker, Harrison, Oleson, & Moeller, 2014; Briscoe, Bishop & Norbury, 2001; Gibbs, 2004), orthographic (Halliday & Bishop, 2005; Most, Aram, & Andorn, 2006) and morphological awareness (Koehlinger, Van Horne, & Moeller, 2013; Tomblin, Harrison, Ambrose, Walker, Oleson, & Moeller, 2015). Therefore, reported deficits in these linguistic skills underpinning spelling may result in both quantitative and qualitative differences in spelling ability among CHH.

Although the connection between profound hearing loss and spelling difficulties has been documented extensively (Apel & Masterson, 2015; L. M. Bowers, Dostal, McCarthy, Schwarz, & Wolbers, 2016; Hayes, Kessler, & Treiman, 2011), only one known study has examined spelling abilities of children with mild to severe hearing loss, referred to collectively as children who are hard of hearing (CHH). Park et al. (2013) examined spelling performance of 21 students with mild to moderate sensorineural hearing loss that ranged in age from 7 to 12 years and compared their performance to 30 age-matched peers with dyslexia and 29 peers with typical hearing. The CHH performed more poorly than their typically developing peers, but better than the students with dyslexia. Despite the restricted range of hearing loss in this study, the severity of hearing loss was negatively correlated with spelling skill. While no other known studies have studied spelling among CHH with permanent hearing loss, two large-scale epidemiological studies have investigated the influence of temporary, fluctuating hearing loss. An early study reported that a history of otitis media with effusion (OME) between 2 and 4 years had minor effects on spelling at age 7 (Peters, Grievink, van Bon, van den Bercken, & Schilder, 1997). Similarly, a history of OME into late childhood was found to predict significantly poorer performance in spelling at both 11 and 13 years of age, even after controlling for gender and SES (Bennett, Haggard, Silva, & Stewart, 2001). While acknowledging that these studies cannot control for the frequency, duration or severity of OME, and the associated fluctuations in hearing loss, the results do suggest that even temporary bouts of attenuated hearing can impact spelling performance. Taken together, these findings suggest that more sustained and severe hearing loss potentially contributes to greater spelling deficits.

Spelling is a Language Skill

As documented by a national survey, student memorization of a weekly spelling lists was reported to formerly dominate educational practice in spelling (Graham et al., 2008), suggesting that spelling was misperceived as a rote memory skill. A more recent survey in Canada reported that the majority of teachers used published programs with lists targeting specific orthographic patterns, but these programs do not identify the types of knowledge that children require to progress in spelling (Doyle, Zhang & Mattatall, 2015). Contemporary research supports language-based views of spelling as even beginning spellers bring phonological, orthographic, and morphological awareness to the task of spelling (Bourassa & Treiman, 2008, 2013; Treiman & Cassar, 1994, 1996; Wolter, Wood, & D'zatko, 2009). Some researchers have therefore purported that spelling development is non-linear, requiring increasingly coordinated integration of multiple forms of linguistic awareness. In particular, phonological, orthographic, and morphological awareness are all featured in Triple Word Form Theory (Berninger, Abott, et al., 2006) and Repertoire Theory (Masterson & Apel, 2010a). Phonological awareness, the understanding of the internal sound structure of words, promotes successful phoneme to grapheme encoding required in spelling (Bourassa & Treiman, 2001). Orthographic awareness, including stored mental representations of specific grapheme sequences as well as generalized awareness of orthographic patterns of sound representation, facilitates the use of statistical patterns in spelling (Apel, 2011; Deacon, Conrad, & Pacton, 2008; Wolter & Apel, 2010). Morphological awareness, which includes the graphemic representation of morphemes as well as the rules for affixing morphemes (Apel, 2014), provides additional information regarding statistically predictable patterns and facilitates systematic storage into the mental lexicon

(Berninger, Raskind, Richards, Abbott, & Stock, 2008; Carlisle, 1988; Deacon, 2008; Nagy, Berninger, & Abbott, 2006).

As spelling builds on oral language skills, it stands to reason that CHH might struggle with spelling due to the documented deleterious effects of all degrees of hearing loss on a variety of language outcomes (Ambrose et al., 2014; Koehlinger et al., 2013; Tomblin et al., 2015). Despite advances in hearing technology, issues with audibility, low pass filtering and spectral degradation result in reduced or limited access to oral language input for CHH (Moeller & Tomblin, 2015). The limited access hypothesis proposes that this reduced access to linguistic input results in a reduction in cumulative 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 to spoken language puts CHH at long-term risk for delays in linguistic areas that support spelling, with cascading effects on their ability to represent spoken language in a written form. While phonology, orthography, and morphology are integrated and attended to in a coordinated way during spelling, they are discussed here separately for clarity.

Phonological awareness

Phonological awareness includes the awareness of and the ability to manipulate the sound structure of a language (Stahl & Murray, 1994). Phonological awareness skills are typically measured in tasks that require students to omit, (What is “wind” without “/d/”? = “win”) blend (What does “s” - “un” make? = “sun”), or make more complex manipulations (Say “winter” without “/t/” = “winner”) of sounds.

Given that auditory access supports the development of phonological awareness, the presence of hearing loss compromises the development of sensitivity to the sound structure of language despite early identification and hearing aid fitting. While the purpose of hearing aids is to amplify speech sounds to an audible level, there are perceptual limitations imposed by the sensory deficit in the presence of noise, distance and reverberation, as well as by the hearing aid bandwidth for the high-frequency region of the speech spectrum (Stelmachowicz, Pittman, Hoover, & Lewis, 2001, 2002). Furthermore, CHH are not reported to achieve full-time use of hearing aids during the critical period of phonological development in the first year of life (Walker et al., 2013). Although hearing aids may support auditory function in CHH, they may not allow CHH to extract sufficient quantity or quality of auditory information to develop appropriate phonological skills. Reduced or limited access to oral language is presumed to result in underspecified or less robust phonological representations. Limitations in auditory access may also compromise the development of the perceptual weighting strategies that support sensitivity to critical acoustic properties that are unique to the phonological space of a particular language (e.g., Japanese listeners do not attend to shifts in third-formant transitions that differentiate "l" and "r" while English listeners do) (Nittrouer & Burton, 2005). It has also been suggested that limited access may interfere with the process of lexical restructuring observed among children with typical hearing, whereby initial holistic representations of words become more highly segmented phonemic structures over time (Nittrouer, Sansom, Low, Rice, & Caldwell-Tarr, 2014).

Several studies have documented reduced phonological awareness among CHH. Briscoe et al. (2001) reported that CHH with mild to moderate hearing loss aged 5 to 10 years performed significantly poorer on phonological awareness tasks when compared to children with typical hearing. Furthermore, CHH who were classified as performing poorly on phonological tasks of discrimination, awareness, and production tended to have more severe hearing loss. Gibbs

(2004) also reported poorer outcomes in phonological awareness among 7- to 9-year-old children with moderate hearing loss. In contrast with Briscoe's (2001) study, hearing thresholds did not differentiate the subgroup of students who demonstrated age level phonological awareness from those with difficulties. More recently Ching and Cupples (2015) evaluated three phonological awareness tasks among a large sample (*n* = 101) of 5-year-old children with a wide range of hearing loss that utilized hearing aids and cochlear implants. Due to floor effects with elision and blending tasks, only data from the sound-matching task were analyzed. Although the average standard scores were below age-appropriate levels, they were within 1 standard deviation of the mean for the normative sample. These studies indicate that while some CHH develop age appropriate phonological awareness skills, a significant number continue to demonstrate less sensitivity to the sound structure of the language and, in some cases, this appears to relate to the severity of the hearing loss.

The noted deficits in phonological awareness among CHH confirm the logical notion that phonemic awareness is largely contingent upon auditory input. The degraded acoustic input associated with sensory deficit is presumed to result in phonological representations that are less clearly specified, underspecified, or unstable. Deficiencies in phonological awareness may have significant implications for language skills that may be more sensitive to phonological structure, like spelling. After controlling for the degree of hearing loss and expressive vocabulary knowledge, Park et al. (2013) reported that phonological processing skills were moderately related to spelling performance among CHH. Given the wealth of research documenting the strong relationship between phonemic awareness and spelling among children with normal hearing (Ball & Blachman, 1991; Bruck & Treiman, 1990; Lundberg, Olofsson, & Wall, 1980;

Sunseth & Bowers, 2002), CHH may be at a distinct disadvantage in their use of phonology to support their spelling.

Orthographic Awareness

Orthographic awareness refers to the implicit and explicit knowledge of representing spoken language in written form, including both the stored mental graphemic representations and orthographic pattern knowledge (Apel, 2011). Orthographic awareness is typically evaluated through a variety of tasks, including real-word reading, decoding (e.g., reading pseudowords), spelling, choice ("Does *akke* or *noop* look more like a real word?), and verification ("Is it *neat* or *neet*?) tasks.

The presence of hearing loss could influence the development of mental graphemic representations as well as orthographic pattern knowledge. The acquisition of mental graphemic representations and orthographic pattern knowledge are hypothesized to be supported by phonological recoding (Ehri, 1992; Share, 1995), as children link letters and letter sequences to sounds as they successfully read new words. Therefore, difficulties experienced by CHH in developing phonological representations and oral language may result in downstream effects on orthographic awareness and subsequently, spelling and literacy in general.

The few studies that have examined orthographic awareness among CHH have primarily focused on reading or decoding tasks. Neither Briscoe and colleagues (2001) nor Gibbs (2004) reported significant differences between CHH in the primary grades and normal hearing controls on tasks tapping nonword reading, real word identification, or real word reading, although wide individual variation was reported. Halliday and Bishop (2005) found that children with mild to moderate hearing loss aged 6 to 13 years demonstrated equivalent nonword reading abilities but significantly poorer performance in single word reading scores compared to children with normal hearing, despite having age-appropriate scores. In contrast, among a group of kindergarten children comprised primarily of children with moderate to severe hearing loss, the findings of Most and colleagues (2006) indicated significantly poorer word recognition, letter identification and orthographic knowledge.

While further investigation is needed among children with mild to severe hearing loss, these studies suggest that orthographic awareness may be more compromised among CHH at the beginning stages of literacy. Furthermore, while group differences may decrease over the primary grades, at least some CHH continue to exhibit difficulties. Therefore, elementary-age CHH may have milder difficulties in orthographic awareness compared to other domains of linguistic knowledge, but these may still be significant enough to influence spelling performance over time.

Morphological Awareness

Morphological awareness includes implicit and explicit understanding of spoken and written morphemes including knowledge of: (a) the ways affixes change the meaning of base words, (b) the rules for adding affixes to base words, and (c) the ways groups of words that share the same base word are related (Apel, 2014). These abilities are typically measured using blending (*manage + ment = management)*, segmenting (*helpful = help + ful)*, analogy (*mess:messy, sun:____)*, reading, and/or production ("Farm. The cow belongs to the _____") tasks (Apel, 2014; Apel, Diehm, Apel, 2013).

Reduced access to the auditory-linguistic signal likely influences the development of morphological awareness among CHH. Some inflectional morphemes are composed of phonemes in the high-frequency region of the speech spectrum (possessive *'s*, third person *–s*, and plural *–s*), which may not be audible due to limitations in hearing aid bandwidth

(Stelmachowicz et al., 2001, 2002). The resulting reduction in input frequency may contribute to delays in acquisition of these morphemes and broader morphological awareness. Furthermore, vocabulary delays secondary to hearing loss may also influence the development of derivational morphology (word formation and principles governing the use of affixes), as has been observed for children with typical hearing (Weisleder & Fernald, 2013).

The studies that have examined morphology in CHH have been limited to inflectional morphology. An early study noted that CHH are 4.5 times more likely to make an error on morphemes of verb voice and tense compared with peers who are typically developing (Elfenbein, Hardin-Jones, & Davis, 1994). In contrast, Norbury and colleagues (2001) found that children with mild to moderate hearing losses (5–11 years old) performed similarly to age-matched hearing peers as well as vocabulary-matched hearing peers on plural and verb–tense agreement, but that the younger children struggled more than the older CHH. In subsequent studies, deficits in grammatical morphemes and verb tense and agreement have been reported among preschool children with hearing loss that were early and late identified, as well as among early elementary school children and adolescents (Delage & Tuller, 2007; Koehlinger et al., 2013; McGuckian & Henry, 2007; Moeller et al., 2010). Severity of hearing loss is also correlated with morphosyntactic deficits among adolescents (Delage & Tuller, 2007), and it explains variations in finite verb morphology performance among preschool children (Koehlinger et al., 2013).

Although greater breadth is needed in the investigation of morphological awareness among CHH, the results of these studies indicate that many struggle with at least one area of morphological awareness, productive inflectional morphology. This reduced awareness of morphological structure among CHH may result in inefficient storage of mental graphemic representations, difficulty with word formation during writing, and reduced ability to use semantic relatedness to inform spelling and word selection (Garcia et al., 2010).

Phonological, Orthographic, and Morphological Influences on the Spelling Errors of Children who are Deaf

Despite the growing body of research regarding the multilinguistic contributions to spelling among children with normal hearing, very little is known about the influence of these linguistic sources of knowledge on spelling errors among groups of children with any severity of hearing loss. As no known studies have investigated categorical errors among CHH, the only information currently available comes from studies that exclusively or primarily included children with more profound degrees of hearing loss. With the exception of two studies (Colombo, Arfé, & Bronte, 2012; Harris & Terlektsi, 2011), most studies that have investigated phonological spelling errors report that the spelling errors of children who are deaf are much less likely to be phonologically plausible than the errors made by their peers with normal hearing (Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Harris & Moreno, 2004; Hayes, et al., 2011; Olson & Caramazza, 2004; Sutcliffe, Dowker, & Campbell, 1999). Within Olson and Caramazza's study (2004), this error trend continued over time, as only 20% of spelling errors made by college students who are deaf were categorized as phonologically plausible compared to 83% of errors made by high school students with normal hearing. Phonological errors were also the most frequent type of error in one multilinguistic analysis of spelling errors among middle school students who are deaf and hard of hearing (L. M. Bowers, McCarthy, Schwarz, Dostal, & Wolbers, 2014).

Several earlier studies that investigated orthographic errors concluded that students who are deaf make transposition errors more frequently than children with typical hearing (Aaron et al., 1998; Leybaert, 2000; Leybaert & Alegria, 1995), but a more recent study found no group differences (Hayes, et al., 2011). In addition to transpositions, omissions (Aaron, Keeta, Boyd, Palmatier, & Wacks, 1998) and substitutions (Padden, 1993) were also reported as frequently occurring among students who are deaf. Apel and Masterson (2015) reported significantly more omissions and illegal orthographic errors among children with cochlear implants. In contrast, college students who are deaf were reported to have similar proportions of "illegal" syllable or word position errors, compared to high school peers with typical hearing (Olson & Caramazza, 2004). Nevertheless, the deaf college students had a higher proportion of deletions and fewer substitutions.

Morphological errors in spelling have been less frequently included in analyses of spelling errors among children with profound degrees of hearing loss. Morphological spelling errors were twice as frequent among French students who are deaf, but a developmental progression was also observed, as students increasingly used morphological knowledge in spelling (Leybaert & Alegria, 1995). Apel and Masterson (2015) reported that children with cochlear implants were more likely to omit affixes or spell them illegally compared to normal hearing peers. Morphological errors of incorrect use or tense were also found to be common among a group of deaf and hard of hearing middle school students (L. M. Bowers et al., 2014)

The existing research suggests that students with more profound degrees of hearing loss have underlying deficits in all of the linguistic domains that inform spelling, as evidenced by direct assessment of those domains as well as by the phonological, orthographic, and morphological errors reported in their misspelled words. In the absence of studies of categorical spelling errors among CHH, there is reason to suspect that documented deficits in phonological, orthographic and morphological awareness may also impact spelling among CHH. Reported and hypothesized spelling deficits among children with a full range of hearing loss may be explained by the lexical quality hypothesis. The lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2001) proposes that literacy skills are supported by the quality of one's word knowledge, as informed by multiple forms of linguistic awareness. Extending the lexical quality hypothesis to spelling in CHH, limited auditory access secondarily results in deficiencies in phonology, orthography, and morphology, which in turn influences the quality of lexical representations and subsequent spelling performance. Each of these underlying linguistic deficits among CHH is likely to have an impact on spelling ability, but a more nuanced analysis of spelling among CHH is required before speech-language pathologists will be able to prescriptively strengthen lexical awareness and better support spelling achievement among this population.

Purpose of Study

Although the spelling skills of students with more profound degrees of hearing loss are well documented, very little is known about CHH, who comprise nearly 75% of children with bilateral hearing loss (Centers for Disease Control and Prevention, 2014). Furthermore, despite the fact that contemporary views of spelling recognize the significant contributions of phonological, orthographic, and linguistic awareness, no studies have simultaneously examined the influence of these domains on the spelling errors of CHH. Additional studies are needed to determine if CHH are at risk for spelling difficulty, and if so, to determine if the degree of auditory access influences spelling performance. While correlations between the degree of unaided hearing and spelling ability have been examined in one study (Park et al., 2013), no studies have investigated the impact of aided audibility (i.e., the degree of access to the speech spectrum provided by hearing aids). If a relationship exists between the degree of auditory access and spelling performance, then under assumptions of consistent hearing aid use, the degree of access to the speech spectrum provided by amplification is likely to be more informative than the degree of access in the absence of amplification. The primary purpose of this study was to examine these assumptions by comparing the spelling skills of CHH to children with normal hearing (CNH), using a multilinguistic analysis framework. The goal was to determine if these groups of students differed in their spelling performance and to examine their respective spelling errors in an effort to gain insight into the type of linguistic awareness children with mild to moderately severe hearing loss bring to the task of spelling. The secondary purpose was to examine the impact of aided audibility on the number and type of categorical errors made by CHH.

The research questions were as follows:

1. Do CHH differ from CNH in the proportion of total spelling errors they produce?
2. Do CHH differ from CNH in the distribution of categorical spelling errors based on the total number of opportunities or total number of errors within writing samples?
3. Do CHH with different degrees of aided audibility differ in the distribution of categorical spelling errors based on the total number of opportunities or the total number of errors within writing samples?

Methods

Participants

The 281 participants in this study were drawn from a larger, ongoing, multi-site longitudinal study, Outcomes of School-Age Children who are Hard of Hearing (OSACHH) during 2013-2016. Participants had no significant additional disabilities, and each had at least one parent whose primary language is English. The sample included 188 (66.9%) CHH and 93 (33.1%) CNH. The participants ranged in age from 7;5 to 11;6 , with the average age among

CHH of 9.25 (*SD* = 1.02) and an average age among CNH of 8.95 (*SD* = 1.08). All children with hearing aids had bilateral sensorineural or permanent conductive hearing loss and a better-ear pure tone average (BE-PTA) of 7.5 dB HL through 90 dB HL (*M* = 45.99, *SD* = 15.09). The typically developing children with normal hearing demonstrated 4 frequency PTAs ≤ 20 dB HL in both ears.

The sample was evenly divided between females (*n* = 139, 49.5%) and males (*n* = 142, 50.5%). There was a bias toward higher levels of maternal education, as nearly two-thirds reported having completed a bachelor's degree or higher (*n* = 171, 61.57%). The racial/ethnic diversity across the two groups was also biased towards children whose parents identified them as white/Caucasian (*n* = 226, 80.4%). Selected demographics of the participants and their families are reported in Table 3.1.

Procedures

The data were collected as part of a larger language and academic battery of the OSACHH study, and assessments were conducted at research laboratories, in facilities near the home of the child, or in specially designed vans. The Writing Samples subtest of the Woodcock Johnson Tests of Cognitive Ability, Third edition (WJ-III; Woodcock, McGrew, & Mather, 2001) was included in the test battery. This subtest is designed to measure a student's ability to write sentences when provided a verbal and picture cue. Initial items require students to write words to complete cloze sentences, the next set of items require students to write a sentence that complies with the examiner's directions, and the final set of items require students to write sentences with more complex constructions. The number of items administered to each student varied based on achievement of basal and ceiling performance. For the purpose of the current

Table 3.1 Selected Demographics of Participants and Their Families

		CHH		CNH	
		n	%	n	%
Gender	Male	104	(55.3%)	38	(40.9%)
	Female	84	(44.7%)	55	(59.1%)
Grade	2nd	109	(58.0%)	60	(64.5%)
	4th	79	(42.0%)	33	(35.5%)
Hearing Loss	Mild	56	(29.8%)	-	-
	Moderate	93	(33.1%)	-	-
	Moderate-Severe	39	(20.7%)	-	-
Mother's Education	High School	27	(14.6%)	14	(15.9%)
	Some College	46	(24.9%)	13	(14.8%)
	Bachelor	58	(31.4%)	32	(33.0%)
	Graduate	54	(29.2%)	29	(30.4%)
	Unreported	-	-	5	(5.9%)
Race	Asian	3	(1.6%)	4	(4.3%)
	Black	8	(4.3%)	7	(7.5%)
	Hispanic	5	(2.7%)	0	(0%)
	Native American	2	(1.1%)	0	(0%)

Multi-Racial	10	(5.3%)	6	(5.7%)
Other	5	(2.7%)	2	(2.2%)
White	153	(81.4%)	73	(78.5%)
Unreported	2	(1.1%)	0	(0%)

study, a secondary language and spelling analysis was conducted on these writing samples. All examiners were trained to administer the subtest in accordance with the test manual.

Linguistic Analysis at the Sentence and Word Level. Irrespective of basal and ceiling rules of the WJII, all collected data was included in the analyses in order to take advantage of the maximum number of words spelled by participants. First, the writing samples were glossed (i.e., the use of context to infer target word), transcribed and analyzed in the Systematic Analysis of Language Transcripts (SALT; Miller & Iglesias, 2012) software in order to describe the linguistic complexity and quality of the writing samples. Conventional SALT procedures were utilized, and the following measures were computed: T-Units (number of clauses with all subordinate clauses and nonclausal phrases), Mean Length of Utterance in Morphemes (MLU-M; average number of words and grammatical morphemes per utterance), Subordination Index (SI; ratio of the total number of clauses to the total number of T-Units), Number of Total Words (NTW; number of total words in sample), Number of Different Words (NDW; number of different words in sample), and Type Token Ratio (TTR; ratio of different words among the total number of words).

Next, all words were manually entered into a spreadsheet, glossed and transcribed. Each word was coded as correct, misspelled, or unanalyzable. Unanalyzable data were removed from further analysis and included illegible words that could not be identified from sentential context, as well as abbreviations and numerals (n = 178, 0.64%). Each analyzable word was coded for one of four types of morphological complexity: monomorphemic, compound/contracted, inflected, and derived. Monomorphemic words include words with a single morpheme (e.g. "stamp", "tractor"). Compound words include single units composed of two free morphemes (e.g. "cowboy", "flowerpot"). Contracted words include single units composed of two words in sequence with omitted sounds and letters (e.g. "we'll", "he's", "they're"). Inflected words include nouns or verbs with inflectional morphemes that modify number or tense (e.g. boy*s*, work*ed*, hitt*ing*). Derived words include roots with one or more affixes (e.g. *dis*trust*ful*, invest*ment*). In addition, the U-Score, an indicator of both the frequency and dispersion of the word in written English, was determined for each word, as reported in the Educators' Word Frequency Guide (Zeno, Ivens, Millard, & Duvvuri, 1995).

