DERIVATIONAL MORPHOLOGY IN FIRST GRADE CHILDREN WHO ARE DEAF OR HARD OF HEARING

by

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DERIVATIONAL MORPHOLOGY IN FIRST GRADE CHILDREN WHO ARE DEAF OR HARD OF HEARING

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ABSTRACT

Derivational morphological knowledge is critical to the acquisition of language and literacy, specifically expressive vocabulary. Current literature suggests that children who are deaf and hard of hearing have deficits in grammatical morphology, but there has not been significant study on derivational morphology in this population. This study aimed to understand derivational morphology in first grade children who are deaf and hard of hearing and how they compare to their peers with typical hearing.

The first-grade children in this study fell into three groups based on hearing status: children with cochlear implants, hearing aids, and children with typical hearing. Participants completed the Test of Morphological Structure to assess their derivational morphological knowledge (Carlisle, 2000).

Based on each group's performance, researchers found that children who are deaf and hard of hearing, specifically those who wear cochlear implants, have significant deficits in derivational morphology. Performance was influenced by audibility of morphemes, shift versus transparent word productions, and age of acquisition of the root word. The present data provides a starting point to examining derivational morphology in children who are deaf and hard of hearing during school aged years.

Introduction

Knowledge of morphology is a central piece of the acquisition of language and literacy for school-aged children. Children with typical hearing (CTH) acquire morphological knowledge naturally during the preschool and elementary years. However, children who are deaf and hard of hearing (DHH) appear to have greater weaknesses in these skills, and specifically, the development of inflectional morphology (Davies et al., 2020). Although numerous studies have evaluated grammatical morphology in children who are DHH, little is known about derivational morphological knowledge in this population. Derivational morphological knowledge is a critical contributor to vocabulary, word reading, phonological awareness, and reading comprehension in school-aged years (Lee et al., 2023). It is an important area of interest because deficits in derivational morphological skills could delay a child's language development (Walker et al., 2020). The purpose of this study is to compare derivational morphological knowledge of children who are deaf or hard of hearing and children with typical hearing.

What is Morphology?

Morphology is the study of morphemes, specifically how root words and affixes are combined and used in word formations (Kutlu et al., 2021). Morphemes are the smallest units of meaning in a language that contribute to the inflectional and derivational features of a word. They also provide information about a word's meaning, spelling, and pronunciation (Carlisle, 2000). Children develop early understanding of morphemic structures of words, even if that knowledge is subconscious, and are able to manipulate the structure of a word in certain contexts (Carlisle, 1995; Choi et al., 2018). Morphological knowledge is important for the acquisition of language and literacy. Furthermore, building on morphological knowledge, morphological analysis is the use of known morphemes to infer the meaning of morphologically complex words

(Levesque et al., 2019). Children utilize this skill in reading comprehension, word reading, and the acquisition of new vocabulary.

Grammatical Morphology versus Derivational Morphology

The study of morphology can be broken down into two areas: derivational morphology, and grammatical (inflectional) morphology. Grammatical morphology examines the inflections, or changes in form (e.g., present to past tense verb changes), of a word. This includes verb tense marking, plurals, and possessives, for example (Carlisle, 1987; Davies et al., 2020). Grammatical morphology is a more fundamental part of language because the inflectional components are integral to functional spoken language (Carlisle 1987).

Derivational morphology includes the addition of morphemes to a word stem that results in the formation of a new word that differs in syntactic category from the base word. Derivational morphological knowledge is significantly correlated with vocabulary growth and word reading (Lee et al., 2023). Derived words are formed by adding affixes (prefixes and suffixes) to base words. Morphologically derived words are separated into two categories: shift words and transparent words. Transparent words have the base word intact in the derived form *(e.g. "improvement" has the base word "improve" intact)*. Oppositely, in shift words, the phonological representation shifts from the base and derived form of the word (Carlisle, 2000) *(e.g. "expansion" does not have the base word "expand" phonologically intact")* . Derivational morphology is still considered relatively ruleful, but word specific knowledge plays a larger role in its development, making it a more complex concept for children to grasp than grammatical morphology (Carlisle, 1987).