Spelling Analysis. Each misspelled word was coded for spelling accuracy using the POMplexity for Roots and Affixes (Quick & Erickson, 2015). This approach separately examines each morpheme of a misspelled word and yields frequency distributions of categorical errors in the domains of phonology, orthography, and morphology for each morpheme.

Reliability

To assess reliability of the SALT transcriptions, two undergraduate students in speech-language pathology were trained to code writing samples using conventional procedures. After achieving .85 or greater reliability with the primary researcher in training, SALT coders separately transcribed 110 (39%) randomly selected samples. Interrater reliability was high between the researcher and each coder across all individual measures (T-Units, MLU-M, NDW, NTW, TTR, and SI) with a mean reliability of .97 (range = .95 - .99).

To assess reliability, three graduate students in speech-language pathology were trained to transcribe and code words. After achieving reliability greater than .85 in training, the research assistants separately transcribed and coded 90 (32%) randomly selected samples. Reliability was conducted in two phases. First all words were transcribed, glossed, coded for spelling accuracy, and coded for morphological word type. Interrater reliability between the researcher and each trained coder was high for these measures with a mean intraclass correlation coefficient of .98 (range = .96 – 1.0). After consensus was reached for disagreements in the above measures, all misspelled words were coded using the POMplexity for Roots and Affixes and intraclass correlation coefficients were computed to assess interrater reliability. Interrater reliability between the researcher and each coder was high across all six individual measures (Root Phonology, Root Orthography, Root Morphology, Affix Phonology, Affix Orthography, Affix Morphology) with a mean intraclass correlation coefficient of.97 (range = .94 – 1.0). All secondary coders were blind to the hypotheses of the study as well as the hearing status of the children.

Measures

Spelling Assessment. The POMplexity for Roots and Affixes was used to separately analyze the roots and affixes of each misspelled word. Analysis of word spelling was multidimensional. The phonological, orthographic and morphological components of each morpheme of a misspelled word were separately evaluated, receiving one categorical ranking for each linguistic area. The ordering of categorical errors was intended to reflect increasing levels of severity within each linguistic domain, with higher rankings indicating increasing levels of severity. However, limited evidence is available regarding the developmental progression of phonological, orthographic, and morphological spelling errors. Therefore data collected from this study will be used to empirically evaluate the ranking order in the future but for now, the data are reported categorically without reference to ranking. Appendix 1 provides a definition of each linguistic category and examples to accompany the criteria for phonological, orthographic and morphological rankings with the POMplexity for Roots and Affixes.

Phonological plausibility (i.e., misspellings that could be phonologically be pronounced according to the target word) and orthographic legality (i.e., orthographic representations that don't violate rules of English orthography) were determined in a similar manner to the criteria outlined by Olson and Caramazza (2004). Phonological plausibility was determined by first identifying phoneme to grapheme(s) correspondences within the misspelled word. Next, to determine if the misspelling could be produced like the target, exemplars of grapheme or grapheme sequences in similar positions were sought within the 36,000-word Merriam-Webster's Elementary Dictionary (2014). Words were deemed phonologically plausible if an exemplar was identified. In order to examine orthographic legality, words were first parsed into word-initial consonants or vowels (e.g., "*a*dventure", "*scr*atch"), word-medial onsets ("ca*m*e*r*a", "wor*sh*ip"), word medial-vowels ("l*ea*p", "b*a*l*a*nc*i*ng"), word-medial codas ("hu*s*band", "ha*r*vest") and word-final consonants or vowels ("se*nt*", "adventu*re*"). When examples of orthographic letter or letter sequences in these categories could not be identified among words in the dictionary, the response was considered illegal (e.g., word-initial: "*bc*one" for "balancing", word-final: "de*llt*" for "belt", word-medial:fl*iyi*ng" for "flying").

Morphological plausibility was ascribed when the target morpheme was spelled with minor orthographic errors that reflect awareness of the target morpheme. These errors included spacing errors ("some where" for "somewhere") and transpositions ("toegther" for "together"), as well as alternate orthographic representations that demonstrated morphological constancy

(Bourassa & Treiman, 2008). Alternative orthographic representations included the range of spelling patterns for a target morpheme that occurred in root, inflected and derived word forms. For example, the spelling patterns of "motive" and "motiv", or "stop" and "stopp" were deemed alternative orthographic representations of the same target morpheme (motive → motivating; stop → stopping). Therefore the misspelled roots of "motiveating" and "stoping" were coded as morphologically plausible.

Grouping of Morphemes for Analysis

Given that the POMplexity for Roots and Affixes separately analyzes all morphemes of misspelled words, and that writing samples included words of different morphological word types (monomorphemic, compound/contracted, inflected, derived), data for nine separate morpheme categories were generated. It was decided to group morphemes that shared similar characteristics into one of three categories: monomorphemic roots, multimorphemic roots, and affixes. Monomorphemic roots included single morpheme words as well as both morphemes of compound and contracted words. Multimorphemic roots included the bases of both inflected and derived words, and affixes included inflectional affixes, prefixes and suffixes. Words with three morphemes (e.g. teach-er-s, blind-fold-ed) were retained, but only the first two morphemes were coded and included in the analysis, due to low frequency of occurrence (n = 150, .06%).

Aided Audibility Groupings

Aided audibility was measured based on the better ear average Speech Intelligibility Index, or the proportion of the amplified speech spectrum for stimuli presented at 65 dB that was audible to CHH when wearing their hearing aids. Further details about SII calculations can be found in McCreery et al., (2015). In the current study, the better ear Speech Intelligibility Index of CHH ranged from .265 to .99, with a median of .765. The median was used to divide children into “low” and “high” aided audibility groups to examine if the degree of auditory access to the speech spectrum influenced spelling performance.

Relative Proportion Calculations

The distribution of categorical errors was separately calculated among the total number of opportunities and the total number of misspellings produced by a participant. Thus, spelling errors were standardized in two ways. Standardizing the frequency of each categorical error based on the total number of opportunities allowed student misspellings to be weighted according to the total number of contributions, while standardizing the frequency of each categorical error based on the total number of errors equalized misspellings among the participants. First, frequency counts of categorical errors among each morpheme group (monomorphemic roots, multimorphemic roots, affixes) were standardized by the total number of times the participant produced a morpheme from that same morpheme group within the writing sample. Next, the frequency count of categorical errors within each morpheme group was standardized by the total number of misspelled words within each morpheme group.

Statistical Comparisons and Significance

Statistical analyses were completed using IBM SPSS Statistics version 24.0 for Mac. As spelling was evaluated in the context of written samples, there was significant variety in the number of spelling opportunities and the number of misspelled morphemes among individual participants. The nature of the categorical data resulted in substantive departures from normality as well as multiple outliers with the potential to exert excessive influence on group comparisons. In addition, some error categories had limited to no frequency counts. Rather than exclude data from the analysis that might reflect infrequent but important variations, all applicable error types were retained. Mann-Whitney U tests were employed for between-group comparisons of rank-ordered categorical data. When the groups demonstrated significantly different ranked distributions but the same median, the mean rank is also provided.

When performing confirmatory studies, adjustment for multiple testing is recommended to strengthen the proof of a predefined hypothesis (Bender & Lange, 2001); however, in the case of exploratory studies the use of multiple comparison adjustments increases the possibility of overlooking an important and meaningful result (Rothman, 1990). As this is an exploratory study, and the first categorical analysis of spelling errors among CHH, results that achieved the 0.05 significance level in the absence of adjustments for multiple testing were preserved. Additionally, those results that survived an adjustment for multiple comparisons are also noted so that future studies can evaluate the scientific strength of all results. In determining effect sizes it was decided to use *r* as proposed by Cohen (1988) because Cohen's effect size estimate is not influenced by sample size (Fritz, Morris, & Richler, 2012).

Results

The first step in analysis was to examine whether students with and without hearing loss demonstrated group equivalence in performance across each of the lexical and syntactical measures of their writing samples. The determination of equivalence was necessary to establish that the writing samples of the groups were similar so that any differences in spelling between groups could be attributed to spelling rather than the overall quantity or complexity of the writing sample. Although assumptions of normality were violated, visual inspection of histograms, box plots, and q-q plots indicated similar distributions of scores between groups. Pretest equivalence was measured with 6 independent samples *t*-tests, and none were significant at the .05 level. As reported in Table 3.2, CHH consistently performed slightly lower than CNH, but there were no significant differences between groups across all measures of lexical and syntactical quantity and diversity.

Table 3.2 Measures of Lexical and Syntactical Quantity and Quality of Writing Samples

	CHH		CNH	
Measure	*M*	*(SD)*	*M*	*(SD)*
T-Units	15.35	*(4.86)*	16.19	*(5.48)*
MLU Morpheme	6.53	*(2.13)*	6.55	*(2.04)*
Number of Different Words	64.10	*(30.06)*	68.20	*(32.34)*
Number of Total Words	96.54	*(51.52)*	102.14	*(54.58)*
Type Token Ratio	.68	*(.06)*	.69	*(.06)*
Subordination Index	1.06	*(.20)*	1.06	*(.25)*

Comparison by Hearing Status

Proportion of Total Spelling Errors and Average U-Score. A total of 27,647 words were analyzed, including 2,597 misspelled words. Individual writing samples ranged from 3 to 315 words, with an average of 98 words, while the number of errors ranged from 0 to 41, with an average of 7 misspelled words. Independent samples *t*-tests were used to determine if there were group differences in the percentage of spelling errors based on the total number of words or morphological word type (monomorphemic, compound, inflected, derived). The mean percentage of spelling errors among all words was significantly lower among CHH (M = .09 +/- .08) than among CNH (M = .13 +/- .11) [$t(140.370) = -2.332$, $p < .05$, $d = -.33$], but it was of a small effect size. The mean percentage of spelling errors of monomorphemic words was significantly lower among CHH (M = .06 +/- .07) than among CNH (M = .13 +/- .11), [$t(136.849) = -2.90$, $p < .05$, $d = -.31$], but also of a small effect size. No significant between-group differences were found in the mean percentage of spelling errors among compound [$t(224) = -.757$, p > .05, $d = -.11$], inflected [$t(278) = -1.006$, p > .05, $d = -.13$], or derived words [$t(141) = -.056$, p > .05, $d = -.01$].

Comparisons of the average U-Score of words were conducted to evaluate group equivalence in the difficulty of targeted words. A higher U-score indicates that words are more frequent and more widely dispersed in written English. Independent samples *t*-tests indicated significant between-group differences in the average U-Score for monomorphemic words [$t(17{,}281.912) = 2.272$, p < .05, $d = .03$] of negligible effect size, with CHH producing a higher mean U-score (M = 12,501 +/- 20,226) than CNH (M = 11,893 +/- 19,540), which means CHH chose to write words that were slightly more frequent and disperse than the CNH. No significant between-group differences were found in the average U-Scores among compound [$t(731) = .220$, p > .05, $d = -.09$], inflected [$t(2{,}353) = .282$, p > .05, $d = .05$] or derived words [$t(308) = .944$, p > .05, $d = .13$]. The percentage of total and misspelled words among different morphological word types, as well as the average U score is reported in Table 3.3.

Based on frequency of occurrence, a similar ranking order of categorical errors was observed across morpheme categories and regardless of hearing status. The most frequent categorical errors in phonology included plausible errors, with substitutions or omissions following in frequency, and with additions and multiple phonological errors occurring least often. In the domain of orthography, legal orthographic errors accounted for nearly 2/3 of all errors. The categories of legal orthographic errors in order of highest to lowest frequency included consonants, vowels and finally errors with both consonants and vowels. Minor or illegal orthographic errors occurred least often. The most frequent morphological error, accounting for approximately half of the monomorphemic and multimorphemic root errors, was

Table 3.3 Percentage of Total and Misspelled Words and Average U-Score among Different Morphological Word Types

		CHH (*n* = 188)		CNH (*n* = 93)	
Word Status	Measure	*M*	*(SD)*	*M*	*(SD)*
All Words	Average U-Score	11,008	*(19,387)*	10,417	*(18,678)*
	% Misspelled	9.5%	*(8.1)*	12.5%	*(11.4)*
Monomorphemic	% of Total Words	88.1%	*(3.5)*	88.5%	*(9.3)*
	Average U-Score	12,501	*(20,226)*	11,892	*(19,540)*
	% Misspelled	6.1%	*(6.8)*	8.6%	*(9.9)*
Compound	% of Total Words	2.3%	*(1.7)*	2.6%	*(2.6)*
	Average U Score	386	*(655)*	449	*(692)*
	% Misspelled	38.1%	*(39.0)*	42.2%	*(38.7)*
Inflected	% of Total Words	8.5%	*(2.3)*	9.2%	*(2.7)*
	Average U Score	167	*(1865)*	97	*(147)*
	% Misspelled	34.1%	*(29.2)*	37.9%	*(30.1)*
Derived	% of Total Words	.9%	*(1.1)*	.8%	*(1.0)*
	Average U Score	58	*(89)*	47	*(85)*
	% Misspelled	48.6%	*(42.1)*	49.0%	*(44.7)*

morphologically plausible errors, morpheme substitutions, and homophone substitutions. A departure from similar between-group orders in categorical errors was noted among affixes. Omitted morphemes comprised the most frequent morphological error among CHH, but only the third most frequent for CNH. Morpheme or non-morpheme substitutions were next highest in occurrence while homophones or morphologically plausible errors were least frequent. Table 3.4 reports the number and percentage of categorical errors.

Table 3.4 Number and Percentage of Categorical Errors in Each Morpheme Group according to Hearing Status

			Monomorphemic Roots		Multimorphemic Roots		Affixes	
			n	%	*n*	%	*n*	%
Correct		CHH	53	4.8%	104	21.1%	325	65.8%
		CNH	43	6.2%	54	18.6%	198	68.0%
Phonology	Plausible	CHH	619	55.6%	227	46.0%	66	13.4%
		CNH	400	57.4%	143	49.1%	50	17.2%
	Substitution	CHH	197	17.7%	49	9.9%	9	1.8%
		CNH	115	16.5%	31	10.7%	15	5.2%
	Omission	CHH	146	13.1%	46	9.3%	12	2.4%
		CNH	89	12.8%	33	11.3%	5	1.7%
	Addition	CHH	36	3.2%	18	3.6%	4	.8%
		CNH	18	2.6%	9	3.1%	1	.3%
	Multiple	CHH	63	5.7%	50	10.1%	3	.6%
		CNH	32	4.6%	21	7.2%	1	.3%
Orthography	Minor	CHH	313	28.1%	28	5.7%	24	4.9%
		CNH	171	24.5%	10	3.4%	16	5.5%
	Vowel	CHH	334	30.0%	110	22.3%	42	8.5%
		CNH	221	31.7%	84	28.9%	28	9.6%
	Consonant	CHH	235	21.1%	157	31.8%	15	3.0%
		CNH	142	20.4%	84	28.9%	13	4.5%
	V& C	CHH	135	12.1%	78	15.8%	12	2.4%

		CNH	86	12.3%	48	16.5%	14	4.8%
	Illegal	CHH	44	3.9%	17	3.4%	1	.2%
		CNH	34	4.9%	11	3.8%	1	.3%
Morphology	Plausible	CHH	232	20.8%	69	14.0%	17	3.4%
		CNH	124	17.8%	33	11.3%	7	2.4%
	Homophone	CHH	136	12.2%	4	.8%	20	4.0%
		CNH	82	11.8%	4	1.4%	16	5.5%
	Morpheme	CHH	184	16.5%	20	4.0%	26	5.3%
		CNH	98	14.1%	10	3.4%	25	8.6%
	Non-morpheme	CHH	505	45.3%	296	59.9%	31	6.3%
		CNH	350	50.2%	190	65.3%	24	8.2%
	Omitted	CHH	-	-	-	-	75	15.2%
		CNH	-	-	-	-	21	7.2%

Correct = correctly spelled morpheme in a multimorphemic misspelled word. The percent correct and percent of categorical errors for each linguistic domain equal 100%. The phonologic and orthographic categorical errors of affixes do not equal 100% because omitted affixes were excluded from phonological and orthographic analysis.

Distribution of Spelling Errors Based on Total Number of Opportunities. The next analysis compared differences in the proportion of categorical spelling errors relative to the total number of opportunities as determined by the number of monomorphemic roots, multimorphemic roots, and affixes produced within the children's writing samples. Mann-Whitney U tests were run to determine if there were differences in the proportion of categorical errors of each linguistic domain based on hearing status.

Monomorphemic Roots. In the domain of phonology, proportions of phonologically plausible errors among CHH (*Mdn* = .029) were significantly lower than CNH (*Mdn* = .040) [U = 10,556, z = 2.836, p = .005, r = .17] and proportions of phonological substitutions were significantly lower among CHH (*Mdn* =.000) than CNH (*Mdn* = .009) [*U* = 9,957, z = 2.016, *p* = .044, *r* = .12]. In the domain of orthography, proportions of legal vowel errors were significantly lower among CHH (*Mdn* = .013) than among CNH (*Mdn* = .018) [*U* = 10,003, *z* = 1.997, *p* = .046, *r* = .12]. In the domain of morphology, proportions of non-morpheme substitutions were significantly lower among CHH (*Mdn* = .015) than among CNH (*Mdn* = .026) [*U* = 10,528.5, *z* = 2.806, *p* = .005, *r* = .17].

*Multimorphemic Roots***.** In the domain of phonology, proportions of phonologically plausible errors among CHH (*Mdn* = .111) were significantly lower than CNH (*Mdn* = .153) [*U* = 9,944, *z* = 1.982, *p* = .048, *r* = .12]. In the domain of orthography, proportions of orthographic legal vowel errors were significantly lower among CHH (*Mdn* = .000) than among CNH (*Mdn* = .091) [*U* = 10,686, *z* = 3.362, *p* = .001, *r* = .20].

*Affixes***.** In the domain of phonology, proportions of phonologically plausible errors among CHH (*Mdn* = .000, Mean Rank 131.49) were significantly lower than CNH (*Mdn* = .000, Mean Rank 158.62) [*U* = 10,380.5, *z* = 3.196, *p* = .001, *r* = .12]. In the domain of orthography, proportions of legal vowel errors among CHH (*Mdn* = .000, Mean Rank = 135.29) were significantly lower than CNH (*Mdn* = .000, Mean Rank = 150.98), [*U* = 9,670.00, *z* = 2.171, *p* = .03, *r* = .13]. In the domain of morphology, proportions of morpheme substitutions among CHH (*Mdn* = .000, Mean Rank = 136.24) were significantly lower than CNH (*Mdn* = .000, Mean Rank = 149.06) [*U* = 9,491.5, *z* = 2.008, *p* = .045, *r* = .12]. Table 3.5 reports the nonparametric comparisons of categorical spelling errors based on hearing status and Table 3.6 reports the median proportions of categorical spelling errors between groups of different hearing status based on the total number of opportunities in each morpheme group.

Table 3.5 Nonparametric Comparisons (Mann-Whitney *Z* and associated two-tailed asymptotic significance) of Categorical Spelling Errors between Hearing Status Groups Based on Total Number of Opportunities in Each Morpheme Group

		Monomorphemic Roots		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		-2.369	.018**	-1.388	.165	-.805	.421
Phonology	Plausible	2.836	.005**	1.982	.048*	3.196	.001**
	Substitution	2.016	.044*	1.154	.248	1.342	.180
	Omission	.465	.642	1.363	.173	-.322	.748
	Addition	.572	.568	.060	.952	-.622	.534
	Multiple	-1.016	.309	-.396	.692	-.355	.723
Orthography	Minor	.839	.402	-.547	.584	.777	.437
	Vowel	1.997	.046*	3.362	.001**	2.171	.030*
	Consonant	1.607	.108	-.905	.365	.897	.370
	V & C	1.338	.181	1.466	.143	.453	.651
	Illegal	1.199	.231	.090	.928	.510	.610
Morphology	Plausible	.643	.520	-.493	.622	-.119	.905
	Homophone	.796	.426	.931	.352	1.326	.185
	Morpheme	.699	.484	-.185	.854	2.008	.045*
	Non-Morpheme	2.806	.005**	1.124	.261	.829	.407
	Omitted	-	-			-1.877	.060

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word. *significant at $p < .05$ level. **significant after applying Holm-Bonferroni Sequential Correction for multiple comparisons

Table 3.6 Group Comparisons of Median Proportions of Categorical Spelling Errors between Hearing Status Groups Based on Total Number of Opportunities in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		CHH	CNH	CHH	CNH	CHH	CNH
Correct		.950	.939	.769	.750	.952	.900
Phonology	Plausible	.029	.040	.111	.154	.000	.000
	Substitution	.000	.009	.000	.000	.000	.000
	Omission	.000	.000	.000	.000	.000	.000
	Addition	.000	.000	.000	.000	.000	.000
	Multiple	.000	.000	.000	.000	.000	.000
Orthography	Minor	.014	.017	.000	.000	.000	.000
	Vowel	.013	.019	.000	.091	.000	.000
	Consonant	.009	.014	.083	.038	.000	.000
	V & C	.000	.000	.000	.000	.000	.000
	Illegal	.000	.000	.000	.000	.000	.000
Morphology	Plausible	.000	.005	.000	.000	.000	.000
	Homophone	.000	.000	.000	.000	.000	.000
	Morpheme	.005	.008	.000	.000	.000	.000
	Non-Morpheme	.016	.026	.189	.222	.000	.000
	Omitted					.000	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Distribution of Spelling Errors Based on Total Number of Errors. The next analysis compared differences in the proportion of categorical spelling errors relative to the total number of errors when children produced monomorphemic roots, multimorphemic roots, and affixes in their writing samples. Mann-Whitney U tests were run to determine if there were differences in the proportion of categorical errors of each linguistic domain based on hearing status.

Monomorphemic Roots. Among monomorphemic roots, there were no significant differences between CHH and CNH in the median proportion of categorical errors in the domains of phonology, orthography or morphology.

Multimorphemic Roots. In the domain of orthography, proportions of orthographic legal vowel errors were significantly lower among CHH (*Mdn* = .000) than CNH (*Mdn* = .250) [U = 8,769.5, z = 2.879, p = .004, r = .18], but proportions of legal consonant errors were significantly higher among CHH (*Mdn* = .333) than CNH (*Mdn* = .183) [U = 6,056, z = -2.242, p = .025, r = -.14].

Affixes. In the domain of phonology, proportions of phonologically plausible errors among CHH (*Mdn* = .600) were significantly lower than CNH (*Mdn* = .625) [U = 8,599.5 z = 2.835, p = .005, r = .17]. In the domain of morphology, proportions of omitted morphemes were significantly higher among CHH (*Mdn* = .000, Mean Rank = 132.72) than among CNH (*Mdn* = .000, Mean Rank = 116.28) [U = 6,317.00 z = -2.169, p = .030, r = -.13]. Table 3.7 reports the nonparametric comparisons of categorical spelling errors based on hearing status and table 3.8 reports the median proportions of categorical spelling errors based on the total number of errors between groups of different hearing status.

Table 3.7 Nonparametric Comparisons (Mann-Whitney *Z* and associated two-tailed asymptotic significance) of Categorical Spelling Errors between Hearing Status Groups Based on Total Number of Errors in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		1.571	.116	.090	.928	-.389	.697
Phonology	Plausible	.190	.849	.741	.459	2.835	.005**
	Substitution	.660	.509	.694	.488	1.172	.241
	Omission	-.216	.829	.473	.636	-.483	.629
	Addition	.247	.805	-.158	.874	-.688	.491
	Multiple	-1.562	.118	-.735	.462	-.417	.676
Orthography	Minor	-.842	.400	-.800	.423	.583	.560
	Vowel	1.049	.294	2.879	.004**	1.838	.066
	Consonant	-.019	.985	-2.242	.025*	.636	.525
	V & C	.435	.663	.981	.327	.261	.794
	Illegal	.762	.446	-.126	.900	.459	.647
Morphology	Plausible	-.556	.578	-.655	.513	-.236	.813
	Homophone	-.047	.962	.931	.352	1.192	.233
	Morpheme	-.438	.661	-.183	.855	1.594	.111
	Non-Morpheme	1.601	.109	.785	.432	.402	.687
	Omitted					-2.169	.030*

Correct = correctly spelled morpheme in a multimorphemic misspelled word. *significant at p < .05 level. **significant after applying Holm-Bonferroni Sequential Correction for multiple comparisons

Table 3.8 Group Comparisons of Median Proportions of Categorical Spelling Errors between Hearing Status Groups Based on Total Number of Errors in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		CHH	CNH	CHH	CNH	CHH	CNH
Correct		.052	.066	.000	.000	.000	.000
Phonology	Plausible	.576	.589	.500	.500	.600	.625
	Substitution	.167	.167	.000	.000	.111	.129
	Omission	.127	.117	.000	.000	.000	.000
	Addition	.027	.031	.000	.000	.000	.000
	Multiple	.051	.031	.000	.000	.000	.000
Orthography	Minor	.314	.263	.000	.000	.250	.250
	Vowel	.284	.319	.000	.250	.250	.279
	Consonant	.226	.210	.333	.183	.167	.167
	V & C	.092	.098	.000	.000	.000	.000
	Illegal	.031	.044	.000	.000	.000	.000
Morphology	Plausible	.217	.177	.000	.000	.125	.067
	Homophone	.146	.133	.000	.000	.000	.053
	Morpheme	.178	.154	.000	.000	.125	.108
	Non-Morpheme	.404	.469	.500	.667	.429	.500
	Omitted					.000	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Comparison by Audibility Status

Proportion of Total Spelling Errors and Average U-Score. Among CHH, "low" and "high" audibility was determined by the median of the better ear average SII. Using independent samples *t*-tests, no significant differences were found in the proportion of spelling errors among all words, the proportion of spelling errors among words of different morphological status, or in the average U-Score of words between children with low and high audibility status.

Distribution of Spelling Errors Based on Total Number of Opportunities. Mann-Whitney U tests were run in each linguistic domain to determine if there were differences in categorical spelling errors between groups of CHH with low and high levels of audibility. Distributions of error scores were similar for both groups, as assessed by visual inspection of boxplots.

Monomorphemic Roots. In the domain of phonology, proportions of phonological omissions among the low audibility group (*Mdn* = .002) were significantly higher than the high audibility group (*Mdn* = .000) [U = 2,559.00, z = -2.040, p = .041, r = -.16].

Multimorphemic Roots. In the domain of phonology, proportions of phonological additions among the low audibility group (*Mdn* = .000, Mean Rank = 85.21) were significantly higher than the high audibility group (*Mdn* = .000, Mean Rank = 74.78) [U = 2,736.5, z = -2.087, p = .037, r = -.17] but proportions of multiple phonological errors among the low audibility group (*Mdn* = .000, Mean Rank = 73.07) were significantly lower than the high audibility group (*Mdn* = .000, Mean Rank= 83.53) [U = 3,445.00, z = 2.193, p = .028, r = .18].

Affixes. Among affixes, there were no significant differences between low and high audibility groups in the median proportions of categorical errors in the domains of phonology, orthography or morphology. Table 3.9 reports the nonparametric comparisons of categorical spelling errors between audibility groups and table 3.10 reports the median proportions of categorical spelling errors based on the total number of opportunities between audibility groups.

Distribution of Spelling Errors Based on Total Number of Errors. Mann-Whitney U tests were run in each linguistic domain to determine if there were differences in categorical spelling errors based on the total number of errors between groups of CHH with low and high levels of audibility. Distributions of error scores were similar for all groups, as assessed by visual inspection of a boxplot.

Monomorphemic Roots. In the domain of phonology, proportions of phonological omissions among the low audibility group (*Mdn* = .111) were significantly higher than the high audibility group (*Mdn* = .000) [U = 1,855.00, z = -2.647, p = .008, r = -.22].

Multimorphemic Roots. In the domain of phonology, median proportions of phonological additions among the low audibility group (*Mdn* = .111) were significantly higher than the high audibility group (*Mdn* = .000) [U = 2,043.50, z = -2.291, p = .022, r = -.20], but proportions of multiple phonological errors among the low audibility group (*Mdn* = .000, Mean Rank = 63.89) were significantly lower than the high audibility group (*Mdn* = .000, Mean Rank = 73.35) [U = 2,653.00, z = 2.003, p = .045, r = .17].

Affixes. Among affixes, there were no significant differences between low and high audibility groups in the median proportions of categorical errors in the domains of phonology, orthography or morphology. Table 3.11 reports the nonparametric comparisons of categorical spelling errors between audibility groups and Table 3.12 reports that median proportions of categorical spelling errors based on the total number of errors between audibility groups.

Table 3.9 Nonparametric Comparisons (Mann-Whitney *Z* and associated two-tailed asymptotic significance) of Categorical Spelling Errors between Audibility Groups Based on Total Number of Opportunities in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		.991	.322	-.596	.551	.317	.751
Phonology	Plausible	-.282	.778	.635	.525	-.568	.570
	Substitution	.847	.397	-1.363	.173	-1.271	.204
	Omission	-2.040	.041*	.478	.633	-.167	.867
	Addition	.340	.734	-2.087	.037*	.962	.336
	Multiple	-.213	.832	2.193	.028*	-.664	.507
Orthography	Minor	.196	.844	.696	.486	-1.051	.293
	Vowel	.068	.945	.006	.995	-.241	.809
	Consonant	-1.862	.063	.061	.952	-.779	.436
	V & C	-1.117	.264	.928	.353	-.485	.628
	Illegal	.094	.925	-.551	.581	.000	1.00
Morphology	Plausible	.609	.543	.349	.727	.547	.584
	Homophone	-.722	.470	1.310	.190	-1.632	.103
	Morpheme	-.754	.451	-.348	.728	-.719	.472
	Non-Morpheme	.182	.856	-.836	.403	-.915	.360
	Omitted					.545	.586

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.*significant at p < .05 level. **significant after applying Holm-Bonferroni Sequential Correction for multiple comparisons

Table 3.10 Group Comparisons of Median Proportions of Categorical Spelling Errors in Audibility Groups Based on Total Number of Opportunities in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
Audibility Group		Low	High	Low	High	Low	High
Correct		.941	.959	.800	.750	1.00	.960
Phonology	Plausible	.031	.026	.091	.111	.000	.000
	Substitution	.000	.000	.000	.000	.000	.000
	Omission	.002	.000	.000	.000	.000	.000
	Addition	.000	.000	.000	.000	.000	.000
	Multiple	.000	.000	.000	.000	.000	.000
Orthography	Minor	.013	.014	.000	.000	.000	.000
	Vowel	.011	.012	.000	.000	.000	.000
	Consonant	.011	.006	.091	.077	.000	.000
	V & C	.000	.000	.000	.000	.000	.000
	Illegal	.000	.000	.000	.000	.000	.000
Morphology	Plausible	.000	.000	.000	.000	.000	.000
	Homophone	.000	.000	.000	.000	.000	.000
	Morpheme	.005	.000	.000	.000	.000	.000
	Non-Morpheme	.014	.014	.182	.167	.000	.000
	Omitted					.000	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Table 3.11 Nonparametric Comparisons (Mann-Whitney *Z* and associated two-tailed asymptotic significance) of Categorical Spelling Errors between Audibility Groups Based on Total Number of Errors in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		-.079	.937	-1.720	.085	.488	.626
Phonology	Plausible	.803	.422	1.113	.266	-.730	.466
	Substitution	1.214	.225	-1.780	.075	-1.353	.176
	Omission	-2.647	.008**	.282	.778	-.271	.786
	Addition	.086	.932	-2.291	.022*	.923	.356
	Multiple	-.624	.532	2.003	.045*	-.741	.459
Orthography	Minor	-.142	.887	.447	.655	-1.131	.258
	Vowel	.406	.685	.132	.895	-.445	.657
	Consonant	-1.683	.092	.088	.930	-.868	.386
	V & C	-1.640	.101	.601	.548	-.606	.545
	Illegal	-.155	.876	-.646	.519	.000	1.00
Morphology	Plausible	.554	.579	.637	.524	.450	.653
	Homophone	-1.141	.254	1.310	.190	-1.741	.082
	Morpheme	-1.251	.211	-.299	.765	-.846	.397
	Non-Morpheme	.322	.747	.353	.724	-1.095	.274
	Omitted					.269	.788

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word. *significant at $p < .05$ level. **significant after applying Holm-Bonferroni Sequential Correction for multiple comparisons

Table 3.12 Median Proportions of Categorical Spelling Errors in Audibility Groups Based on the Total Number of Errors in Each Morpheme Group

		Monomorphemic Words		Multimorphemic Roots		Affixes	
Error		Low	High	Low	High	Low	High
Correct		.000	.000	.200	.000	.667	.750
Phonology	Plausible	.611	.667	.500	.500	.000	.000
	Substitution	.000	.111	.000	.000	.000	.000
	Omission	.111	.000	.000	.000	.000	.000
	Addition	.000	.000	.000	.000	.000	.000
	Multiple	.000	.000	.000	.000	.000	.000
Orthography	Minor	.250	.250	.000	.000	.000	.000
	Vowel	.250	.222	.000	.000	.000	.000
	Consonant	.222	.143	.333	.333	.000	.000
	V & C	.000	.000	.000	.000	.000	.000
	Illegal	.000	.000	.000	.000	.000	.000
Morphology	Plausible	.000	.000	.000	.000	.000	.000
	Homophone	.000	.000	.000	.000	.000	.000
	Morpheme	.005	.000	.000	.000	.000	.000
	Non-Morpheme	.014	.014	.500	.633	.000	.000
	Omitted					.000	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Discussion

Among the writing samples of all participants in the current study, nearly 90% of the words written were monomorphemic, and nearly 10% of the words were inflected. On average, across both groups, monomorphemic words were misspelled less than 10% of the time, derived words nearly 50% of the time, and compound and inflected words approximately 33% of the time. This increased difficulty with multimorphemic words has also been reported among children with normal hearing and cochlear implants (Apel & Masterson, 2015). These morphologically complex words can involve phonological and orthographic changes at the morpheme boundary (e.g. get vs. getting, vacate vs. vacation), making them more difficult to spell. The greater difficulty with compound words in comparison to monomorphemic words is in contrast to the results reported by Hayes et al., (2011), who reported that students with cochlear implants and normal hearing more accurately spelled compound words than non-compound words in a word dictation task. This discrepancy may be due to differences in the assessment context. In the current study, many student misspellings of compound words were due to spacing errors (i.e., spelling a compound word as two words *some where)* in their writing samples, which are errors that are less likely to occur when students are presented with single word units in a dictation task.

When investigating group performance, the writing samples of CHH were comparable to those of typical hearing peers using traditional measures of linguistic complexity provided by SALT (i.e., T-Units, MLU-M, TTR, NTW, NDW and SI). Group equivalence strengthens the conclusions that any differences in the proportions or distributions of categorical spelling errors associated with hearing status reported in the current investigation are not related to significant quantitative or qualitative group differences in the writing samples. When examining morphological status, similar group distributions were also observed in the proportion of words coded as monomorphemic, compound, inflected and derived.

CHH demonstrated better accuracy than CNH when spelling monomorphemic words, and equivalent performance when spelling compound, inflected or derived words. These results differ from the poorer spelling reported by Park et al. (2013) among a group of students with mild to moderate hearing loss during a dictation task. These contrasting results may in part reflect different assessment contexts. In written compositions, poor spellers are more likely to select familiar words and avoid taking vocabulary risks (Kohnen, Nickels, & Castles, 2009), whereas in a dictation task word targets are more tightly controlled. In our study, the words CHH wrote had a statistically significant but negligibly higher average U-Score, which possibly reflect a less robust vocabulary or compensation for spelling difficulty, as words with higher U-Scores may be easier to spell because they are more frequently encountered. In addition, while the students in this study had a similar mean Pure Tone Average ($M = 45.98$ dB HL, $SD = 15.09$) to those in the study by Park et al., ($M = 46.7$ dB HL, $SD = 14.1$), they had a younger average age of identification ($M = 11$ months, $SD = 19$ vs. $M = 35$ months, $SD = 18$ months) and a younger average age at which they were fitted with hearing aids ($M = 21$ months vs $M = 45$ months) (Park & Lombardino, 2012). Given that earlier age of identification and hearing aid fitting have a positive impact on oral language outcomes (Fitzpatrick, Durieux-Smith, Eriks-Brophy, Olds, & Gaines, 2007; Yoshinaga-Itano, 2003), it is reasonable to assume that early detection and intervention may also have cascading benefits in written language outcomes in the domain of spelling. The sample of the current study was also biased toward higher levels of maternal education, which may be associated with better spelling outcomes, as has been reported in some studies examining other language outcomes in this population (Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Fitzpatrick et al., 2007; Sarant, Holt, Dowell, Rickards, & Blamey, 2009).

In addition to documenting overall spelling accuracy, it was of interest to investigate whether the distribution of categorical errors made by CHH was similar to that of children with typical hearing. A number of differences were observed, but they were all of weak effect size (Cohen, 1988). When examining the distribution of categorical errors based on the total number of opportunities children had to produce a particular morpheme, two patterns emerged. First, consistent with most studies of children with profound degrees of hearing loss, CHH consistently produced fewer phonologically plausible errors, and this pattern was observed across all morpheme types (Aaron et al., 1998; Harris & Moreno, 2004; Hayes et al., 2011; Sutcliffe et al., 1999). These results suggest that phonological representations may be incomplete for some CHH, resulting in a reduced ability to make sound-to-spelling mappings.

Second, CHH consistently produced fewer legal vowel errors than CNH across all morpheme types, and this finding has several possible explanations. Some researchers argue that orthographic development is contingent upon the development of phonemic awareness (Ehri, 1980; Share, 1995). Among CHH, phonemic awareness of vowels may be stronger relative to consonants because they are easier to perceive due to their lower frequency and higher intensity. Therefore, it is possible that CHH are more inclined to attend to the components of words for which they have stronger auditory access, resulting in stronger phoneme to grapheme linkages for vowels and more complete stored mental images for vowels in words. In addition, vowels are more orthographically salient, as only six primary vowels assume nearly thirty-nine percent of the character spaces (Mayzner & Tresselt, 1965). Therefore this limited, but highly frequent set of graphemes may provide sufficient orthogonal significance to attract the visuo-orthographic attention to the components of words that are also more acoustically prominent for CHH. Other researchers suggest that orthographic awareness is not wholly contingent upon phonemic awareness (Apel, 2009). The observed orthographic strength of vowel representation in the presence of reduced sensitivity to phonological mappings during spelling also reflects the possibility that orthographic awareness is an independently developing skill. A fourth possible explanation for group differences in the current study may be related to word effects. Compared to CNH, the words produced by CHH had a significantly U-Score, which may have facilitated improved orthographic representations of vowels due to increased familiarity with the word.

When examining the distribution of categorical errors based on the total number of errors, between-group differences were only found for multimorphemic words. The roots of multimorphemic words only differed in legal orthographic categorical errors. CHH produced a significantly lower proportion of legal vowel errors and a significantly higher proportion of legal consonant errors. As was suggested above for vowels, the relationship between phonemic awareness and the development of orthographic knowledge may also be influencing the representation of consonants. Consonants are more difficult for children with hearing loss to perceive due to their high frequencies (e.g., /s/, /z/), or low intensity (e.g. /f/, /θ/), particularly in the presence of noise. Because consonants are more likely to be underspecified, CHH may experience more difficulty creating letter-sound bonds, leading to more legal consonant errors and fewer vowel errors than children with normal hearing.

As for affixes, one important finding in this study is that school-aged CHH had a higher proportion of omissions in inflectional morphology. Given the data that shows CHH have difficulty with grammatical morphology in spoken language at preschool and school ages (Koehlinger et al., 2013; McGuckian & Henry, 2007), it is not entirely surprising that morphological difficulties persist in the spelling of school-age children. It has been hypothesized that poorer perception of speech in background noise secondary to cochlear damage among children with hearing loss results in a Morpheme in Noise Perception Deficit, whereby less than optimal perception of some grammatical morphemes in oral language negatively impacts the acquisition of these morphemes (Hammer, 2010). In addition, these smaller, less stressed units tend to be shorter in duration, placing even greater demands on the speed of processing (Hsieh, Leonard, & Swanson, 1999). When students do not correctly use morphological elements in expressive language, they are more likely to struggle with morphology in written language (Scott & Windsor, 2000).

When comparing CHH with different levels of aided audibility, the only significant differences in the proportion of categorical errors occurred in the domain of phonology, with the distributions based on the total number of opportunities being mirrored in the total number of errors. Children with poorer audibility demonstrated more single phonological errors than children with better aided- audibility, including more omissions in misspelled monomorphemic roots and more phonological additions in misspelled multimorphemic roots. Both of these results indicate an expected relationship between poorer aided hearing and increased phonological errors in misspelled words. This confirms 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 contrast to these results, children with poorer aided audibility also had significantly fewer misspelled words containing multiple phonological errors. This finding is difficult to explain, and may simply be an artifact of this sample of children. It is also important to note that although CHH had a significantly higher proportion of omitted bound morphemes compared to CNH, there were no differences based on levels of aided audibility. This finding suggests that regardless of the degree of aided audibility, CHH are at increased risk for difficulty with inflectional morphology in their spelling, as they are often unstressed and in the part of the speech spectrum where most children with hearing loss have reduced hearing.

Implications

The superior spelling accuracy demonstrated by CHH in comparison to their peers with typical hearing in the current investigation was unexpected, but very encouraging. These results suggest that the population of CHH formerly described as "our forgotten children" (Davis, 1990), is now being redefined by a newly emerging generation of CHH who have benefitted from the legislative efforts to achieve early identification and intervention among this population. The sample bias toward earlier ages of identification, earlier ages of hearing aid fitting, and higher levels of maternal education may serve as protective factors for spelling development in this population, and it is important to note that these demographics may not be representative of the larger population of CHH.

Despite contemporary research documenting the linguistic underpinnings of spelling, the nonlinguistic approach of word memorization paired with weekly spelling tests continued to dominate spelling instruction in the United States at least through the last decade (Graham et al., 2008). The different spelling profiles that emerged from this study suggest that individual children can bring different profiles of linguistic awareness to the task of spelling, challenging the continuation of this instructional norm. Qualitative assessments of spelling such as the POMplexity for Roots and Affixes can be used to identify underlying linguistic causes of spelling difficulty, design interventions that target areas of need, and evaluate the impact of intervention through pre- and post-assessment. Furthermore, the use of naturally occurring writing samples as an assessment context provides an efficient means of yielding rich data for assessing, monitoring, and supporting spelling achievement among children.

Given the unique profiles of linguistic vulnerability among CHH, those CHH who struggle with spelling may require different types of intervention compared to those children with normal hearing that struggle with spelling. First, lower proportions of phonologically plausible errors suggest that some CHH may have reduced phonological awareness, difficulty with phoneme to grapheme correspondence, or both. Therefore CHH who struggle with spelling may benefit from phonological awareness activities that require them to manipulate sounds, as well as direct instruction in specific letter-sound correspondences (Ehri et al., 2001; Wolter & Squires, 2013). Second, difficulties in productive morphology of oral expressive language among younger CHH appear to persist in the spelling of school-aged CHH. Therefore, it would be appropriate to monitor inflectional morphemes and track progress not only in oral language but in written language as well. Those CHH who struggle with bound morphemes may require direct instruction in appropriate use of affixes and generalization across written language contexts or support in self-editing written work. In addition to yielding positive outcomes in spelling, intervention targeting morphological awareness may benefit reading outcomes in this population as well (P. G. Bowers, Kirby, & Deacon, 2010; Carlisle, McBride-Chang, Nagy, & Nunes, 2010; Goodwin & Ahn, 2010; Reed, 2008).

Given the relative orthographic strength of vowel representation over consonant representation, CHH may benefit from targeted orthographic instruction that uses vowels as a bootstrapping mechanism for spelling consonants. Even young spellers with normal hearing have been reported to take advantage of vowel contexts for determining both word-initial and word-final consonants (Hayes, Treiman, & Kessler, 2006). Therefore orthographic instruction that identifies words with vowel-consonant pairings targeting the most frequently misspelled consonants may facilitate the storage of mental graphemic representations. Orthographic intervention that promotes self-discovery through word sorting activities is recommended over direct instruction in spelling rules (Wolter & Squires, 2013).

There were fewer differences in the spelling performance of children with different levels of aided hearing than expected. The lack of better spelling accuracy among children with better aided hearing may be confounded by differences in consistency of hearing aid use. Children with milder degrees of hearing loss, who have more potential for better aided hearing due to better auditory system integrity, are also reported to have less consistency in hearing aid use than their peers with more severe hearing loss (Walker et al., 2013). Therefore any spelling advantage potentially provided by *relatively better quality* in access associated with milder hearing loss, may be offset by *relatively less consistency* in access due to underutilized amplification. Better aided-audibility did result in fewer phonological errors of omissions and additions, highlighting the importance of providing optimal access to the frequencies encompassed by speech. A previous study reported that approximately one-third of CHH had inadequate aided audibility of speech, and the data suggested that many CHH could have fittings potentially optimized (McCreery et al., 2015). Taken together with the results of this study, these findings suggest the need for vigilance in regular audiological follow-up to ensure hearing aids are optimally fit, as well as the need for emphasis in parent and teacher education about the importance of consistency in hearing aid use. Appropriately fit technology and consistent technology use not only provide optimal access to the auditory-linguistic signal for the development of oral language, but for literacy and spelling as well.