Typical Morphological Development

Studies of language and literacy development have provided a basis of what morphology looks like in CTH. In broad terms, grammatical morphemes are acquired before derivational morphemes (Spencer et al., 2015). CTH follow a predictable order in which they develop grammatical markers throughout their preschool years. Children first develop noun plural morphemes, then the use of the uncontractable copula, and finally, regular past tense marking (Svirsky et al., 2002). Grammatical morphological markers emerge in children as early as 24 months of age. This is when the morphosyntactic representations for plurals develop, following with singular representations at 36 months of age (Davies et al., 2023). Kindergarteners and first graders exhibit near-adult-level mastery in grammatical morphological knowledge (Spencer et al., 2015). By the age of 7, children can use inflectional morphemes without error when speaking (Carlisle, 1987).

Derivational morphology, particularly conscious morphological knowledge, is developed later as children progress through the school-aged years. Mid-to-late elementary is a period of derivational morphological growth. Prior to this time, children have limited awareness of the structure and meaning of derived word forms. For instance, early elementary students can decompose phonologically transparent forms of a word (e.g. knowledge that the base word of "helpful" is "help"), but do not yet exhibit signs of understanding or using complex words (Carlisle & Flemming, 2003). Children learn to decompose and then derive transparent words before shift words (Carlisle, 2000).

In Joanne F. Carlisle's study (2000), she explored 3rd and 5th grade students' ability to read and recognize morphologically complex words. The study results concluded that 3rd grade marked the age when the number of derived words known was significantly greater than the root words or inflected forms of words. By 5th grade, this difference was even more pronounced as children continued to learn new derived words. Therefore, 4th grade is widely recognized as the age when derivational morphological knowledge shows the most rapid growth (Carlisle, 2000; Walker et al., 2020).

Morphological knowledge in DHH kids with hearing aids and cochlear implants

Studies of morphological development in children who are DHH and learning spoken language through hearing aids (HA) or cochlear implants (CI) have primarily focused on grammatical morphology. Children who are DHH demonstrate delays in comprehension and production of grammatical morphology. In a study evaluating productive grammatical morphology in children who are DHH who use CI or HA, children had specific difficulty with bound morphemes with hard to hear fricative phonemes such as /s/ and /z/ (Davies et al., 2020). This difficulty translates into their ability to use subject-verb agreement in sentences. Children who are DHH can use subject-verb agreement to predict upcoming nouns, but they appear to be slower at the prediction of plural subject verb agreement than typical hearing peers (Davies et al., 2023; Moeller et al., 2010).

There are several reasons that children who are DHH might have difficulty with the acquisition of language, and morphology in particular. Difficulty in grammatical morphology can be attributed to the perceptual prominence theory: the pattern of language development in cochlear implant and hearing aid users will be affected by the audibility of relevant morphological markers (Svirsky et al., 2002). Other studies point to the linguistic approach, or the language instinct, which supports that children who are DHH will acquire language in the same sequences as CNH but will be delayed in acquisition (Pinker, 1994). However, the bulk of research indicates that struggles with morphological knowledge as a combination of both (Werfel et al., 2018).

Children with late-identified hearing loss have an especially difficult time with the onset and productive use of morphemes with reduced audibility. Moeller et al. examined the impact of late identification of mild-moderate hearing loss in a longitudinal study following four children from 28-41 months through 84 months in relation to age matched peers. In DHH children, onset and productive use of verb tense marking was delayed. In TH children, third person singular tense is one of the first tense markers to emerge. However, children who are DHH exhibited delayed initial productivity of third person singular morphemes at 48 months. In the study, three out of the four children made atypical, persistent errors in grammatical morphology with third person singular, contracted copula and auxiliary, and past tense at 54 months (Moeller et al., 2010). Additionally, school aged children with CIs have been found to perform best on the copulas "is" and "are," because they are easier to hear than the higher frequency sounds that represent other morphemes (e.g., plurals and possessives) (Svirsky et al., 2002).