Limitations and Future Directions

While assessing spelling in writing samples provides important information because this context mimics real-world demands, it also introduces a variety of limitations, including variation in sample length and lack of control over spelling targets. Furthermore, spelling performance during prose or narrative discourse may differ from highly contextualized, sentential writing tasks like that of the current study. 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 CHH.

Although better aided-audibility resulted in fewer overall phonological errors, this study did not consider the frequency and duration of hearing aid use. The oral language and spelling benefits associated with optimal access to the auditory linguistic signal provided by optimally fit hearing aids are not fully realized unless hearing aids are consistently worn during all waking hours. 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.

The spelling analysis was conducted with children who had recently completed second and fourth grades. A more nuanced analysis by grade level would provide important information about developmental changes that occur in spelling, and the different types of linguistic awareness children bring to spelling over time. Furthermore, developmental data from CNH would better inform our understanding of observed differences in the distribution of categorical errors among CHH, and whether they represent delays or differences in spelling development.

Although there were many similarities between CHH and CNH in the proportion of categorical spelling errors, potentially important information about those CHH students who struggle with spelling may be obscured by group data. Future studies should examine if 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 be used to assist in both the identification of struggling spellers, as well as the development of multilinguistic evidenced-based spelling intervention based on a multilinguistic theoretical model.

Conclusion

The present study represents the first in-depth quantitative and qualitative analysis of spelling in writing samples among school-age CHH in comparison to their peers with typical hearing. The spelling accuracy of CHH was significantly better, with statistically significant but negligible differences in the use of more frequent and dispersed words. Closer examination of categorical spelling errors suggests that CHH may rely more heavily on visuo-orthographic and visuo-morphological strategies to compensate for difficulties with phonological encoding. It is hoped that these findings may add to our understanding of the strategies CHH use to spell words, and guide the direction of future studies in developing targeted interventions for those CHH that struggle with spelling.

REFERENCES

Aaron, P. G., Keetay, V., Boyd, M., Palmatier, S., & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal*, *10*, 1–22. doi:10.1023/A:1007917929226

Ambrose, S. E., Fey, M. E., & Eisenberg, L. S. (2012). Phonological awareness and print knowledge of preschool children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *55*, 811–823. doi:10.1044/1092-4388(2011/11-0086)b

Ambrose, S. E., Unflat Berry, L. M., Walker, E. A., Harrison, M., Oleson, J., & Moeller, M. P. (2014). Speech sound production in two-year-olds who are hard of hearing. *American Journal of Speech-Language Pathology*, *23*, 91–104. doi:10.1044/2014

Apel, K. (2009). The acquisition of mental orthographic representations for reading and spelling development. *Communication Disorders Quarterly*, *31*, 42–52. doi:10.1177/1525740108325553

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, *42*, 592–603. doi:10.1044/0161-1461(2011/10-0085)

Apel, K. (2014). A comprehensive definition of morphological awareness. *Topics in Language Disorders*, *34*, 197–209. doi:10.1097/TLD.0000000000000019

Apel, K., Diehm, E., & Apel, L. (2013). Using Multiple Measures of Morphological Awareness to Assess its Relation to Reading. *Topics in Language Disorders*, *33*, 42–56. doi:10.1097/TLD.0b013e318280f57b

Apel, K., & Masterson, J. J. (2001). Theory-guided spelling assessment and intervention: A case study. *Language, Speech, and Hearing Services in the Schools*, *32*, 182–195. doi:10.1044/0161-1461(2001/017)

Apel, K., & Masterson, J. J. (2015). Comparing the spelling and reading abilities of students with cochlear implants and students with typical hearing. *Journal of Deaf Studies and Deaf Education*, *20*, 125–135. doi:10.1093/deafed/env002

Ball, E. W., & Blachman, B. A. (1991). Does phoneme awareness training in kindergarten make a difference in early word recognition and developmental spelling? *International Reading Association*, *26*, 49–66.

Bender, R., & Lange, S. (2001). Adjusting for multiple testing - When and how? *Journal of Clinical Epidemiology*, *54*, 343–349. doi:10.1016/S0895-4356(00)00314-0

Bennett, K. E., Haggard, M. P., Silva, P. A., & Stewart, I. A. (2001). Behaviour and developmental effects of otitis media with effusion into the teens. *Archives of Disease in Childhood*, *85*, 91–95. doi:10.1136/adc.85.2.91

Berninger, V. W., Abott, R. D., Thomson, J., Wagner, R. K., Swanson, H. L., Wijsman, E. M., & Raskind, W. (2006). Modeling phonological core deficits within a working memory architecture in children and adults with developmental dyslexia. *Scientific Studies of Reading*, *10*, 165–198. doi:10.1207/s1532799xssr1002

Berninger, V. W., Raskind, W., Richards, T. L., Abbott, R., & Stock, P. (2008). A multidisciplinary approach to understanding developmental dyslexia within working-memory architecture: genotypes, phenotypes, brain, and instruction. *Developmental Neuropsychology*, *33*, 707–744. doi:10.1080/87565640802418662

Bourassa, D. C., & Treiman, R. (2001). Spelling development and disability: The importance of linguistic factors. *Language, Speech, and Hearing Services in Schools*, *32*, 172–181. doi:10.1044/0161-1461(2001/016)

Bourassa, D. C., & Treiman, R. (2008). Morphological constancy in spelling: A comparison of children with dyslexia and typically developing children. *Dyslexia (Chichester, England)*, *14*, 155–169. doi:10.1002/dys

Bourassa, D. C., & Treiman, R. (2013). Spelling development and disability in English. In C. A. Stone, E. R. Silliman, B. J. Ehren, & G. P. Wallach (Eds.), *Handbook of language and literacy, second edition: Development and disorders* (pp. 569–583). New York: The Guildford Press.

Bowers, L. M., Dostal, H., McCarthy, J. H., Schwarz, I., & Wolbers, K. (2016). An analysis of deaf students' spelling skills during a year-long instructional writing approach. *Communication Disorders Quarterly*, *37*, 160–170. doi:10.1177/1525740114567528

Bowers, L. M., McCarthy, J., Schwarz, I., Dostal, H., & Wolbers, K. (2014). Examination of the spelling skills of middle school students who are deaf and hard of hearing. *The Volta Review*, *114*, 29–56. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The effects of morphological instruction on literacy skills: A systematic review of the literature. *Review of Educational Research*, *80*, 144–179. doi:10.3102/0034654309359353

Briscoe, J., Bishop, D. V. M., & Norbury, C. F. (2001). Phonological processing, language, and literacy: A comparison of children with mild-to-moderate sensorineural hearing loss and those with specific language impairment. *Journal of Child Psychology and Psychiatry*, *42*, 329–340. doi:10.1111/1469-7610.00726

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Child Psychology*, *50*, 156–178. doi:10.1016/0022-0965(90)90037-9

Carlisle, J. F. (1988). Knowledge of derivational morphology and spelling ability in fourth, sixth, and eighth graders. *Applied Psycholinguistics*, *9*, 247–266. doi:10.1017/S0142716400007839

Carlisle, J. F., McBride-Chang, C., Nagy, W., & Nunes, T. (2010). Effects of instruction in morphological awareness on literacy achievement: An integrative review. *Reading Research Quarterly*, *45*, 464–487. doi:10.1598/RRQ.45.4.5

Centers for Disease Control and Prevention. (2014). 2014 Summary of laterality, type and severity of identified hearing losses: By ear. Retrieved February 4, 2017, from https://www.cdc.gov/ncbddd/hearingloss/ehdi-data2014.html

Ching, T. Y. C., & Cupples, L. (2015). Phonological awareness at 5 years of age in children who use hearing aids or cochlear implants. *Perspectives on Hearing and Hearing Disorders in Childhood*, *25*, 48–59.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Hillsdale, N.J.: Lawrence Earlbaum Associates.

Colombo, L., Arfé, B., & Bronte, T. (2012). The influence of phonological mechanisms in written spelling of profoundly deaf children. *Reading and Writing*, *25*, 2021–2038. doi:10.1007/s11145-011-9343-6

Davis, J. M. (Ed.). (1990). *Our forgotten children: Hard of hearing pupils in the schools*. Office of Special Education and Rehabilitative Services, Office of Special Institutions. Washington, DC: [Dept. of Education].

Deacon, S. H. (2008). The metric matters: Determining the extent of children's knowledge of morphological spelling regularities. *Developmental Science*, *11*, 396–406. doi:10.1111/j.1467-7687.2008.00684.x

Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian Psychology*, *49*, 118–124. doi:10.1037/0708-5591.49.2.118

Delage, H., & Tuller, L. (2007). Language development and mild-to-moderate hearing Loss: Does language normalize with age? *Journal of Speech, Language, and Hearing Research*, *50*, 1300–1313. doi:10.1044/1092-4388(2007/091)

Devonshire, V., & Fluck, M. (2010). Spelling development: Fine-tuning strategy-use and capitalising on the connections between words. *Learning and Instruction*, *20*, 361–371. doi:10.1016/j.learninstruc.2009.02.025

Doyle, A., Zhang, J., & Mattatall, C. (2015). Spelling instruction in the primary grades: Teachers' beliefs, practicies, and concerns. *Reading Horizons*, *54*, 1–34. Retrieved from http://scholarworks.wmich.edu/reading_horizons/

Ehri, L. C. (1980). The development of orthographic images. In *Cognitive processes in spelling* (pp. 311–338). London: Academic Press.

Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–143). Hillsdale, N.J.: Lawrence Erlbaum.

Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghoub-zadeh, Z., Shanahan, T., … Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the National Reading Panel's meta-analysis. *Reading Research Quarterly*, *36*, 250–287. doi:10.3102/00346543071003393

Elfenbein, J. L., Hardin-Jones, M. A., & Davis, J. M. (1994). Oral communication skills of chidren who are hard of hearing. *Journal of Speech and Hearing Research*, *37*, 216–226. doi:10.1044/jshr.3701.216

Fitzpatrick, E. M., Crawford, L., Ni, A., & Durieux-Smith, A. (2011). A descriptive analysis of language and speech skills in 4- to 5-yr-old children with hearing loss. *Ear and Hearing*, *32*, 605–616. doi:doi.org/10.1097/AUD.0b013e31821348ae

Fitzpatrick, E. M., Durieux-Smith, A., Eriks-Brophy, A., Olds, J., & Gaines, R. (2007). The impact of newborn hearing screening on communication development. *Journal of Medical Screening*, *14*, 123–131. doi:10.1258/096914107782066248

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology*, *141*, 2–18. doi:10.1037/a0024338

Garcia, N. P., Abbott, R. D., & Berninger, V. W. (2010). Predicting poor, average, and superior spellers in grades 1 to 6 from phonological, orthographic, and morphological, spelling, or reading composites. *Written Language & Literacy*, *13*, 61–98. doi:10.1075/wll.13.1.03gar

Gibbs, S. (2004). The skills in reading shown by young children with permanent and moderate hearing impairment. *Educational Research*, *46*, 17–27. doi:10.1080/0013188042000178791

Goodwin, A. P., & Ahn, S. (2010). A meta-analysis of morphological interventions: Effects on literacy achievement of children with literacy difficulties. *Annals of Dyslexia*, *60*, 183–208. doi:10.1007/s11881-010-0041-x

Graham, S., Morphy, P., Harris, K. R., Fink-Chorzempa, B., Saddler, B., Moran, S., & Mason, L. (2008). Teaching spelling in the primary grades: A national survey of instructional practices and adaptations. *American Educational Research Journal*, *45*, 796–825. doi:10.3102/0002831208319722

Halle, F., & Duchesne, L. (2015). Morphosyntactic skills in deaf children with cochlear implants: A systematic review. *Canadian Journal of Speech-Language Pathology and Audiology*, *39*, 260–297.

Halliday, L. F., & Bishop, D. V. M. (2005). Frequency discrimination and literacy skills in children with mild to moderate sensorineural hearing loss. *Journal of Speech, Language, and Hearing Research*, *48*, 1187–1204. doi:10.1044/1092-4388(2005/083)

Hammer, A. (2010). *The acquisition of verbal morphology in cochlear-implanted and specific language impaired children* (Doctoral dissertation). University of Leiden, Leiden, Netherlands.

Harris, M., & Moreno, C. (2004). Deaf children's use of phonological coding: Evidence from reading, spelling, and working memory. *Journal of Deaf Studies and Deaf Education*, *9*, 253–268. doi:10.1093/deafed/enh016

Harris, M., & Terlektsi, E. (2011). Reading and spelling abilities of deaf adolescents with cochlear implants and hearing aids. *Journal of Deaf Studies and Deaf Education*, *16*, 24–34. doi:10.1093/deafed/enq031

Hayes, H., Kessler, B., & Treiman, R. (2011). Spelling of deaf children who use cochlear implants. *Scientific Studies of Reading*, *15*, 522–540. doi:10.1080/10888438.2010.528480

Hayes, H., Treiman, R., & Kessler, B. (2006). Children use vowels to help them spell consonants. *Journal of Experimental Child Psychology*, *94*, 27–42. doi:10.1016/j.jecp.2005.11.001

Hoemann, H. W., Andrews, C. E., Florian, V. A., Hoemann, S. A., & Jensema, C. J. (1976). The spelling proficiency of deaf children. *American Annals of the Deaf*, *121*, 489–493.

Koehlinger, K. M., Van Horne, A. J. O., & Moeller, M. P. (2013). Grammatical outcomes of 3- and 6-year-old children who are hard of hearing. *Journal of Speech, Language, and Hearing Research*, *56*, 1701–1714. doi:10.1044/1092-4388(2013/12-0188)

Kohnen, S., Nickels, L., & Castles, A. (2009). Assessing spelling skills and strategies: A critique of available resources. *Australian Journal of Learning Difficulties*, *14*, 113–150. doi:10.1080/19404150902783450

Leybaert, J. (2000). Phonology acquired through the eyes and spelling in deaf children. *Journal of Experimental Child Psychology*, *75*, 291–318. doi:10.1006/jecp.1999.2539

Leybaert, J., & Alegria, J. (1995). Spelling development in deaf and hearing children: Evidence for use of morpho-phonological regularities in French. *Reading and Writing*, *7*, 89–109. doi:10.1007/BF01026949

Lundberg, I., Olofsson, Å., & Wall, S. (1980). Reading and spelling skills in the first school years predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology*, *21*, 159–173. doi:10.1111/j.1467-9450.1980.tb00356.x

Masterson, J. J., & Apel, K. (2010a). Linking characteristics discovered in spelling assessment to intervention goals and methods. *Learning Disability Quarterly*, *33*, 185–198. doi:10.1177/073194871003300307

Masterson, J. J., & Apel, K. (2010b). The Spelling Sensitivity Score: Noting developmental changes in spelling knowledge. *Assessment for Effective Intervention*, *36*, 35–45. doi:10.1177/1534508410380039

Mayzner, M. S., & Tresselt, M. E. (1965). Tables of single-letter and digram frequency counts for various word-length and letter position combinations. *Psychonomic Monograph Supplements*, *1*, 13–32. Retrieved from http://psycnet.apa.org/psycinfo/1967-02842-001

McCreery, R. W., Walker, E. A., Spratford, M., Bentler, R., Holte, L., Roush, P., … Moeller, M. P. (2015). Longitudinal predictors of aided speech audibility in infants and children. *Ear and Hearing*, *36*, 24S–37S. doi:10.1097/AUD.0000000000000211

McGuckian, M., & Henry, A. (2007). The grammatical morpheme deficit in moderate hearing impairment. *International Journal of Language and Communication Disorders*, *42*, 17–36. doi:10.1080/13682820661171555

Merriam-Webster Elementary Dictionary. (2014). Springfield, MA: Merriam Webster Inc.

Miller, J. F., & Iglesias, A. (2012). Systematic Analysis of Language Transcripts (SALT). Middleton; WI: SALT Software; LLC.

Moeller, M. P., McCleary, E., Putman, C., Tyler-Krings, A., Hoover, B., & Stelmachowicz, P. G. (2010). Longitudinal development of phonology and morphology in children with late-identified mild-moderate sensorineural hearing loss. *Ear and Hearing*, *31*, 625–635. doi:10.1097/AUD.0b013e3181df5cc2

Moeller, M. P., & Tomblin, J. B. (2015). An introduction to the outcomes of children with hearing loss study. *Ear & Hearing*, *36*, 4S–13S. doi:10.1097/AUD.0000000000000210

Most, T., Aram, D., & Andorn, T. (2006). Early literacy in children with hearing loss: A comparison between two educational systems. *Volta Review*, *106*, 5–28. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Nagy, W. E., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology*, *98*, 134–147. doi:10.1037/0022-0663.98.1.134

Nittrouer, S., & Burton, L. T. (2005). The role of early language experience in the development of speech perception and phonological processing abilities: Evidence from 5-year-olds with histories of otitis media with effusion and low socioeconomic status. *Journal of Communication Disorders*, *38*, 29–63. doi:10.1016/j.jcomdis.2004.03.006

Nittrouer, S., Sansom, E., Low, K., Rice, C., & Caldwell-Tarr, A. (2014). Language structures used by kindergartners with cochlear implants: Relationship to phonological awareness, lexical knowledge and hearing loss. *Ear and Hearing*, *35*, 506–518. doi:10.1097/AUD.0000000000000051

Norbury, C. F., Bishop, D. V. M., & Briscoe, J. (2001). Production of English Finite Verb Morphology: A Comparison of SLI and Mild-Moderate Hearing Impairment. *Journal of Speech, Language, and Hearing Research*, *44*, 165–178. doi:10.1044/1092-4388(2001/015)

Olson, A. C., & Caramazza, A. (2004). Orthographic structure and deaf spelling errors: Syllables, letter frequency, and speech. *The Quarterly Journal of Experimental Psychology Section A*, *57*, 385–417. doi:10.1080/02724980343000396

Padden, C. A. (1993). Lessons to be learned from the young deaf orthographer. *Linguistics and Education*, *5*, 71–86. doi:10.1016/S0898-5898(05)80005-1

Park, J., & Lombardino, L. J. (2012). A comparison of phonological processing skills of children with mild to moderate sensorineural hearing loss and children with dyslexia. *American Annals of the Deaf*, *157*, 289–306. doi:10.1353/aad.2012.1621

Park, J., Lombardino, L. J., & Ritter, M. (2013). Phonology matters: a comprehensive investigation of reading and spelling skills of school-age children with mild to moderate sensorineural hearing loss. *American Annals of the Deaf*, *158*, 20–40. doi:10.1353/aad.2013.0013

Perfetti, C. A. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading*, *11*, 357–383. doi:10.1080/10888430701530730

Perfetti, C. A., & Hart, L. (2001). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189–214). Philadelphia, PA: John Benjamins Publishing Company.

Peters, S. A., Grievink, E. H., van Bon, W. H., van den Bercken, J. H., & Schilder, A. G. (1997). The contribution of risk factors to the effect of early otitis media with effusion on later language, reading, and spelling. *Developmental Medicine and Child Neurology*, *39*, 31–9.

Quick, N., & Erickson, K. (2015, November). Spelling derivationally complex words: An error classification system for measuring progress and planning treatment. Paper presented at *American Speech-Language and Hearing Association Annual Convention*, Denver, CO.

Rittle-Johnson, B., & Siegler, R. S. (1999). Learning to spell: Variability, choice, and change in children's strategy use. *Child Development*, *70*, 332–348. doi:10.1598/RRQ.43.3.1

Rothman, K. J. (1990). No adjustments are needed for multiple comparisons. *Epidemiology*, *1*, 43–46. doi:10.1097/00001648-199001000-00010

Sarant, J. Z., Holt, C. M., Dowell, R. C., Rickards, F. W., & Blamey, P. (2009). Spoken language development in oral preschool children with permanent childhood deafness. *Journal of Deaf Studies and Deaf Education*, *14*, 205–217. doi:10.1093/deafed/enn034

Scott, C. M., & Windsor, J. (2000). General language performance measures in spoken and written narrative and expository discourse of school-age children with language learning disabilities. *Journal of Speech and Hearing Research*, *43*, 324–339. doi: 10.1044/jslhr.4302.324

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, *55*, 151–218. doi:10.1016/0010-0277(94)00645-2

Stahl, S. A., & Murray, B. A. (1994). Defining phonological awareness and its relationship to early reading. *Journal of Educational Psychology*, *86*, 221–234. doi:10.1037/0022-0663.86.2.221

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., & Lewis, D. E. (2001). Effect of stimulus bandwidth on the perception of /s/ in normal- and hearing-impaired children and adults. *The Journal of the Acoustical Society of America*, *110*, 2183–2190. doi:10.1121/1.1400757

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., & Lewis, D. E. (2002). Aided perception of /s/ and /z/ by hearing-impaired children. *Ear and Hearing*, *23*, 316–324. doi:10.1097/00003446-200208000-00007

Sunseth, K., & Bowers, P. G. (2002). Rapid naming and phonemic awareness: Contributions to reading, spelling and orthographic knowledge. *Scientific Studies of Reading*, *6*, 369–400. doi:10.1207/S1532799XSSR0604

Sutcliffe, A., Dowker, A., & Campbell, R. (1999). Deaf children's spelling: Does it show sensitivity to phonology? *Journal of Deaf Studies and Deaf Education*, *4*, 111–123. doi:10.1093/deafed/4.2.111

Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and Hearing*, *36*, 76S–91S. doi:10.1097/AUD.0000000000000219

Treiman, R., & Cassar, M. (1994). What types of linguistic information do children use in spelling?: The case of flaps. *Child Development*, *65*, 1318–1337. doi:10.2307/1131501

Treiman, R., & Cassar, M. (1996). Effects of morphology on children's spelling of final consonant clusters. *Journal of Experimental Child Psychology*, *63*, 141–170. doi:10.1006/jecp.1996.0045

Walker, E. A., Spratford, M., Moeller, M. P., Oleson, J., Ou, H., Roush, P., & Jacobs, S. (2013). Predictors of hearing aid use time in children with mild-to-severe hearing loss. *Language, Speech, and Hearing Services in Schools*, *44*, 73–88. doi:10.1044/0161-1461(2012/12-0005)

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science*, *24*, 2143–52. doi:10.1177/0956797613488145

Wolter, J. A., & Apel, K. (2010). Initial acquisition of mental graphemic representations in children with language impairment. *Journal of Speech, Language, and Hearing Research*, *53*, 179–195. doi:10.1044/1092-4388(2009/07-0130)

Wolter, J. A., & Squires, K. (2013). Spelling instructional and intervention frameworks. In C. A. Stone, E. R. Silliman, B. J. Ehren, & G. P. Wallach (Eds.), *Handbook of language and literacy, Second Edition: Development and disorders* (pp. 602–616). New York: The Guildford Press.

Wolter, J. A., Wood, A., & D'zatko, K. W. (2009). The influence of morphological awareness on the literacy development of first-grade children. *Language, Speech, and Hearing Services in Schools*, *40*, 286–298. doi:10.1044/0161-1461(2009/08-0001)

Woodcock, R., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson-III*. Itasca, IL: Riverside Publishing.