Further study of language samples of preschoolers who are DHH points to lower percent correct of regular plurals, past tense, and regular and irregular 3rd person singular by 30-40% compared to children with TH, and more omissions relative to age- and language- matched peers. Lower accuracy was observed as compared to children who are TH, but the children who are DHH did not differ in their patterns of production. For preschoolers, tense marking was more difficult than non-tense morphemes, hinting at a linguistic component to the acquisition of morphology. The results indicated that tense marking deficits in DHH children may be driven by speech perception-based deficits that are also complicated by linguistic knowledge (Werfel et al., 2018).

In spoken narrative, profoundly deaf children with early-implanted CIs produced shorter, less complex speech that contained more morphological errors. Interestingly though, when compared to age-matched peers, they produced equal numbers of utterances (Boons et al., 2013). This indicates a deficit in overall morphological markers.

Walker et al. (2020) have conducted one of the only studies to date that evaluates derivational morphology in the DHH population. The study included 60 children with mild bilateral hearing loss (MBHL) who used hearing aids. The authors found that for this population, vocabulary size and reading skills reached an age-appropriate level by 4th grade. Ten-year-old children with MBHL present a significant difference in mean scores on the Test of Morphological Structure (MBHL: 16.64, NH: 18.84), meaning there was a variance in derivational morphological awareness; however, this study did not provide detail on the types of structures missed. The conclusions of this study were that even in the mild range of hearing loss, exposure to morphemes is likely reduced in daily language exposure as compared to children with TH, which causes inconsistency in production and comprehension.

Why would morphological knowledge be different for DHH children with hearing aids and cochlear implants?

Morphological knowledge may differ between children with hearing aids and cochlear implants, in addition to differing from children with TH. Put simply, the two technologies process sound differently. HAs amplify sound, which can distort acoustic signal characteristics. This distortion could make it difficult for users to acquire certain distinct grammatical morphemes. CIs produce an entirely different type of acoustic signal due to the technological functions of the devices. Cochlear implants convert acoustic signals from sound into electrical pulses, which may impede morphosyntactic cues (Davies et al., 2023). Additionally, HAs are often fitted to children with milder degrees of hearing loss but often minimally benefit more severe or profound degrees of hearing loss. CIs, on the other hand, are implanted in children with higher degrees of hearing loss. As a result of these device- and degree-related differences in sound access, children with HAs seem to develop grammatical morphological markers differently than children with CI. For instance, HA users seemingly develop initial representations of the singular before plurals, whereas CI users are suspected to first develop the comprehension of the syllabic plural allomorph instead (Davies et al., 2020).

Other factors can also predict differences in morphological knowledge of children with HA and CIs. Linda Cupples et al. conducted a study in 2018 investigating the factors that influence the speech, language, and functioning of 339 age five children who either used HA or CI. In the study, they addressed which variables contribute to the success of language acquisition of HA and CI. The study did not only focus on morphology, but the results point to factors that may impact morphological knowledge. Overall, they found that both the same and different predictors contribute to the success of either device. Notably, degree of hearing loss plays a role in the effectiveness of HA, but not of CI. For children with HA, the amount of usage was substantially correlated with their success. From the population with CI, researchers indicated that the presence of additional disabilities predicted performances. One factor that contributed to the outcomes for both CI and HA was the age of fitting (Cupples et al., 2018). Thus, we might predict that children with CI and HA could vary in their knowledge of derivational morphology as a result of numerous audiological factors.

Why does derivational morphological knowledge matter?

Derivational morphology is a key building block of language and literacy development. Children use derivational morphemes to read words. Knowledge of derivational morphology is identified as a notable moderate predictor of spelling, text processing speed, phonological awareness, word reading, and reading comprehension proficiency. It also has a significant correlation with vocabulary knowledge (Choi et al., 2018; Lee et al., 2023; Levesque et al., 2019; Spencer et al., 2015). Moreover, the morphological tasks presented to the participants in Carlisle's study revealed that derivational morphology knowledge accounted for 41% variance in vocabulary in 3rd grade, and 53% in 5th grade (Carlisle, 2000).