Yoshinaga-Itano, C. (2003). From screening to early identification and intervention: Discovering predictors to successful outcomes for children with significant hearing loss. *Journal of Deaf Studies and Deaf Education*, *8*, 11–30. doi:10.1093/deafed/8.1.11

Zeno, S. M., Ivens, S. H., Millard, R. T., & Duvvuri, R. (1995). *The educator's word frequency guide*. Brewster, NY: Touchstone Applied Science.

CHAPTER 4: A MULTILINGUISTIC ANALYSIS OF SPELLING ERRORS AMONG CHILDREN WITH COCHLEAR IMPLANTS

Introduction

Over the last century, evolving views of English orthography and spelling have changed our understanding of the influence of deafness on the development of spelling. Traditionally, English was perceived as “unphonetic” due to sound-to-letter inconsistencies, and spelling was considered a mechanical skill acquired through repetitive rote drill and visual memorization (Templin, 1948). Because of increased reliance upon visual memory, deafness was presumed to be more conducive than normal hearing for learning orthography which lacked phonemic-graphemic regularity (Gates & Chase, 1926; Templin, 1948). Contemporary views consider English orthography to have robust morphophonemic regularity (Chomsky, 1970; Katz & Frost, 1992) and spelling to be a complex skill that requires integration of multiple domains of language (Berninger, Abbott, Nagy & Carlisle, 2010; Masterson & Apel, 2010). Given the difficulties children with cochlear implants (CIs) have acquiring oral language (Nittrouer & Caldwell-Tarr, 2016), it is reasonable to assume the presence of deafness would introduce resistance, rather than conductance, to the development of the language domain of spelling.

Spelling Accuracy of Children with Cochlear Implants

Most studies of spelling among children who are deaf have focused on children without CIs (Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Bowers, Dostal, McCarthy, Schwarz, & Wolbers, 2016; Olson & Caramazza, 2004; Sutcliffe, Dowker, & Campbell, 1999), and either did not report hearing technology use (Bowers, McCarthy, Schwarz, Dostal & Wolbers, 2014;

Wakefield, 2006) or only included a few children with CIs whose data was not separately examined (Colombo, Arfé, & Bronte, 2012; Kyle & Harris, 2006). These studies reported deficits in spelling, which is not unexpected among children who have little to no access to oral language, but the findings are not likely generalizable to children who have benefitted from improved access to the auditory-linguistic signal afforded by CI technology.

Only a few studies have investigated the spelling accuracy of children with CIs in comparison to peers with normal hearing. Thirty-nine children with CIs aged 6 to 12 years, most of whom received a cochlear implant by 72 months, were compared to reading-matched hearing peers with typical hearing (Hayes, Kessler, & Treiman 2011). All of the children primarily used spoken language for communication, and attended mainstreamed classrooms or special oral schools for the deaf. After controlling for age and reading comprehension, children with CIs demonstrated equivalent performance in spelling compared to their typical hearing peers. In addition, spelling accuracy among both groups was similarly influenced by the same word factors; all children had more difficulty spelling words that were longer, not compound, and included atypical sound-spelling correspondences.

Another study compared French students with CIs in grades 2 to 5 with reading-matched peers who had normal hearing (Bouton & Cole, 2014). The age of implantation among children with CIs ranged from 2 years, 3 months to 8 years, 2 months. Using inter-quartile range scores, group performance was compared on words with regular and irregular phoneme to grapheme correspondence. While 80% of the children with CIs demonstrated equivalent performance to hearing peers on words that have irregular phoneme to grapheme correspondence, only 60% of children with CIs had equivalent performance on words with regular phoneme to grapheme correspondence. These results suggest that spelling accuracy among children with CIs may differ based on word factors such as phoneme to grapheme consistency.

More recently, Apel and Masterson (2015) compared nine children with CIs (average age 8;11) with nine typically hearing peers matched for reading level. Seven of the children with CIs primarily used spoken language and three utilized total communication. On a standardized single word dictation test, children with CIs performed significantly poorer than children without hearing loss. In addition, graded word lists were examined using the Spelling Sensitivity System, which assigns point values to the phonemes of base words, juncture changes (changes at morpheme boundary of multimorphemic words), and affixes. The four-point scale evaluates whether elements are correct, orthographically legal, orthographically illegal, or omitted. Children with CIs were reported to have a lower mean spelling score that was not statistically significant, but with a large effect size. While there were no significant between-group differences in the average junction score, the average affix score was significantly lower for children with CIs.

The limited research suggests that at least some students with CIs struggle with accuracy in their spelling. Contradictions in results among studies may reflect small sample sizes, differences in difficulty of word dictation lists, the wide range of ages, the wide range in the age of implantation, and differences in the metric of evaluation of linguistic ability. The paucity of information demonstrates the need for further understanding of spelling among the population of children with CIs.

Spelling is a Language Skill

Two deeply rooted and erroneous beliefs may persist among educators and continue to influence spelling practices in classrooms and often in research. First, some may consider spelling to be primarily a visual-spatial skill (Kamhi & Hinton, 2000). Second, some may still consider spelling ability to be a predetermined talent that is impervious to intervention, resulting in a predestined status of being either a "good speller" or a "poor speller" (Masterson & Apel, 2013). These erroneous beliefs would stand in contrast to brain and behavioral studies that inform views of spelling as a language skill (Berninger, Abott, Jones et al., 2006; Berninger et al., 2010; Berninger, Raskind, Richards, Abbott, & Stock, 2008; Garcia, Abbott, & Berninger, 2010; Richards, et al., 2006). Among the complex linguistic processes involved in spelling, both Triple Word Form Theory (Berninger, Abott, Thomson et al., 2006) and Repertoire Theory (Masterson & Apel, 2010) feature the triad of phonological awareness, orthographic awareness, and morphological awareness. These theories propose that all three are involved in spelling, with changes occurring in the way phonological, orthographic and morphological word forms are involved over the course of spelling development. Increased efficiency in coordination among these linguistic domains is believed to be influenced by educational instruction and approaches (Berninger et al., 2010; Masterson & Apel, 2010; Richards, Berninger, & Fayol, 2009).

Phonological awareness, the understanding of and ability to manipulate the sounds of a language, promotes successful sound-to-letter linkages required in spelling (Bourassa & Treiman, 2001). Orthographic awareness, which includes stored mental representations of words as well as permissible orthographic patterns, facilitates the abstraction of statistical patterns in spelling (Apel, 2011; Deacon, Conrad, & Pacton, 2008; Wolter & Apel, 2010). Morphological awareness, which includes knowledge of spoken or written morphemes, as well as the rules for combining morphemes (Apel, 2014), provides additional statistically predictable patterns and facilitates systematic storage into the mental lexicon (Berninger et al., 2008; Carlisle, 1988; Deacon, 2008; Nagy, Berninger, & Abbot, 2006).

Given the critical roles of phonological, orthographic and morphological awareness in supporting spelling, it is important to understand the development of these domains among children with CIs. Identifying potential strengths and weaknesses in linguistic awareness will assist clinicians in understanding the types of linguistic knowledge children with CIs bring to the task of spelling.

Linguistic Underpinnings of Spelling among Children with Cochlear Implants

Phonological Awareness. Phonological awareness includes the ability to recognize, discriminate, and manipulate the syllabic and phonological units that comprise speech (Stahl & Murray, 1994). Phonological awareness skills are typically measured in tasks that require students to segment a word into sounds, blend sounds into words, or make judgments of phonological similarity or difference.

Children with CIs experience reduced auditory access presumed to be critical to developing sensitivity to the sounds that comprise oral language. Prior to activation of the implant, children experience varying degrees and lengths of auditory deprivation. The programming strategies of the device filter the broad speech spectrum into a number of discrete frequency bands, utilizing an electrical signal that is delivered to the cochlear nerve by the implant. For children with CIs, this electrical signal differs from the acoustic wave provided by a normal hearing mechanism, and the sensorineural hearing loss compromises the functional integrity of their auditory system, impacting the quality of spectral resolution (Henry & Turner, 2003, 2005). This restricted access to oral language experienced by children with CIs may compromise or delay the development of phonological awareness due to underspecified or less robust phonological representations, compromised development of auditory sensitivity to the critical acoustic properties unique to a particular language (e.g., Japanese listeners do not attend to shifts in third-formant transitions that differentiate “l” and “r” while English listeners do) (Nittrouer & Burton, 2005), or interference with the developmental process of lexical restructuring whereby initially holistic representations become segmented into phonemic structures (Nittrouer, Sansom, Low, Rice, & Caldwell-Tarr, 2014).

Studies of phonological awareness among children with CIs suggest that phonological awareness does improve over time (James, Brown, & Brinton, 2005), but there may be a longer developmental course (Spencer & Tomblin, 2009). Similar to children with normal hearing, children with CIs tend to acquire awareness of larger units such as syllables prior to awareness of smaller units such as phonemes (James, et al., 2005; James, Rajput, Brinton, & Goswami, 2008; Ziegler & Goswami, 2005). Children with CIs also demonstrate some phonological awareness skills on par with normal hearing peers such as sound matching (Ching & Cupples, 2015), rhyme awareness (Johnson & Goswami, 2010; Spencer & Tomblin, 2009) and syllable counting (Nittrouer et al., 2014). Nevertheless, many studies have indicated that children with CIs tend to perform more poorly than normal hearing peers on phonological awareness tasks related to phonemic structure (Ambrose, Fey, & Eisenberg, 2012; Desjardin, Ambrose, & Eisenberg, 2008; Dillon, de Jong, & Pisoni, 2012; James et al., 2008; Johnson & Goswami, 2010; Nittrouer et al., 2014).

Given that phonological awareness largely depends upon auditory input, the noted deficits in phonological awareness are not surprising. Reduced phonological awareness may have significant implications for language skills like spelling that are more vulnerable to delayed development in sensitivity to phonological structure. Given the strong correlation between phonemic awareness and spelling among children with normal hearing (Ball & Blachman, 1991; Bruck & Treiman, 1990; Lundberg Olofsson, & Wall, 1980; Sunseth & Bowers, 2002), children with CIs may be at a distinct phonological disadvantage in their use of phonology to support their spelling.

Orthographic Awareness. Orthographic awareness encompasses the understanding needed to represent oral language in written form. This implicit and explicit knowledge includes the stored mental graphemic representations of words, as well as the knowledge of rules and patterns governing the individual representation of words in print (Apel, 2011). Orthographic awareness is evaluated through a variety of tasks, including word reading, identification, decoding and spelling, as well as orthographic choice and verification.

Children with CIs may be vulnerable to difficulties developing mental graphemic representations, as well as orthographic pattern knowledge. The restricted auditory access may compromise a child's ability to phonologically recode letters to sounds that is presumed to be the process by which words are stored as mental graphemic representations (Ehri, 1992; Share, 1995). The foundations of orthographic pattern knowledge, oral language and phonological awareness, are noted areas of difficulty for this population. As the process of reading drives further progress in orthographic awareness as well as language development, persistent language and literacy challenges may represent, in part, a Matthew effect across domains; the rich get richer and the poor get poorer (Stanovich, 1986).

A variety of measures have been used to examine orthographic awareness among children with CIs. Dutch students with CIs ($n = 50$, mean age 12;9) showed equivalent performance to that of hearing peers in their ability to distinguish words from non-words (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). A small sample of students with CIs in the U.S. ($n = 9$; mean age 8;9) demonstrated no significant differences in real or nonsense word reading compared to hearing peers with matched age-equivalency reading scores (Apel &

Masterson, 2015), but a sample of secondary students demonstrated single word reading abilities approximately 3 years below chronological age (Harris & Terlektsi, 2011). Delays have been reported among preschool children with hearing aids and cochlear implants in foundational orthographic awareness skills of print knowledge and word concept knowledge (Werfel, Lund, & Schuele, 2015). In addition, children with cochlear implants demonstrated less sensitivity to word effects of typicality (i.e., how typical the spelling of a phoneme is in a written word) during spelling than children with normal hearing, which may reflect reduced awareness of orthographic pattern knowledge (Hayes et al., 2011).

These studies suggest that orthographic awareness may be vulnerable among some students with CIs; however, orthographic abilities may be mediated by the age of implant technology, age at implantation, and the consistency of use. Compared to phonological awareness, children with CIs may have milder difficulties in orthographic awareness, but these could be significant enough to impact spelling performance for at least some children. Further investigation is warranted.

Morphological Awareness. Morphological awareness includes understanding of how written and spoken language represent the smallest units of meaning. This knowledge includes recognition of: (a) morphemes in a word, (b) the rules for adding affixes, (c) the ways affixes alter meaning, and (d) the ways groups of words with the same base word are related in meaning (Apel, 2014). These abilities are typically measured using experimenter-developed tasks that require judgment, blending, segmenting, analogy, written identification, and/or production (Apel, 2014; Apel, Diehm, Apel, 2013).

The development of morphological awareness may be vulnerable among children with CIs. Given that children with cochlear implants have more difficulty with speech perception in noise than children with normal hearing, they may be less able to perceive low-salient morphological aspects of language, described as a Morpheme-In-Noise-Deficit (Hammer, 2010). Morphological elements that are less acoustically prominent such as inflectional morphemes (e.g., plural *_s,* third person singular *_s)* are more likely to be vulnerable to delayed development because of reduced uptake for establishing hypotheses regarding the morphosyntactic functions of these morphemes (Svirsky, Stallings, Lento, Ying, & Leonard, 2002).

A cross-linguistic systematic review identified 18 studies of children who were implanted prior to 3 years and revealed persistent deficits in both receptive and expressive morphological development (Halle & Duchesne, 2015). Some studies noted that fewer than 50% of the CI children reach age appropriate scores on the production of bound (e.g., walk<u>ing</u>) and free morphemes (e.g., She <u>is</u> coming) (Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012; Hammer, Coene, Rooryck, & Govaerts, 2014; Young & Killen, 2002). Difficulties with bound morphemes have been observed in language samples (Nicholas & Geers, 2007), narratives (Guo, Spencer, & Tomblin, 2013), and sentence completion tasks (Boons et al., 2013; Young & Killen, 2002).

When students do not correctly use morphological elements in expressive language, they are more likely to struggle with morphology in written language (Scott & Windsor, 2000). Furthermore, lower levels of language experience secondary to hearing loss would be expected to influence the development of derivational morphology (word formation and principles governing the use of affixes), as has been observed for vocabulary development among children with typical hearing (Weisleder & Fernald, 2013). Although more research is needed, the results of these studies indicate that many children with CIs struggle with at least one area of morphological awareness, productive inflectional morphology. Reduced awareness of morphological structure among children with CIs may result in inefficient storage of mental graphemic representations, difficulty with word formation during writing, and reduced ability to use semantic relatedness to inform spelling and word selection (Garcia, Abbott & Berninger, 2010).

In summary, the development of phonological, orthographic, or morphological awareness may be compromised among children with CIs. As each of these areas of linguistic awareness supports spelling, it is of interest to understand how particular linguistic deficits may influence spelling accuracy or the types of spelling errors produced by children.

Linguistic Influences on the Spelling Errors of Children with Cochlear Implants

Given the linguistic underpinnings of spelling, traditional spelling assessments that focus on correct versus incorrect of whole words are of limited value in determining why some students struggle with spelling. Spelling metrics that examine the qualitative nature of misspellings may provide better insight into linguistic deficiencies contributing to spelling errors. Two studies have examined categorical spelling errors of children with CIs in comparison to peers with typical hearing. Hayes and colleagues (2011) reported that elementary children with CIs did not produce a higher proportion of transposition errors, but did make significantly fewer phonologically plausible errors (defined as when all phonemes in a word are sequentially represented by a grapheme that can represent that phoneme in any position of a word in general English), even after controlling for age, reading level, parental education level, and age at implantation. Apel and Masterson (2015) reported that children with CIs were more likely to produce omissions and illegal errors while children with typical hearing were more likely to produce correct or legal spellings. Furthermore, when examining the distribution of categorical errors, there were no significant group differences with junctures, but children with CIs were more likely to omit or illegally spell affixes.

Taken together, these studies indicate potential deficiencies in all of the linguistic areas that support spelling among children with CIs. Lower proportions of phonologically plausible errors (Hayes et al., 2011) and higher proportions of omissions (Apel & Masterson, 2015) suggest difficulties with phonological awareness. Although Hayes et al., (2011) found no significant differences in transpositions, increased proportions of illegal errors in the study by Apel and Masterson (2015), suggests weakness in orthographic awareness. Finally, increased omissions and illegal errors among affixes indicate less developed morphological awareness (Apel & Masterson, 2015).

Comparisons of Morphological Status and Spelling

Few studies have investigated the impact of morphological status on the number or type of word errors. Hayes et al (2011) reported that both children with CIs and normal hearing more accurately spelled compound words than monomorphemic words when controlling for word length. Apel and Masterson (2015) found no significant differences in spelling accuracy of monomorphemic or multimorphemic words based on hearing status, but instead both groups had more difficulty with multimorphemic words.

Comparisons of Hearing Technology and Spelling

Many children with CIs or hearing aids are provided sufficient auditory-linguistic access to utilize spoken language as their primary mode of communication. Nevertheless, differences in early auditory experiences and the quality of the acoustic signal may influence spelling outcomes. Children who are candidates for CIs must demonstrate little or no benefit from amplification prior to implantation, and the earliest age of implantation is 12 months of age. Therefore, compared to children with hearing aids who can be fit with amplification soon after identification, children who receive CIs have a more protracted length of limited hearing, as well as more restricted early access, if any, to spoken language. All children with hearing loss receive degraded input due to the effects of sensorineural hearing loss, noise and reverberation (Delage & Tuller, 2007). Nevertheless, relative to children who are hard of hearing, children with CIs who have more profound degrees of hearing loss, and are therefore more likely to have greater hair cell loss and subsequent poorer integrity of the auditory mechanism. Therefore it is of interest whether differences in early auditory experiences and severity of hearing loss have an effect on literacy domains such as spelling.

Only one study has compared the spelling performance of children with hearing loss that utilize different types of technology. Harris and Terlektsi (2011) investigated 86 adolescents with hearing loss who were subdivided into three groups: those who wore hearing aids, those that received a CI before 42 months, and those that received a CI after 42 months. The children with CIs and hearing aids both had profound degrees of hearing loss, but the children with hearing aids had a less profound degree of hearing loss that was statistically significant. Across all three groups, 57% of the students primarily communicated with sign language, or utilized sign language in addition to oral language. There were no significant between-group differences in spelling scores, but students with hearing aids performed the best. Age of implantation was not found to have an effect on spelling accuracy. After excluding 14 good spellers who achieved 95% accuracy or higher, no differences were reported between groups in the number of phonetic spelling errors made (i.e., defined as containing the incorrect use of letter/s to represent a sound). Age of implantation did not have an effect on the proportion of phonetic errors. While the results of this study seem to suggest that personal hearing technology has little influence on the quantity or quality of spelling errors, the heterogeneity in communication modalities, frequency of device use, and age of identification among the participants confound the results.

Purpose of the Study

Despite differences in inclusion criteria, morphological complexity of stimuli, and metrics for categorical analysis, the above findings suggest that when compared to peers with normal hearing, at least some children with CIs either have more difficulty with spelling, different patterns of errors, or both. The present work extends earlier studies in several ways. First, given that different modes of communication and different ages of implantation have the potential to affect outcomes (Leybaert, Bravard, Sudre, & Cochard, 2009), only those children who primarily use spoken language and who received an implant by age two were retained for group analyses in the current study. Due to concerns regarding vague scoring parameters among some previous studies with this population, great care was taken to supply detailed definitions of categorical errors, and guidelines for determining them. Additionally, this spelling study expanded the number and type of categorical errors within each linguistic domain (i.e., phonological, orthographic and morphological), and simultaneously evaluated errors across all three domains rather than requiring errors to exist in mutually exclusive domains. This more nuanced approach was intended to provide better understanding of the linguistic knowledge that children with CIs brought to the task of spelling. Spelling performance was examined in the context of monomorphemic, compound, inflected, and derived words, which provided a more detailed examination of morphological complexity on spelling accuracy than previous studies.

The present study is the first investigation to compare children with CIs to both children with normal hearing and children with mild to severe hearing loss who use hearing aids. The inclusion of both comparison groups provides more understanding about the impact of different histories and degrees of auditory access on spelling performance. Finally this is the first study to examine spelling in the context of writing samples with the population of children with CIs.

While word dictation tasks better control for word targets, writing samples provide an ecologically valid assessment of student performance in tasks that mimic the demands of the classroom and everyday life.

The purpose of the current study was to conduct an in-depth quantitative and qualitative analysis of spelling errors among elementary school age children with CIs who primarily use a spoken language approach. The first goal was to determine whether there were quantitative or qualitative differences in the spelling errors between children who were implanted early (e.g. by 24 months) and age-matched peers with typical hearing. The second aim was to determine whether there were quantitative or qualitative differences in spelling errors between children who were implanted early and age-matched peers with mild to severe hearing loss that utilize hearing aids. The specific research questions were:

1. Do children with CIs differ from children with normal hearing in the proportion of total spelling errors they produce in written language samples?
2. Do children with CIs differ from children with normal hearing in the distribution of categorical spelling errors?
3. Do children with CIs differ from children who are hard of hearing in the proportion of total spelling errors they produce?
4. Do children with CIs differ from children who hard of hearing in the distribution of categorical spelling errors?

Methods

Participants

The spelling of twenty-three children with CIs, ranging in age from 7 years 3 months to 11 years, was analyzed in this study. The children with CIs were recruited through audiology clinics, special schools for the deaf, and centers that served children with hearing loss in North Carolina, Alabama, Pennsylvania and Missouri. The children with CIs primarily used spoken English, and had at least one CI. The age of identification ranged from 0 to 40 months, and the age of initial implantation ranged from 12 to 83 months. Table 4.1 reports the average chronological age, age of identification and age of cochlear implantation.

Table 4.1 Average Chronological Age, Age of Identification and Age of Implantation in Months among All Children with Cochlear Implants

	n	*M*	*SD*	Minimum	Maximum
Age		105.49	*13.57*	87	132
Age of identification		8.5	*12.2*	0	40
Age of first implantation	23	30.05	*17.52*	12	83
Age of second implantation	18	41.44	*21.65*	12	96

Approximately one quarter of the children with CIs were reported to have additional disabilities such as ADHD, apraxia, learning disabilities, and neurological disorders. Six of the children came from homes where a second language was spoken in addition to English, including Punjabi, Urdu, Bosnian ($n = 2$), Hindi and Italian. All of the children attended mainstream classrooms or special deaf schools that ascribed to an auditory-oral communication philosophy. There was a bias toward higher levels of maternal education, as more than half reported having completed a bachelor's degree or higher ($n = 12$, 52.2 %). In addition, nearly 75% of the families identified their children as white/Caucasian. Table 4.2 reports selected demographics of all children with cochlear implants and their families.

Table 4.2 Selected Demographics of All Children with Cochlear Implants and Their Families

		n	%
Gender	Male	12	52.2%
	Female	11	47.8%
Educational Setting	Mainstream	11	47.8%
	Schools for the deaf	12	52.2%
Race	Asian	4	17.4%
	Black	1	4.3%
	Other	1	4.3%
	White	17	73.9%
Maternal Education	High school	5	21.7%
	Some college	4	17.4%
	College	7	30.4%
	Graduate	5	21.7%
	Unreported	2	8.7%
Cochlear Implant Manufacturer	Advanced Bionics	5	21.7%
	Cochlear America	15	65.2%
	Med-El	2	8.7%
	Unreported	1	4.3%
Additional Disabilities	none	18	73.9%
	one or more	5	26.1%

The children with CIs differed in several important dimensions such as age of diagnosis, additional disabilities, and age of implantation, all of which can significantly affect language and literacy development. Therefore, the subset of 9 children who were implanted by 24 months and did not have additional disabilities was selected for comparison with children who have typical hearing and children who are hard of hearing. The children in comparison groups were selected from an extant database of an ongoing multi-site longitudinal study, Outcomes of School-Age Children who are Hard of Hearing (OSACHH). The OSACHH database included test information collected from 93 children with normal hearing and 188 children with mild to severe hearing loss. The data from children with normal hearing and mild to severe hearing loss was collected as part of a larger language and academic battery of the ongoing OSACHH study in sessions that averaged four to six hours. Attempts were made to match comparison groups on age, gender, and maternal education level. All participants in comparison groups were matched for age within 4 months. Gender was matched for all but one participant in the hard of hearing group. Maternal education level was matched for all but one participant in each comparison group. The children with normal hearing and the children who are hard of hearing had no significant additional disabilities, and had at least one parent whose primary language was English. Selected demographics of the participants for group comparisons are reported in Table 4.3.

The typically developing children with normal hearing demonstrated 4-frequency Pure Tone Averages ≤ 20 dB HL in both ears, and the children who are hard of hearing demonstrated mean 4-frequency Pure Tone Averages of 47.92 dB HL (+/- 9.12). Selected demographics of the children with hearing loss are reported in Table 4.4.

Table 4.3 Selected Demographics of Participants for Group Comparisons

		CI	NH	CHH
Age	7;5 – 8;2	5	5	5
	8;3 – 10;10	4	4	4
Gender	M	5	5	6
	F	4	4	3
Maternal Education	High School	2	1	1
	Some College	2	3	2
	Bachelor's	3	3	4
	Graduate	2	2	2

Table 4.4 Selected Demographics of Children with Hearing Loss for Group Comparisons

	CCI		CHH	
Age in Months	M	(SD)	M	(SD)
Age of Identification	4.0	(7.194)	21.00	(29.70)
Age of hearing aid fitting	9.17	(6.52)	14.33	(13.00)
Age of first implantation	18.22	(5.36)	-	-
Age of second implantation	31.56	(13.91)	-	-

Data collection was conducted in research laboratories, schools, community facilities, clinics, specially designed vans or the student's home. The Writing Samples subtest of the Woodcock Johnson Tests of Cognitive Ability, Third edition (WJ-III; Woodcock, McGrew, & Mather, 2001) was administered to all students in the larger OSACHH study, as well as the current study, and used as the context for investigating spelling. The data from students with CIs was completed in sessions that lasted 45 to 60 minutes, and included three assessments of linguistic awareness in addition to the WJ-III.

Linguistic Analysis at the Sentence and Word Level. The Systematic Analysis of Language Transcripts (SALT; Miller & Iglesias, 2012) software was used to provide a quantitative and qualitative description of the students' writing samples. All written responses from the WJ-III were glossed (i.e., using context to infer target word), transcribed and analyzed utilizing conventional SALT procedures, as well as those for written transcripts. The following measures were generated: Total Number of T-Units (T-Units; total number of utterances as determined by the number of independent clauses and their modifiers), Mean Length of Utterance in Morphemes (MLU-M; average number of words and grammatical morphemes per utterance), Subordination Index (SI; ratio of the total number of clauses to the total number of T-Units), Total Number of Words (TNW; total number of words in writing sample), Number of Different Words (NDW; total number of different words in writing sample), and Type Token Ratio (TTR; ratio of the number of different words to the total number of words).

After manually transcribing and glossing words, each word was coded as correct, misspelled, or unanalyzable. Unanalyzable data included illegible words that could not be identified from sentential context, as well as abbreviations and numerals (n = 15, .8%). Unanalyzable data were removed from further analysis. Each analyzable word was coded for morphological complexity: monomorphemic, compound/contracted, inflected, and derived. Monomorphemic words are comprised of a single morpheme (e.g. "go", "scissors"). Compound words include single units composed of two free morphemes (e.g. "cowboy", "flowerpot"). Contracted words include single units composed of two words in sequence with omitted sounds and letters (e.g. "we'll", "he's", "they're"). Inflected words include nouns or verbs with inflectional morphemes that modified number or tense (e.g. boy*s*, work*ed*, hitt*ing*). Derived words include root words with one or more affixes (e.g. *dis*trust*ful*, invest*ment*). In addition, the U-Score for each word was determined, which is an indicator of the frequency and dispersion of the word in written English as reported in the Educators' Word Frequency Guide (Zeno, Ivens, Millard, & Duvvuri, 1995).

Reliability

To assess reliability of the SALT transcriptions, two undergraduate students in speech-language pathology were trained to code writing samples using conventional procedures. After achieving .85 or greater reliability with the primary researcher in training, SALT coders separately transcribed 8 (24%) randomly selected samples. Interrater reliability between the researcher and each coder was high across all individual measures (T-Units, MLU-M, NDW, NTW, TTR, and SI) with a mean reliability of .97 (range = .94 - .99).

To assess reliability for the POMplexity for Roots and Affixes (Quick & Erickson, 2013), three graduate students in speech-language pathology were trained to transcribe and code words. After achieving reliability greater than .85 in training, the research assistants separately transcribed and coded 12 (35%) randomly selected samples. Reliability was conducted in two phases. First all words were transcribed, glossed, coded for spelling accuracy, and coded for morphological word type. Interrater reliability was high for these measures with a mean reliability of .98 (range = .97 – .98). After consensus was reached for disagreements in the above measures, all misspelled words were coded using the POMplexity for Roots and Affixes and intraclass correlation coefficients (ICCs) were computed to assess interrater reliability. Interrater reliability between the researcher and each trained coder was high across all individual measures (Root Phonology, Root Orthography, Root Morphology, Affix Phonology, Affix

Orthography, Affix Morphology) with mean ICCs of .98 (range = .94 – .99). All secondary coders were blind to the hypotheses of the study as well as the hearing status of the children.

Measures

The Writing Samples subtest of the WJ-III was administered to all students in the study. This subtest is designed to measure a student's ability to write words and sentences according to directions, many of which include a picture cue (e.g., *Write a good sentence that tells what the boy is doing)*. The examiner prompts are first designed to elicit words or phrases, then simple sentences, and finally complex sentences. The starting point was determined at the discretion of the examiner based on age and language level, and the number of items administered to each student varied based on basal and ceiling performance as defined by the WJ-III. All examiners were trained to administer the subtest in accordance with the test manual. For the purpose of the current study, a secondary language and spelling analysis was conducted on these writing samples.

Spelling Assessment. The POMplexity for Roots and Affixes separately analyzes each morpheme of a misspelled word, and then provides a phonological, orthographic and morphological categorical ranking. The ordering of categorical errors within each domain were intended to reflect increasing levels of severity within each linguistic domain, with higher rankings indicating increasing levels of severity. However, limited evidence is available regarding the developmental progression of phonological, orthographic, and morphological spelling errors. Therefore, data collected from this study will be combined with data from other studies to empirically evaluate the ranking order in a future investigation. In the current study, the errors will be reported categorically without reference to ranking. Appendix A provides a definition of each linguistic category and examples to accompany the criteria for phonological, orthographic and morphological rankings with the POMplexity for Roots and Affixes.

Phonological plausibility (i.e., misspellings that could be phonologically pronounced according to the target word) and orthographic legality (i.e., orthographic representations that do not violate rules of English orthography) were determined in a similar manner to the criteria outlined by Olson and Caramazza (2004). Phonological plausibility was determined by first identifying phoneme to grapheme(s) correspondences from left to right within the misspelled word. If grapheme or grapheme sequences could be identified within the 36,000-word Merriam-Webster's Elementary Dictionary (2014) in a pronunciation like the phonemes in the target morpheme, it was deemed phonologically plausible. In order to examine orthographic legality, words were first parsed into word-initial consonants or vowels (e.g., "*a*dventure", "*scr*atch"), word-medial onsets ("ca*m*e*r*a", "wor*sh*ip"), word medial-vowels ("l*ea*p", "b*a*l*a*nc*i*ng"), word-medial codas ("hu*s*band", "ha*r*vest") and word-final consonants or vowels ("se*nt*", "adventu*re*"). If a student produced a grapheme or grapheme sequence in any of those categories for which no examples could be found among words in the dictionary, the response was considered illegal (e.g., word-initial: "*bc*one" for "balancing", word-final: "de*llt*" for "belt", word-medial:fl*iyi*ng" for "flying").

In the POMplexity for Roots and Affixes, the category of morphological plausibility is ascribed when the target morpheme is misspelled in such a way that it reflects existing, but incomplete, awareness of the target morpheme or the misapplication of morphological constancy. Incomplete morphological awareness is presumed with between-morpheme spacing errors ("some where" for "somewhere") or transpositions ("toegther" for "together"). Morphological constancy is the preservation of the spelling of a morpheme in the presence of phonological changes accompanying the addition of affixes (e.g. heal → health). Children are considered to have misapplied morphological constancy when they incorrectly select alternative orthographic representations of the target morpheme. Alternative orthographic representations include the range of spelling patterns for a target morpheme that occur in root, inflected and derived word forms. For example, the spelling patterns of "motive" and "motiv" are alternative orthographic representations of the same target morpheme (motive → motivating), so "motiveating" for "motivating" is morphologically plausible. Similarly, the spelling pattern of "stop" and "stopp" are alternative orthographic representations of the same target morpheme (stop → stopping), and therefore "stoping" for "stopping" is also considered morphologically plausible.

Grouping of Morphemes for Analysis

As each morpheme is separately evaluated in the POMplexity for Roots and Affixes, this assessment offers flexibility when analyzing words with different morphological status. Categorical errors were assigned for all morphemes of misspelled monomorphemic (root morpheme), compound (first root + second root), contracted (first root + second root), inflected (root + inflectional affix), and derived words (root + derivational affix), and therefore data for nine separate morpheme categories were generated. Morphemes with similar characteristics were grouped into one of three categories: monomorphemic roots, multimorphemic roots, and affixes. Monomorphemic roots are comprised of free morphemes, including single morpheme words, as well as both morphemes of compound and contracted words. Multimorphemic roots include the roots of both inflected and derived words, and affixes include inflectional affixes, prefixes and suffixes. Words with three morphemes (e.g. teach-er-s, blind-fold-ed) were retained, but only the first two morphemes were coded and included in the analysis, due to low frequency of occurrence (*n* = 150, .06%).

Relative Proportion Calculations

The relative frequency of each categorical error was computed based on the total number of opportunities as well as the total number of misspellings produced by each participant. Computing the relative frequency based on the number of errors equalized all misspellings across the group. Computing the relative frequency based on the total number of opportunities ensured that students who contributed more words with a lower percentage of errors were weighted differently from students who contributed fewer words with a higher percentage of errors. Thus, spelling errors were standardized in two ways. First, frequency counts of categorical errors among each morpheme group (monomorphemic roots, multimorphemic roots, affixes) were standardized by the total number of times the participant produced a morpheme from that same group within the writing sample. Next, the frequency of categorical errors in each morpheme group was standardized by the total number of misspelled words (i.e., errors) within each morpheme group.

Statistical Comparisons and Significance

Statistical analyses were completed using IBM SPSS Statistics version 24.0 for Mac. Among the written samples, there was significant variety in the total number of words and the total number of misspelled words contributed by each participant. In addition, some categorical spelling error categories had limited to no frequency counts. As a result, the data were not normally distributed and included multiple outliers with the potential to bias group comparisons. Rather than exclude data from the analysis that might reflect infrequent but important variations, data from all categorical errors were retained. Mann-Whitney tests were utilized for between-group comparisons of rank-ordered categorical data, with median proportions reported. In cases where median proportions of groups were identical, the mean rank is also provided.

As this was an exploratory study, multiple pairwise comparisons of categorical errors were conducted within the linguistic domains of phonology, orthography and morphology. The use of adjustments for multiple comparisons in exploratory studies increases the likelihood of rejecting a potentially significant finding and meaningful result, and therefore shielding it from a more intensive scrutiny in future confirmatory studies (Rothman, 1990). Consequently, results that achieved the 0.05 significance level in the absence of adjustments for multiple testing were preserved, but also distinguished from those results that survived an adjustment for multiple comparisons. Effect sizes were calculated using *r* as proposed by Cohen (1988). This statistic was utilized because the effect size estimate is not influenced by sample size (Fritz, Morris, & Richler, 2012).

Results

Descriptive Statistics of Spelling Performance among Children with CIs

The writing samples of children with CIs ranged from 29 to 289 words, with an average of 84% (+/- .13) of each participant's words spelled correctly. The sentences children with CIs produced were primarily comprised of monomorphemic words (87.3%, +/- 4.0%) and inflected words (10.3%, +/- 4.5%), but only occasionally by compound (1.7%, +/- 1.7%) or derived words (.6%, +/- 1.1%). Most monomorphemic words were spelled correctly (89.4%, +/- 10.8%), while approximately half of the compound words (51.6%, +/-42.1%), inflected words (50.0%, +/- 32.0%), and derived words (48.0%, +/- 50.0%) were spelled correctly. The total number of words and total number of correctly spelled words are reported in Table 4.5.

Table 4.5 Total Number of Words and Total Number of Correctly Spelled Words Based on Morphological Status among Children with Cochlear Implants

		Number of Words		U-Score	
		M (%)	*SD*	*M*	*SD*
Total	Total	84.91	61.97	12,811.14	3,193.32
	Correct	75.78 (84.0%)	62.64	15,651.53	4,899.52
	Incorrect	9.13 (16.0%)	4.54	494.94	676.92
Monomorphemic	Total	74.43 (87.3%)	54.12	13,777.82	22,084.72
	Correct	69.35 (89.4%)	54.82	14,725.79	22,572.91
	Incorrect	5.09 (11.0%)	3.49	743.11	2,437.93
Compound	Total	2.09 (1.7%)	3.03	258.48	439.26
	Correct	1.35 (51.6%)	2.48	231.42	395.85
	Incorrect	.74 (48.4%)	1.01	307.82	518.62
Inflected	Total	7.61 (10.3%)	5.09	115.56	177.81
	Correct	4.61 (50.0%)	5.26	151.16	154.26
	Incorrect	3.00 (50.0%)	1.73	61.64	154.26
Derived	Total	.78 (.64%)	1.48	68.48	120.28
	Correct	.48 (48.0%)	1.34	44.00	94.60
	Incorrect	.30 (52.0%)	.70	106.94	152.48

The U-Score of correct and incorrect words was analyzed to determine if there were significant differences in the frequency and dispersion of correct versus misspelled words. Among monomorphemic words, proportions of average U-scores were significantly higher for correct words (*Mdn* = 3,584.00) than misspelled words (*Mdn* = 92.00) [U = 151,262.50, z = 11.451, p = .000, r = .28]. Also, among inflected words, proportions of average U-scores were significantly higher for correct words (*Mdn* = 89.00) than misspelled words (*Mdn* = 29.00) [U =

5329.5, $z = 4.902$, $p = .000$, $r = .37$]. There were no significant differences in the proportions of U-scores based on spelling accuracy among compound or derived words. These data indicate that children with CIs are more likely to correctly spell more familiar and frequent monomorphemic and inflected words.

There were similarities in the ranking order of categorical errors based on frequency across the three morpheme groups. In the domain of phonology, phonologically plausible errors had the highest proportion of errors, comprising one-fourth to more than one-third of the errors. In the domain of orthography, legal consonant errors comprised approximately one-fourth of the errors among roots, while legal vowel and consonant errors comprised more than one-third of the errors among affixes. In the domain of morphology, non-morpheme substitutions comprised nearly half of the errors among roots, while omitted morphemes comprised more than one-third of the errors among affixes. The number and percentage of categorical errors among the three morpheme groups are reported in Table 4.6.

Comparison of Children with CIs and Children with Normal Hearing

The next set of analyses compared the proportion of total spelling errors and the distribution of categorical errors among children with CIs and children with normal hearing. Due to heterogeneity within the sample of children with CIs, only the subset of children who received an implant by 24 months of age and did not have additional disabilities was compared to the control group.

Table 4.6 Number and Percentage of Categorical Spelling Errors in Monomorphemic Roots, Multimorphemic Roots and Affixes among Children with Cochlear Implants

		Monomorphemic Roots		Multimorphemic Roots		Affixes	
		n	%	*n*	%	*n*	%
Correct		8	5.3%	29	37.2%	32	41.0%
Phonology	Plausible	54	36.0%	20	25.6%	7	9.0%
	Substitution	33	22.0%	11	14.1%	4	5.1%
	Omission	26	17.3%	6	7.7%	3	3.8%
	Addition	8	5.3%	1	1.3%	0	-
	Multiple	21	14.0%	11	14.1%	4	5.1%
Orthography	Minor	32	21.3%	0	0.0%	4	5.1%
	Vowel	33	22.0%	8	10.3%	5	6.4%
	Consonant	35	23.3%	20	25.6%	2	2.6%
	V & C	24	16.0%	16	20.5%	7	9.0%
	Illegal	18	12.0%	5	6.4%	0	-
Morphology	Plausible	24	16.0%	2	2.6%	5	6.4%
	Homophone	9	6.0%	2	2.6%	2	2.6%
	Morpheme	31	20.7%	6	7.7%	4	5.1%
	Non-Morpheme	78	52.0%	39	50.0%	7	9.0%
	Omitted	-	-	-	-	28	35.9%

Note: Correct = correctly spelled morpheme in a multimorphemic misspelled word. For monomorphemic and multimorphemic roots, the percentage of errors within each domain is equal to 100%. For affixes the domains of phonology or orthography do not equal 100% because omitted morphemes were not scored for phonological or orthographic categorical errors.

Proportion of Total Spelling Errors and Average U-Score. It was necessary to determine prior equivalence in lexical and syntactic measures of the writing samples, so that any group differences in spelling could be attributed to spelling rather than overall complexity or quality of the writing samples. Visual inspection of the data indicated similar distributions of scores, although assumptions of normality were violated. Six independent samples *t*-tests were used to evaluate group equivalence of the variables, and none were significant at the .05 level. As reported in Table 4.7, children with CIs performed more poorly than children with normal hearing in all but one measure, but the differences were not statistically significant.

Table 4.7 Measures of Lexical and Syntactical Quantity and Quality of Writing Samples

	Children with CIs		Children with Normal Hearing	
Measure	*M*	*(SD)*	*M*	*(SD)*
T-Units	15.35	*(4.86)*	16.19	*(5.48)*
MLU Morpheme	6.53	*(2.13)*	6.55	*(2.04)*
Number of Different Words	64.10	*(30.06)*	68.20	*(32.34)*
Number of Total Words	96.54	*(51.52)*	102.14	*(54.58)*
Type Token Ratio	.68	*(.06)*	.69	*(.06)*
Subordination Index	1.06	*(.20)*	1.06	*(.25)*

The next analysis investigated if there were differences in the percentage of spelling errors, among the total number of words or among each morphological word type (monomorphemic, compound, inflected, derived). Independent samples *t*-tests revealed no significant group differences in the percentage of spelling errors among the total number of words or among words of different morphological status. Independent samples *t*-tests also indicated no significant between-group differences in the average U Score based on morphological status. Therefore there were no significant group differences in the types of words children produced in their writing samples, based on word frequency and dispersion. Morphological status as a percentage of total words and the average U score and percentage of misspelled words for each morphological word type are reported in Table 4.8.

Distribution of Spelling Errors Based on Total Number of Opportunities. The proportion of categorical spelling errors among children with and without hearing loss relative to the total number of opportunities within each morpheme group (monomorphemic roots, multimorphemic roots, and affixes) was compared with Mann-Whitney U tests. The nonparametric comparisons of categorical spelling errors based on the total number of opportunities are reported in Table 4.9 and the median proportions are reported in Table 4.10.

Monomorphemic Words. In the domain of phonology, proportions of phonologically plausible errors among children with CIs (*Mdn* = .012) were significantly lower than children with normal hearing (*Mdn* = .066) with a large effect size (Cohen, 1988) [$U = 13.00$, $z = -2.433$, $p = .014$, $r = -.57$]. In the domain of morphology, proportions of homophone substitutions were significantly lower among children with CIs (*Mdn* = .000) than children with normal hearing (*Mdn* = .015) with a large effect size [$U = 6.00$, $z = -3.255$, $p = .001$, $r = -.77$].

Table 4.8 Percentage of Misspelled Words and Average U-Score among Different Morphological Word Types

		Children with CIs		Children with Normal Hearing	
Word Status	Measure	*M*	*(SD)*	*M*	*(SD)*
Monomorphemic	% of Total Words	80.0%	(87.1)	86.7%	(2.1)
	Average U Score	12501	(20226)	11892	(19540)
	% Misspelled	6.0%	(4.8)	10.0%	(6.4)
Compound	% of Total Words	1.6%	(1.5)	2.8%	(1.8)
	Average U Score	386	(655)	230	(507)
	% Misspelled	44.2%	(46.9)	28.4%	(32.1)
Inflected	% of Total Words	10.9%	(5.1)	9.3%	(2.4)
	Average U Score	167	(1865)	97	(147)
	% Misspelled	39.9%	(22.8)	43.2%	(33.4)
Derived	% of Total Words	.3%	(.7)	1.1%	(1.1)
	Average U Score	58	(89)	47	(85)
	% Misspelled	50.0%	(70.7)	50.0%	(46.8)

*Multimorphemic Roots***.** In the domain of orthography, proportions of orthographic legal vowel errors were significantly lower among children with CIs (*Mdn* = .000) than among children with normal hearing (*Mdn* = .200) with a large effect size [U = 10.00, z = -2.737, p = .006, r = -.65].

*Affixes***.** Among affixes, there were no significant differences between children with CIs and children with normal hearing in the proportions of categorical errors in the domains of phonology, orthography or morphology. Table 4.8 reports the nonparametric comparisons of categorical spelling errors between children with CIs and children with normal hearing, and Table 4.9 reports the median proportions of categorical spelling errors between these two groups.

Distribution of Spelling Errors Based on Total Number of Errors. Mann-Whitney U tests were also used to compare proportions of categorical spelling errors among children with and without hearing loss relative to the total number of errors within each morpheme group (monomorphemic roots, multimorphemic roots, and affixes). The nonparametric comparisons of categorical spelling errors based on the total number of errors are reported in Table 4.10 and the median proportions are reported in Table 4.11.

*Monomorphemic Roots***.** In the domain of morphology, proportions of homophone substitutions were significantly lower among children with CIs (*Mdn* = .000) than CNH (*Mdn* = .231) with a large effect size [$U = 10.00$, $z = -2.87$, $p = .006$, $r = -.68$].

*Multimorphemic Roots***.** The proportions of correctly spelled multimorphemic roots among misspelled multimorphemic words were significantly higher among children with CIs (*Mdn* = .000) than CNH (*Mdn* = .400) with a large effect size [$U = 8.00$, $z = -64.5$, $p = .031$, $r = .55$]. In the domain of orthography, proportions of orthographic legal vowel errors were significantly lower among children with CIs (*Mdn* = .000) than CNH (*Mdn* = .500) with a large effect size [$U = 8.00$, $z = -2.923$, $p = .003$, $r = -.69$].

*Affixes***.** Among affixes, there were no significant differences between children with CIs and CNH in the proportions of categorical errors in the domains of phonology, orthography or morphology. Table 4.11 reports the nonparametric comparisons of categorical spelling errors between children with CIs and children with normal hearing, and Table 4.12 reports the median proportions of categorical spelling errors between these two groups.

Table 4.9 Nonparametric Comparisons of Categorical Spelling Errors Based on Total Number of Opportunities in Each Morpheme Group (Mann-Whitney *Z* and associated two-tailed asymptotic significance) between Children with Cochlear Implants and Children with Normal Hearing

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		1.369	.190	1.372	.190	-1.505	.161
Phonology	Plausible	-2.433	.014*	-.753	.489	-.754	.546
	Substitution	-1.649	.136	-.158	.931	.081	1.00
	Omission	.976	.340	-1.273	.387	.000	1.00
	Addition	1.835	.258	-1.455	.436	.000	1.00
	Multiple	.615	.666	.081	1.00	1.00	.730
Orthography	Minor	-1.432	.190	-1.00	.730	.947	.436
	Vowel	.177	.863	-2.737	.006**	-.612	.730
	Consonant	.930	.387	.683	.546	.000	1.00
	V & C	-.838	.546	.391	.796	-.081	1.00
	Illegal	.000	1.00	-1.00	.730	.000	1.00
Morphology	Plausible	.053	1.00	-1.1.52	.436	1.835	.258
	Homophone	-3.255	.001**	1.00	.730	-.121	.931
	Morpheme	.855	.436	.000	1.00	-1.455	.436
	Non-Morpheme	-.662	.546	-1.066	.297	-.081	1.00
	Omitted					2.514	.050

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word. *significance at the p < .05. **significance after Holm-Bonferroni Sequential Correction applied for multiple comparisons

Table 4.10 Group Comparisons of Median Proportions of Categorical Spelling Errors in Each Morphem Group (percent of opportunities) between Children with Cochlear Implants and Children with Normal Hearing

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		CI	NH	CI	NH	CI	NH
Correct		.942	.896	.889	.600	.857	1.00
Phonology	Plausible	.019	.066	.077	.333	.000	.000
	Substitution	.000	.014	.000	.000	.000	.000
	Omission	.017	.009	.000	.000	.000	.000
	Addition	.000	.000	.000	.000	.000	.000
	Multiple	.000	.000	.000	.000	.000	.000
Orthography	Minor	.000	.014	.000	.000	.000	.000
	Vowel	.024	.014	.000	.200	.000	.000
	Consonant	.024	.009	.077	.038	.000	.000
	V & C	.000	.000	.000	.000	.000	.000
	Illegal	.000	.000	.000	.000	.000	.000
Morphology	Plausible	.000	.000	.000	.000	.000	.000
	Homophone	.000	.015	.000	.000	.000	.000
	Morpheme	.019	.005	.000	.000	.000	.000
	Non-Morpheme	.032	.051	.111	.222	.000	.000
	Omitted					.071	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Table 4.11 Nonparametric Comparisons of Categorical Spelling Errors Based on Total Number of Errors in Each Morpheme Group (Mann-Whitney *Z* and associated two-tailed asymptotic significance) between Children with Cochlear Implants and Children with Normal Hearing

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		Z	*p*	*Z*	*p*	*Z*	*p*
Correct		.000	1.00	2.329	.031**	-1.823	.077
Phonology	Plausible	-1.684	.094	-1.117	.297	-.101	.931
	Substitution	-1.164	.297	.000	1.00	.000	1.00
	Omission	2.000	.050	-1.031	.489	.000	1.00
	Addition	1.835	.258	-1.455	.436	.000	1.00
	Multiple	.615	.666	.081	1.00	1.00	.730
Orthography	Minor	-1.251	.258	-1.00	.730	1.166	.340
	Vowel	.531	.605	-2.923	.003**	-.680	.666
	Consonant	1.375	.190	.319	.796	.000	1.00
	V & C	-.615	.666	.394	.796	-.081	1.00
	Illegal	.000	1.00	-1.00	.730	.000	1.00
Morphology	Plausible	.263	.863	-1.214	.387	1.837	.258
	Homophone	-2.877	.006**	1.00	.730	.122	.931
	Morpheme	1.575	.136	-.182	.931	-1.455	.436
	Non-Morpheme	.089	.931	-1.303	.222	-.081	1.00
	Omitted					2.517	.05

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word. *significance at the p < .05. **significance after Holm-Bonferroni Sequential Correction applied for multiple comparisons

Table 4.12 Group Comparisons of Median Proportions of Categorical Spelling Errors (percent of total errors) in Each Morpheme Groups between Children with Cochlear Implants and Children with Normal earing

		Monomorphemic Words		Multimorphemic Roots		Affixes	
		CI	NH	CI	NH	CI	NH
Correct		.000	.000	.400	.000	.600	1.00
Phonology	Plausible	.333	.625	.400	.600	.000	.000
	Substitution	.000	.125	.000	.000	.000	.000
	Omission	.000	.000	.000	.000	.000	.000
	Addition	.000	.000	.000	.000	.000	.000
	Multiple	.000	.250	.000	.000	.000	.000
Orthography	Minor	.000	.250	.000	.000	.000	.000
	Vowel	.272	.250	.000	.500	.000	.000
	Consonant	.333	.200	.333	.200	.000	.000
	V & C	.000	.000	.000	.000	.000	.000
	Illegal	.000	.000	.000	.000	.000	.000
Morphology	Plausible	.000	.000	.000	.000	.000	.000
	Homophone	.000	.231	.000	.000	.000	.000
	Morpheme	.250	.125	.000	.000	.000	.000
	Non-Morpheme	.500	.423	.500	.800	.000	.000
	Omitted					.200	.000

Note. Correct = correctly spelled morpheme in a multimorphemic misspelled word.

Comparison of Children with CIs and Children who are Hard of Hearing

To address the second goal of the study, the same sets of analyses were completed comparing children with CIs and age-matched peers who are hard of hearing. No significant differences were found in the writing samples at the word or sentence level, in the proportion of errors among words of different morphological complexity, or in the distribution of categorical errors relative to the total number of opportunities or total number of errors. These results indicated that the writing samples and spelling performance of children who receive cochlear implants by 24 months are similar to those of peers who have mild to severe hearing loss and wear hearing aids.

Discussion

In examining the descriptive statistics of spelling words contained in writing samples of children with CIs who use spoken language, monomorphemic words comprised nearly 90% of the sample, with inflected words comprising an additional 10%, while compound and derived words were very infrequent. Although monomorphemic words were spelled correctly approximately 85% of the time, inflected, compound and derived words were only spelled correctly about half of the time. This distribution of words by morphological status and spelling accuracy was comparable to the writing samples of children with normal hearing, as well as children with mild to severe hearing loss reported elsewhere (see Chapter 3). Similar to what has been reported among children with normal hearing, the spelling of children with CIs in this study was also influenced by a frequency effect with more frequent and disperse words spelled more accurately, as determined by comparing U-Scores of correctly and incorrectly spelled words (Treiman, 1993).

When comparing the subset of children who were implanted by 24 months to peers with normal hearing, there were no significant quantitative differences in the proportion of spelling errors among the total set of words produced or among words of different morphological status. These results are consistent with those reported using age-matched peers in a word dictation task that controlled for reading ability (Hayes et al., 2011), but the results are in contrast to the results with reading-matched peers on a standardized assessment and graded-level word dictation task (Apel & Masterson, 2015). The contradictory findings in spelling accuracy may be an artifact of the assessment context and the difficulty of the targeted words. The standardized and graded-level word lists in the study by Apel and Masterson may have been more challenging than the experimenter-developed list of Hayes and colleagues. Similarly, the contextualized, sentential writing samples in the current study may not have challenged student spelling in the same way as the standardized or graded-level word dictation tests. When students produce written compositions, they may select familiar words they feel more confident spelling. This conservative approach to word selection is particularly true of poor spellers (Kohnen, Nickels, & Castles, 2009), and therefore the presence of poorer spellers in a group may be partially masked by the use of writing samples as an assessment context. Finally, although the mothers in this sample represented a wide range of educational backgrounds, it is important to note that the sample was biased toward higher levels of education, which is associated with better language outcomes among children with CIs (Szagun & Stumper, 2012). Thus the children in this study may not be representative of the greater population of children with CIs.

Despite the lack of differences in spelling accuracy, there were several qualitative differences in spelling errors produced by the children with CIs in comparison to children with normal hearing, and all of them had large effect sizes. Children with CIs had significantly fewer phonologically plausible errors among monomorphemic roots, which comprised the majority of the morphemes in these writing samples. Hayes and colleagues (2011) also reported fewer phonologically plausible errors in a word dictation task, using a similar definition of phonological plausibility. These results suggest that children with CIs are less efficient in using phonological coding when orthographically representing words they do not know how to spell, which may be the result of underspecified phonological representations due to a degraded acoustic signal.

The use of significantly fewer homophone substitutions in misspelled monomorphemic roots among children with CIs also suggests weakness in phonological coding. The presumed weakness in phonological awareness may compromise the ability of children with CIs to recognize familiar oral vocabulary words with identical phoneme sequences. Nevertheless, this error pattern also suggests that students with CIs may compensate for unspecified phonological representations by relying more heavily on uncompromised visuo-orthographic skills to efficiently map morphological meaning to familiar morphographic sequences. In other words, although children with CIs may have more difficulty recognizing that "right" and "write" are homophones on the basis of sound, they may also be more apt to use visual memory to pair meaning with the morphographic representation, thus reducing the proportion of homophone substitution errors.

Children with CIs produced fewer legal vowel errors in multimorphemic roots than children with normal hearing. As previously reported, a similar, but more pronounced error pattern was observed among children who are hard of hearing across all morpheme groups (see Chapter 3). In comparison to consonants, vowels are composed of more acoustically salient components and are thus more readily perceived by children with hearing loss. Therefore, it is not surprising that vowels would be a relative strength compared to consonants among this population. In addition, vowels have increased orthographic saliency as only six primary vowels account for approximately thirty-nine percent of the characters comprising words (Mayzner & Tresselt, 1965). The auditory saliency of these word components paired with robust visuo-orthographic skills may allow children with CIs to capitalize upon this limited set of highly frequent graphemes as a platform for creating stronger sound-to-letter linkages for these components of written words.

Children with CIs demonstrated significantly more correctly spelled roots among misspelled multimorphemic words. Based on auditory perceptual saliency, the relative strength of roots over affixes among this population is also not surprising. In comparison to roots, affixes are comprised of phonemes that are higher in frequency and lower in intensity (e.g. /s/, /z/, /t/), and when in medial sentence positions they are often less salient due to shorter durations (Hsieh, Leonard, & Swanson, 1999), making them more difficult to hear. Therefore, this error pattern may represent a bootstrapping mechanism whereby children with CIs take advantage of stronger phonological access to successfully read roots, which then facilitates the development of stored mental graphemic representations that support spelling of those roots.

Given that children who are hard of hearing omit significantly more affixes relative to children with normal hearing (See Chapter 3), a similar error pattern was expected among children with CIs. Children with CIs had a statistically insignificant higher proportion of omitted affixes ($p = .05$), but the effect size was large ($r = .59$). These results suggest that the study may lack power to detect a statistically significant difference, and that reported difficulties in morphological awareness in spoken language among this population (Halle & Duchesne, 2015) persist in written language as well.

This is the first known study to compare children with CIs to children with mild to severe hearing loss. Despite differences associated with various technologies, children with CIs demonstrated indistinguishable performance from children with mild to severe hearing loss in this study, which has also been reported when comparing children with CIs to children who wear hearing aids with more profound degrees of hearing loss (Harris & Terlektsi, 2011). Group differences in both studies may be masked by insufficient sample size and the lack of control for potentially confounding factors such as age of identification, age of hearing aid fitting, and frequency of technology use. It is also possible that equivalent performance reflects more similarities than differences in auditory-linguistic access. Although children who are hard of hearing have the potential to experience optimal access following initial hearing aid fitting within the first months of life, Walker et al., (2013) found that many of these children do not achieve full-time use until 18 to 24 months of age. In addition, Walker et al., reported that children with milder hearing loss were reported to have less consistent hearing aid use. In contrast, families of children with more profound hearing loss may be more motivated to pursue earlier consistent hearing aid use because trials are required prior to establishing cochlear implant candidacy. Therefore, children with CIs may experience less optimal but consistent hearing aid use early on relative to children who are hard of hearing. In addition, children with CIs may benefit from optimal auditory access with their implants just prior to, or around the same time as children with hearing aids benefit from optimal auditory access due to more consistent use. Furthermore, children with CIs may experience more duration or frequency in services due to larger early gaps in speech, language and auditory skills. Thus despite the divergent early auditory experiences and acoustic signals experienced by these two populations, they may experience similar uptake in language domains that inform spelling, leading to more similarities than differences in orthographic development.

Implications

The results of this study have several important educational implications for children with CIs. First, the insignificant differences in performance in spelling accuracy between children with CIs and their peers with typical hearing were unexpected, but very encouraging. In the absence of other disabilities, profound hearing loss may no longer need to be associated with deleterious effects on literacy skills such as spelling, particularly when children are able to benefit from earlier implantation of newer implant technology and a spoken language approach. Nevertheless, as seen with this small study, these demographics may not be representative of the greater population of children with CIs, as nearly two-thirds of the recruited children had additional disabilities, later ages of implantation, or both.

Second, the group differences in spelling profiles between children with and without hearing loss suggest that children with CIs bring different linguistic strengths and weaknesses to the spelling of less familiar or unknown words, as compared to same-age peers with normal hearing. The distribution of errors suggests that at least some children with CIs have difficulty with phonological coding during spelling. Therefore children with CIs, particularly those that struggle with spelling, may benefit from spelling instruction that targets this area of weakness through phonological awareness tasks or direct instruction in sound to grapheme encoding for linkages of identified difficulty. Vulnerability in the development of phonological awareness also highlights the importance of ensuring optimal and consistent auditory access as early as possible, in order to support the development of phonological representations required for both oral and written language development.

Although most professionals today would discount earlier claims of a "deafness advantage" in spelling due to visual memory strengths (Templin, 1948), the distribution of categorical spelling errors among children with CIs does suggest that these children compensate for weaknesses in phonological processing by capitalizing upon relative strengths in visual processing. Therefore, children with CIs who struggle with spelling may benefit from instruction that highlights forms of linguistic awareness that can take advantage of relative strengths in visuo-orthographic skills. Repertoire Theory postulates that children with normal hearing use different forms of linguistic knowledge to varying degrees across time (Masterson & Apel, 2013). Therefore, it is possible that children with CIs, who struggle using phonological knowledge due to auditory challenges, would benefit from instruction that strengthens orthographic or morphological knowledge, as these domains are able to harness the power of vision for probabilistic learning and storage of mental graphemic representations.

While the reliable information provided by word dictation tasks for spelling is not to be discounted, the results of this study suggest that important information about spelling achievement can also be obtained from contextualized writing tasks. This context of formative assessment provides information about the students' ability to spell within the multilayered subsystems of writing such as planning, organization, cohesion, vocabulary, grammar, reviewing and monitoring (Mackenzie, Scull, & Munsie, 2013). Given the ever increasing demands on the time of speech-language pathologists, evaluating spelling within writing samples provides an efficient means for assessing and monitoring skills, as well as evaluating intervention through pre- and post-assessment, as clinicians collaborate with classroom teachers to support spelling achievement.

Limitations and Future Directions

The results of this study must be interpreted with caution due to several limitations. The sample size was limited as a result of recruitment challenges associated with low-incidence populations. Increasing the number of participants in future studies could reveal true significant differences between the groups. This study is also limited by the matching procedures. Participants were not matched for reading or language level, and including a control group matched in one or both of these domains would strengthen conclusions about spelling abilities while controlling for potential covariates. In comparing groups of children who utilize different hearing technologies, future investigations should consider controlling for age of identification, audibility, and consistency of technology use. Finally, while the use of student generated writing samples provides an ecologically valid measure of spelling achievement, it also introduces significant heterogeneity in the sampling context. Using a combination of both writing samples and word dictation tasks may provide a more thorough and comprehensive understanding of spelling ability in this population. Nevertheless, this study contributed important information about the spelling of children of with CIs, particularly by identifying qualitative differences in spelling errors that should provoke further investigation in both assessment and intervention.

Conclusion

The present study suggests that at least some children with CIs demonstrate equivalent spelling accuracy in contextualized, sentential writing tasks to that of children with normal hearing. This study adds to the existing literature among children with CIs by providing a more nuanced analysis of spelling errors. Differences in the distribution of categorical spelling errors suggest that children with CIs may differ in the degree to which they utilize various linguistic domains that support spelling relative to children with normal hearing, while being more similar in the strategies they use to spell words relative to children who are hard of hearing. For those children with CIs that struggle with spelling, these findings may provide an important first step in identifying strengths and weaknesses in the linguistic foundations of spelling that may be used to inform the development of targeted spelling interventions.

REFERENCES

Aaron, P. G., Keetay, V., Boyd, M., Palmatier, S., & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal*, *10*, 1–22. doi:10.1023/A:1007917929226

Ambrose, S. E., Fey, M. E., & Eisenberg, L. S. (2012). Phonological awareness and print knowledge of preschool children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *55*, 811–823. doi:10.1044/1092-4388(2011/11-0086)b

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, *42*, 592–603. doi:10.1044/0161-1461(2011/10-0085)

Apel, K. (2014). A comprehensive definition of morphological awareness. *Topics in Language Disorders*, *34*, 197–209. doi:10.1097/TLD.0000000000000019

Apel, K., Diehm, E., & Apel, L. (2013). Using Multiple Measures of Morphological Awareness to Assess its Relation to Reading. *Topics in Language Disorders*, *33*, 42–56. doi:10.1097/TLD.0b013e318280f57b

Apel, K., & Masterson, J. J. (2015). Comparing the spelling and reading abilities of students with cochlear implants and students with typical hearing. *Journal of Deaf Studies and Deaf Education*, *20*, 125–135. doi:10.1093/deafed/env002

Ball, E. W., & Blachman, B. A. (1991). Does phoneme awareness training in kindergarten make a difference in early word recognition and developmental spelling? *International Reading Association*, *26*, 49–66.

Berninger, V. W., Abbott, R. D., Jones, J., Wolf, B. J., Gould, L., Anderson-Youngstrom, M., … Apel, K. (2006). Early development of language by hand: Composing, reading, listening, and speaking connections; three letter-writing modes; and fast mapping in spelling. *Developmental Neuropsychology*, *29*, 61–92. doi:10.1207/s15326942dn2901_5

Berninger, V. W., Abbott, R. D., Nagy, W., & Carlisle, J. (2010). Growth in phonological, orthographic, and morphological awareness in grades 1 to 6. *Journal of Psycholinguistic Research*, *39*, 141–63. doi:10.1007/s10936-009-9130-6

Berninger, V. W., Abott, R. D., Thomson, J., Wagner, R. K., Swanson, H. L., Wijsman, E. M., & Raskind, W. (2006). Modeling phonological core deficits within a working memory architecture in children and adults with developmental dyslexia. *Scientific Studies of Reading*, *10*, 165–198. doi:10.1207/s1532799xssr1002

Berninger, V. W., Raskind, W., Richards, T. L., Abbott, R., & Stock, P. (2008). A multidisciplinary approach to understanding developmental dyslexia within working-memory architecture: Genotypes, phenotypes, brain, and instruction. *Developmental Neuropsychology*, *33*, 707–744. doi:10.1080/87565640802418662

Boons, T., De Raeve, L., Langereis, M., Peeraer, L., Wouters, J., & van Wieringen, A. (2013). Expressive vocabulary, morphology, syntax and narrative skills in profoundly deaf children after early cochlear implantation. *Research in Developmental Disabilities*, *34*, 2008–2022. doi:10.1016/j.ridd.2013.03.003

Bourassa, D. C., & Treiman, R. (2001). Spelling development and disability: The importance of linguistic factors. *Language, Speech, and Hearing Services in Schools*, *32*, 172–181. doi:10.1044/0161-1461(2001/016)

Bouton, S., & Cole, P. (2014). Spelling acquisition in French children with cochlear implants. In B. Arfe, J. Dockrell, & V. Berninger (Eds.), *Writing development in children with hearing loss, dyslexia or oral language problems: Implications for assessment and instruction* (pp. 583–605). New York: Oxford University Press. doi:10.1093/acprof:oso/9780199827282.003.0005

Bowers, L. M., McCarthy, J., Schwarz, I., Dostal, H., & Wolbers, K. (2014). Examination of the spelling skills of middle school students who are deaf and hard of hearing. *The Volta Review*, *114*, 29–56. Retrieved from http://www.agbell.org/VoltaReviewOnline/

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Child Psychology*, *50*, 156–178. doi:10.1016/0022-0965(90)90037-9

Carlisle, J. F. (1988). Knowledge of derivational morphology and spelling ability in fourth, sixth, and eighth graders. *Applied Psycholinguistics*, *9*, 247–266. doi:10.1017/S0142716400007839

Caselli, M. C., Rinaldi, P., Varuzza, C., Giuliani, A., & Burdo, S. (2012). Cochlear implant in the second year of life: Lexical and grammatical outcomes. *Journal of Speech, Language, and Hearing Research*, *55*, 382–394. doi:10.1044/1092-4388(2011/10-0248)382

Ching, T. Y. C., & Cupples, L. (2015). Phonological awareness at 5 years of age in children who use hearing aids or cochlear implants. *Perspectives on Hearing and Hearing Disorders in Childhood*, *25*, 48–59. doi: 10.1044/hhdc25.2.48

Chomsky, C. (1970). Reading, writing, and phonology. *Harvard Educational Review*, *40*, 287–309. Retrieved from http://hepg.org/her-home/home

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Hillsdale, N.J.: Lawrence Earlbaum Associates.

Colombo, L., Arfé, B., & Bronte, T. (2012). The influence of phonological mechanisms in written spelling of profoundly deaf children. *Reading and Writing*, *25*, 2021–2038. doi:10.1007/s11145-011-9343-6

Deacon, S. H. (2008). The metric matters: Determining the extent of children's knowledge of morphological spelling regularities. *Developmental Science*, *11*, 396–406. doi:10.1111/j.1467-7687.2008.00684.x

Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian Psychology*, *49*, 118–124. doi:10.1037/0708-5591.49.2.118

Delage, H., & Tuller, L. (2007). Language development and mild-to-moderate hearing loss: Does language normalize with age? *Journal of Speech, Language, and Hearing Research*, *50*, 1300–1313. doi:10.1044/1092-4388(2007/091)

Desjardin, J. L., Ambrose, S. E., & Eisenberg, L. S. (2008). Literacy skills in children with cochlear implants: The importance of early oral language and joint storybook reading. *Journal of Deaf Studies and Deaf Education*, *14*, 22–43. doi:10.1093/deafed/enn011

Dillon, C. M., de Jong, K., & Pisoni, D. B. (2012). Phonological awareness, reading skills, and vocabulary knowledge in children who use cochlear implants. *Journal of Deaf Studies and Deaf Education*, *17*, 205–226. doi:10.1093/deafed/enr043

Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–143). Hillsdale, N.J.: Lawrence Erlbaum.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect Size Estimates : Current Use , Calculations , and Interpretation. *Journal of Experimental Psychology*, *141*, 2–18. doi:10.1037/a0024338

Garcia, N. P., Abbott, R. D., & Berninger, V. W. (2010). Predicting poor, average, and superior spellers in grades 1 to 6 from phonological, orthographic, and morphological, spelling, or reading composites. *Written Language & Literacy*, *13*, 61–98. doi:10.1075/wll.13.1.03gar

Gates, A. I., & Chase, E. H. (1926). Methods and theories of learning to spell tested by studies of deaf children. *Journal of Educational Psychology*, *17*, 289–300. doi:10.1037/h0068697

Guo, L.-Y., Spencer, L. J., & Tomblin, J. B. (2013). Acquisition of tense marking in English-speaking children with cochlear implants: A longitudinal study. *Journal of Deaf Studies and Deaf Education*, *18*, 187–205. doi:10.1093/deafed/ens069

Halle, F., & Duchesne, L. (2015). Morphosyntactic skills in deaf children with cochlear implants: A systematic review. *Canadian Journal of Speech-Language Pathology and Audiology*, *39*, 260–297. Retrieved from http://www.cjslpa.ca/

Hammer, A. (2010). *The acquisition of verbal morphology in cochlear-implanted and specific language impaired children* (Doctoral dissertation). University of Leiden, Leiden, Netherlands.

Hammer, A., Coene, M., Rooryck, J., & Govaerts, P. J. (2014). The production of Dutch finite verb morphology: A comparison between hearing-impaired CI children and specific language impaired children. *Lingua*, *139*, 68–79. doi:10.1016/j.lingua.2013.11.010

Harris, M., & Terlektsi, E. (2011). Reading and spelling abilities of deaf adolescents with cochlear implants and hearing aids. *Journal of Deaf Studies and Deaf Education*, *16*, 24–34. doi:10.1093/deafed/enq031

Hayes, H., Kessler, B., & Treiman, R. (2011). Spelling of deaf children who use cochlear implants. *Scientific Studies of Reading*, *15*, 522–540. doi:10.1080/10888438.2010.528480

Henry, B. A., & Turner, C. W. (2003). The resolution of complex spectral patterns by cochlear implant and normal-hearing listeners. *The Journal of the Acoustical Society of America*, 2861–2873. doi:10.1121/1.1561900

Henry, B. A., & Turner, C. W. (2005). Spectral peak resolution and speech recognition in quiet: Normal hearing, hearing impaired, and cochlear implant listeners. *The Journal of the Acoustical Society of America*, *118*, 1111–1121. doi:10.1121/1.1944567

Hsieh, L., Leonard, L. B., & Swanson, L. (1999). Some differences between English plural noun inflections and third singular verb inflections in the input: The contributions of frequency, sentence position, and duration. *Journal of Child Language*, *26*, 531–543. doi:10.1017/S030500099900392X

James, D., Brown, T., & Brinton, J. (2005). Phonological awareness in deaf children who use cochlear implants. *Journal of Speech, Language, and Hearing Research*, *48*, 1511–1529. doi:10.1044/1092-4388(2005/105)

James, D., Rajput, K., Brinton, J., & Goswami, U. (2008). Phonological awareness, vocabulary, and word reading in children who use cochlear implants: Does age of implantation explain individual variability in performance outcomes and growth? *Journal of Deaf Studies and Deaf Education*, *13*, 117–137. doi:10.1093/deafed/enm042

Johnson, C., & Goswami, U. (2010). Phonological awareness, vocabulary, and reading in deaf children with cochlear implants. *Journal of Speech, Language & Hearing Research*, *53*, 237–261. doi:10.1044/1092-4388(2009/08-0139)

Kamhi, A. G., & Hinton, L. N. (2000). Explaining individual differences in spelling ability. *Topics in Language Disorders*, *20*, 37–49. doi:10.1097/00011363-200020030-00006

Katz, L., & Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology and meaning* (pp. 67–84). Amsterdam, the Netherlands: Elsevier North Holland.

Kohnen, S., Nickels, L., & Castles, A. (2009). Assessing spelling skills and strategies: A critique of available resources. *Australian Journal of Learning Difficulties*, *14*, 113–150. doi:10.1080/19404150902783450

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education*, *11*, 273–288. doi:10.1093/deafed/enj037

Leybaert, J., Bravard, S., Sudre, S., & Cochard, N. (2009). La adquisicion de la lectura y la orthographia en ninos sordos con implante coclear: Efectos de la Palabra Complementada [Reading and spelling acquisition in deaf children with a cochlear implant]. In *Lineas actuales en el estudio de la lengua escrita y sus dificultades: dislexia & sordera. Libro de lecturas en honor de Jésus Alegria* (pp. 29–50). Malaga, Spain: Aljibe.

Lundberg, I., Olofsson, Å., & Wall, S. (1980). Reading and spelling skills in the first school years predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology*, *21*, 159–173. doi:10.1111/j.1467-9450.1980.tb00356.x

Mackenzie, N. M., Scull, J., & Munsie, L. (2013). Analysing writing: The development of a tool for use in the early years of schooling. *Issues in Educational Research*, *23*, 375–393.

Masterson, J. J., & Apel, K. (2010). Linking characteristics discovered in spelling assessment to intervention goals and methods. *Learning Disability Quarterly*, *33*, 185–198. doi:10.1177/073194871003300307

Masterson, J. J., & Apel, K. (2013). Spelling assessment frameworks. In C. A. Stone, E. R. Silliman, B. J. Ehren, & G. P. Wallach (Eds.), *Handbook of language and literacy, Second edition: Development and disorders* (pp. 584–601). New York: The Guildford Press.

Mayzner, M. S., & Tresselt, M. E. (1965). Tables of single-letter and digram frequency counts for various word-length and letter position combinations. *Psychonomic Monograph Supplements*, *1*, 13–32. Retrieved from http://psycnet.apa.org/psycinfo/1967-02842-001

Merriam-Webster Elementary Dictionary. (2014). Springfield, MA: Merriam Webster Inc.

Miller, J. F., & Iglesias, A. (2012). *Systematic Analysis of Language Transcripts* (SALT). Middleton; WI: SALT Software; LLC.

Nagy, W. E., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology*, *98*, 134–147. doi:10.1037/0022-0663.98.1.134

Nicholas, J. G., & Geers, A. E. (2007). Will they catch up? The role of age at cochlear implantation in the spoken language development of children with severe to profound hearing loss. *Journal of Speech, Language, and Hearing Research*, *50*, 1048–1062.

Nittrouer, S., & Burton, L. T. (2005). The role of early language experience in the development of speech perception and phonological processing abilities: Evidence from 5-year-olds with histories of otitis media with effusion and low socioeconomic status. *Journal of Communication Disorders*, *38*, 29–63. doi:10.1016/j.jcomdis.2004.03.006

Nittrouer, S., & Caldwell-Tarr, A. (2016). Language and literacy skills in children with cochlear Implants: Past and present findings. In N. M. Young & K. Iler Kirk (Eds.), *Pediatric Cochlear Implantation* (pp. 177–197). Springer Science and Business Media. doi:10.1007/978-1-4939-2788-3

Nittrouer, S., Sansom, E., Low, K., Rice, C., & Caldwell-Tarr, A. (2014). Language structures used by kindergartners with cochlear implants: Relationship to phonological awareness, lexical knowledge and hearing loss. *Ear and Hearing*, *35*, 1–13. doi:10.1097/AUD.0000000000000051

Olson, A. C., & Caramazza, A. (2004). Orthographic structure and deaf spelling errors: Syllables, letter frequency, and speech. *The Quarterly Journal of Experimental Psychology Section A*, *57*, 385–417. doi:10.1080/02724980343000396

Quick, N., & Erickson, K. (2015, November). Spelling derivationally complex words: An error classification system for measuring progress and planning treatment. Paper presented at *American Speech-Language and Hearing Association Annual Convention*, Denver, CO.

Richards, T. L., Aylward, E. H., Field, K. M., Grimme, A. C., Raskind, W., Richards, A. L., … Berninger, V. W. (2006). Converging evidence for triple word form theory in children with dyslexia. *Developmental Neuropsychology*, *30*, 547–589. doi:10.1207/s15326942dn3001_3

Richards, T. L., Berninger, V. W., & Fayol, M. (2009). fMRI activation differences between 11-year-old good and poor spellers' access in working memory to temporary and long-term orthographic representations. *Journal of Neurolinguistics*, *22*, 327–353. doi:10.1016/j.jneuroling.2008.11.002

Rothman, K. J. (1990). No Adjustments Are Needed for Multiple Comparisons. *Epidemiology*, *1*, 43–46. doi:10.1097/00001648-199001000-00010

Scott, C. M., & Windsor, J. (2000). General language performance measures in spoken and written narrative and expository discourse of school-age children with language learning disabilities. *Journal of Speech and Hearing Research*, *43*, 324–339. doi: 10.1044/jslhr.4302.324

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, *55*, 151–218. doi:10.1016/0010-0277(94)00645-2

Spencer, L. J., & Tomblin, J. B. (2009). Evaluating Phonological Processing Skills in Children With Prelingual Deafness Who Use Cochlear Implants. *Journal of Deaf Studies and Deaf Education*, *14*, 1–21. doi:10.1093/deafed/enn013

Stahl, S. A., & Murray, B. A. (1994). Defining phonological awareness and its relationship to early reading. *Journal of Educational Psychology*, *86*, 221–234. doi:10.1037/0022-0663.86.2.221

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, *21*, 360–407. doi:10.1598/RRQ.21.4.1

Sunseth, K., & Bowers, P. G. (2002). Rapid naming and phonemic awareness: Contributions to reading, spelling and orthographic knowledge. *Scientific Studies of Reading*, *6*, 369–400. doi:10.1207/S1532799XSSR0604

Sutcliffe, A., Dowker, A., & Campbell, R. (1999). Deaf children's spelling: Does it show sensitivity to phonology? *Journal of Deaf Studies and Deaf Education*, *4*, 111–123. doi:10.1093/deafed/4.2.111

Svirsky, M. A., Stallings, L. M., Lento, C. L., Ying, E., & Leonard, L. B. (2002). Grammatical morphologic development in pediatric cochlear implant users may be affected by the perceptual prominence of the relevant markers. *The Annals of Otology, Rhinology & Laryngology*, *111*, 109–112. doi: 10.1177/00034894021110S522

Szagun, G., & Stumper, B. (2012). Age or experience? The influence of age at implantation and social and linguistic environment on language development in children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *55*, 1640–1655. doi:10.1044/1092-4388(2012/11-0119)German

Templin, M. C. (1948). A comparison of the spelling achievement of normal and defective hearing subjects. *The Journal of Educational Psychology*, *39*, 337–346. doi:10.1037/h0056153

Treiman, R. (1993). *Beginning to spell*. New York: Oxford .University Press.

Vermeulen, A. M., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education*, *12*, 283–302. doi:10.1093/deafed/enm017

Wakefield, P. (2006). Deaf children's approaches to spelling - Difficulties, strategies and teaching techniques. *Deafness and Education International*, *8*, 174–189. doi:10.1002/dei

Walker, E. A., Spratford, M., Moeller, M. P., Oleson, J., Ou, H., Roush, P., & Jacobs, S. (2013). Predictors of hearing aid use time in children with mild-to-severe hearing loss. *Language, Speech, and Hearing Services in Schools*, *44*, 73–88. doi:10.1044/0161-1461(2012/12-0005)

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science*, *24*, 2143–52. doi:10.1177/0956797613488145

Werfel, K. L., Lund, E., & Schuele, C. M. (2015). Print knowledge of preschool children with hearing loss. *Communication Disorders Quarterly*, *36*, 107–111. doi:10.1177/1525740114539002

Wolter, J. A., & Apel, K. (2010). Initial acquisition of mental graphemic representations in children with language impairment. *Journal of Speech, Language, and Hearing Research*, *53*, 179–195. doi:10.1044/1092-4388(2009/07-0130)

Woodcock, R., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson-III*. Itasca, IL: Riverside Publishing.

Young, G. A., & Killen, D. H. (2002). Receptive and expressive language skills of children with five years of experience using a cochlear implant. *The Annals of Otology, Rhinology & Laryngology*, *111*, 802–810. doi: 10.1177/000348940211100908

Zeno, S. M., Ivens, S. H., Millard, R. T., & Duvvuri, R. (1995). *The educator's word frequency guide*. Brewster, NY: Touchstone Applied Science.

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131*, 3–29. doi:10.1037/0033-2909.131.1.3

APPENDIX A: POMPLEXITY FOR ROOTS AND AFFIXES CRITERIA FOR PHONOLOGICAL, ORTHOGRAPHIC, AND MORPHOLOGICAL RANKINGS

	Phonology	Orthography	Morphology
0	Correct	Correct	Correct
	Root	*Root*	*Root*
	somewhere/somewhere	mysteries/mysterious	somewhere/somewhere
	walk/walking	ask/asked	walk/walking
	Affix	*Affix*	*Affix*
	trators/tractors	waking/walking	waking/walking
	runing/running	happyness/happiness	happyness/happiness
1	Plausible/Syncope	Transposition, Capitalization, Spacing or Apostrophe error	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
	mysteries/mysterious	singnig/singing	radient/radiant
	walkt/walked	girls/girls'	singnig/singing
2	Substitution or Transposition Substitutions	Legal Grapheme 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	mysteries/mysterious
	hopin/hoping	laborotory/laboratory	avoidence/avoidance
3	Omission	Legal Grapheme 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

4	Addition	Legal Grapheme Errors: Vowels & Consonants	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
5	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
6	Missing Morpheme	Missing Morpheme	
	Affix	*Affix*	
	walk_/walked	walk_/walked	
	hop_/hoping	hop_/hoping	

APPENDIX B: RECORDING FORM FOR POMPLEXITY FOR ROOTS AND AFFIXES

Administration and Scoring

1. Collect a writing sample.
2. Record misspelled words and their targets in appropriate section of the Coding Protocol Form according to the morphological word type: A (Monomorphemic Words), B (Compound/Contracted words), C (Inflected Words), or D (Derived Words).
3. Parse misspelled words with more than one morpheme into separate morphemes using a slash.
4. For each morpheme of a misspelled word, determine:
   - the phonological categorical ranking and record in the corresponding P column.
   - the orthographic categorical ranking and record in the corresponding O column.
   - the morphological categorical ranking and record in the corresponding M column.
5. After completing error analysis, total the total number of errors within each linguistic category and enter in the Frequency Count Form.
6. To calculate frequency of a categorical error, divide the frequency of occurrence of each error by the total number of errors in that category

POMPLEXITY FOR ROOTS AND AFFIXES

Categorical Errors: Phonology (P), Orthography (O), Morphology (M)							
	0	1	2	3	4	5	6
Phonology	Correct	Plausible	Substitution	Omission	Addition	Multiple	Omitted Bound
Orthography	Correct	Minor	Vowel	Consonant	Vowel & Consonant	Illegal	Omitted Bound
Morphology	Correct	Plausible	Homophone	Morpheme	Non-morpheme	Omitted Bound	

CODING PROTOCOL FORM

A. MONOMORPHEMIC					
	Misspelling	Target	P Root	O Root	M Root
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

B. COMPOUND/CONTRACTED								
	Misspelling	Target	P Root	O Root	M Root	P Root	O Root	M Root
1.								
2.								
3.								
4.								
5.								

6.								
7.								
8.								
C: INFLECTED								
	Misspelling	**Target**	**P Root**	**O Root**	**M Root**	**P Affix**	**O Affix**	**M Affix**
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
D. DERIVED								
	Misspelling	**Target**	**P Root**	**O Root**	**M Root**	**P Affix**	**O Affix**	**M Affix**
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

FREQUENCY COUNT FORM

Monomorphemic Frequency Counts (Total number of errors from section A of Coding Protocol)							
	0	**1**	**2**	**3**	**4**	**5**	**6**
Phonology	**Correct**	**Plausible**	**Substitution**	**Omission**	**Addition**	**Multiple**	**Omitted Bound**
Orthography	**Correct**	**Minor**	**Vowel**	**Consonant**	**Vowel & Consonant**	**Illegal**	**Omitted Bound**
Morphology	**Correct**	**Plausible**	**Homophone**	**Morpheme**	**Non-morpheme**	**Omitted Bound**	
Compound & Contracted Frequency Counts (Total number of errors from first and second morphemes from section B of Coding Protocol)							
	0	**1**	**2**	**3**	**4**	**5**	**6**
Phonology	**Correct**	**Plausible**	**Substitution**	**Omission**	**Addition**	**Multiple**	**Omitted Bound**
Orthography	**Correct**	**Minor**	**Vowel**	**Consonant**	**Vowel & Consonant**	**Illegal**	**Omitted Bound**
Morphology	**Correct**	**Plausible**	**Homophone**	**Morpheme**	**Non-morpheme**	**Omitted Bound**	
Roots of Inflected & Derived/Morphemes (Total number of errors from roots of sections C and D of Coding Protocol)							
	0	**1**	**2**	**3**	**4**	**5**	**6**
Phonology	**Correct**	**Plausible**	**Substitution**	**Omission**	**Addition**	**Multiple**	**Omitted Bound**
Orthography	**Correct**	**Minor**	**Vowel**	**Consonant**	**Vowel & Consonant**	**Illegal**	**Omitted Bound**
Morphology	**Correct**	**Plausible**	**Homophone**	**Morpheme**	**Non-morpheme**	**Omitted Bound**	

Affixes of Inflected & Derived Frequency Counts/Morphemes (Total number of errors from affixes of from sections C and D of Coding Protocol)							
	0	**1**	**2**	**3**	**4**	**5**	**6**
Phonology	**Correct**	**Plausible**	**Substitution**	**Omission**	**Addition**	**Multiple**	**Omitted Bound**
Orthography	**Correct**	**Minor**	**Vowel**	**Consonant**	**Vowel & Consonant**	**Illegal**	**Omitted Bound**
Morphology	**Correct**	**Plausible**	**Homophone**	**Morpheme**	**Non-morpheme**	**Omitted Bound**	

APPENDIX C: SCORED STUDENT FORMS OF POMPLEXITY FOR ROOTS AND AFFIXES

POMplexity for Roots and Affixes for Student 1

Misspelling/ Target	Root			Affix			
	P	O	M	P	O	M	Word Type
a go/ago	1	1	2				single
gorge/George	1	2	3				single
buffilo/buffalo	1	2	4				single
buffilo/buffalo	1	2	4				single
buffilo/buffalo	1	2	4				single
mountin/mountain	1	2	4				single
field/field	1	1	1				single
cave man/caveman	1	1	1				compound
	1	1	1				
some where/somewhere	1	1	1				compound
	1	1	1				
runing/running	1	3	1	0	0	0	inflected
stoped/stopped	1	3	1	0	0	0	inflected

P = Phonology, O = Orthography, M = Morphology

POMplexity for Roots and Affixes for Student 2

Misspelling/ Target	Root			Affix			
	P	O	M	P	O	M	Word Type
knowbody/nobody	1	3	2				compound
	0	0	0				compound
knifes/knives	2	3	1	0	0	0	inflected
got/gotten	1	3	1	6	6	5	inflected
mysteries/mysterious	0	0	0	1	2	3	derived
monsteris/monstrous	4	2	1	1	2	3	derived

P = Phonology, O = Orthography, M = Morphology

POMplexity for Roots and Affixes for Student 3

Misspelling/ Target	Root			Affix			
	P	O	M	P	O	M	Word Type
tow/two	2	1	1				single
glir/girl	2	1	1				single
are/our	1	2	3				single
viggle/village	5	4	4				single
moutain/mountain	3	3	4				single
an/and	3	3	3				single
an/and	3	3	3				single
elepht/elephant	5	5	4				single
there/their	1	2	2				single
nife/knife	1	3	4				single
elepht/elephant	5	5	4				single
an/and	3	3	3				single
vigglue/village	5	4	4				single
dint/didn't	1	3	4				contracted
	1	1	1				contracted
garndpa/grandpa	2	1	1				compound
	0	0	0				compound
grand fater/grandfather	1	1	1				compound
	2	3	4				compound
name/named	0	0	0	6	6	5	inflected
ask/asked	0	0	0	6	6	5	inflected
suprised/surprised	3	3	4	0	0	0	inflected
ask/asked	0	0	0	6	6	5	inflected
moutains/mountains	3	3	4	0	0	0	inflected
elephts/elephants	5	5	4	0	0	0	inflected
tusk/tusks	0	0	0	6	6	5	inflected
point/pointed	0	0	0	6	6	5	inflected
sitks/sticks	5	4	4	0	0	0	inflected
kill/killed	0	0	0	5	5	5	inflected

P = Phonology, O = Orthography, M = Morphology

POMplexity for Roots and Affixes for Student 4

Misspelling/ Target	Root			Affix			
	P	O	M	P	O	M	Word Type
pepun/people	2	4	4				single
thash/trash	5	3	4				single
anmp/animal	5	5	4				single
weny/when	4	4	4				single
thay/they	1	2	4				single
theny/then	4	2	4				single
thay/they	1	2	4				single
ane/are	2	3	4				single
it/eat	1	2	3				single
oll/all	1	2	4				single
theny/then	4	2	4				single
thay/they	1	2	4				single
cari/carry	1	4	4				single
thay/they	1	2	4				single
thay/they	1	2	4				single
it/eat	1	2	3				single
win/when	2	4	3				single
thay/they	1	2	4				single
gint/get	4	4	4				single
bunh/done	2	5	4				single
thay/they	1	2	4				single
sum/some	1	4	2				single
muhr/more	2	4	4				single
maden/maybe	2	4	3				compound
	5	4	4				compound
thry/throwing	5	4	4	5	4	3	inflected
celly/killing	1	4	4	5	4	5	inflected
gueng/going	2	2	4	1	2	4	inflected
anmps/animals	5	5	4	0	0	0	inflected
anmps/animals	5	5	4	0	0	0	inflected

P = Phonology, O = Orthography, M = Morphology