Derivational morphological knowledge is a foundational metalinguistic skill that provides a basis for middle elementary children to understand the structure and meaning of written words as well as develop their breadth of vocabulary. In understanding the structure of words, children have a greater ability to read complex and unfamiliar words (Carlisle, 2000; Levesque et al., 2022). Reading comprehension builds directly on derivational knowledge. Specifically, a study showed that grade 3 morphological analysis of words predicted gains in reading comprehension in grade 4 (Levesque et al., 2019). Carlisle's study mentioned previously also found this. She found that 3rd and 5th graders' derivational morphology contributes significantly to reading comprehension levels (Carlisle, 2000). It also then is necessary for efficient lexical processing (Carlisle, 2000; Carlisle & Flemming, 2003).

Comprehensively, derivational morphological awareness is of central importance in language and literacy (Lee et al., 2023). Virtually all facets of language, such as reading, vocabulary, and spelling, are impacted by the acquiring the skill of derivational morphology. Due to the contributions derivational morphology has on language and literacy skills, it is deemed an essential skill to function in a learning environment and provides the necessary foundation to facilitate growth.

Although derivational morphology has not been intensely studied in children who are DHH and learning spoken language, it has been studied in other populations who struggle to learn language. Carlisle's 1987 study addressed the learning of derivational morphology and spelling of children with dyslexia. She examined whether children with learning impairments learn rulefully, and the extent to which they use their knowledge of morphological relationships between base and derived forms in spelling. The study compared a group of 9th graders with dyslexia to groups of 4th, 6th, and 8th graders. Results showed that 9th graders performed at a 6th to 8th grade level on the experimental Test of Morphological Structure, meaning their derivational development was 1-3 years delayed. There was also a greater discrepancy between orally deriving words and orthographically spelling them; therefore, the students knew more about morphemic structure than application of the concept. Thus, children with dyslexia appear to follow the same patterns of derivational performance as typically developing children, but they lag behind in mastery (Carlisle, 1987).

How do people measure derivational morphology?

Derivational morphology is often measured by the Test of Morphological Structure (TMS; Carlisle, 2000). The TMS assesses school-aged students' knowledge of derivational morphology through an orally administered task of completing a sentence by changing the target item (Levesque et al., 2019). For example, the tester reads the sentence: Help. My sister is always ____. The child would be expected to answer "helpful" to satisfy the sentence. The assessment is comprised of two parts: derivation and decomposition. The derivation portion of the test consists of 28 target items. Each target item in this section is a base word, and students are asked to derive it into a form that satisfies the sentence (i.e. farm: My uncle is a farmer.). The decomposition section of the assessment is also made up of 28 items. This time, students are asked to identify the base form of the derived word given (i.e. driver: Children are too young to drive). Both sections of the exam each have 14 transparent words and 14 shift (opaque) words (Carlisle, 2000).

To date, although the TMS has been used to assess children with other disabilities, this assessment has only been used to evaluate children who are DHH in one previous study as one test in the testing battery for children with MBHL (Walker et al., 2020).

This Study:

For children who are DHH, it appears that grammatical morphemes develop in order (but delayed) as for children with TH. However, in some circumstances, children who have substantially diminished access to sound do not develop morphemes that are difficult to hear. Nevertheless, we do not have adequate knowledge about the derivational morphological knowledge of DHH who use cochlear implants or hearing aids, or how audibility affects derivational morphology. This would be crucial to know because morphological knowledge (including derivational morphology) helps children to grow their vocabulary knowledge, which we know is delayed for DHH. The current study aims to investigate the following research questions:

1. Does decomposition performance differ between children with CI, HA, and TH in Grade 1 (G1)?
2. Does derivational performance differ between children with CI, HA, and TH in G1?
3. Does the audibility of a derivational morpheme sound influence performance differentially for CI, HA, and TH kids?
4. Does the production change for shift words versus transparent words affect performance differently for children with CI, HA, and TH?
5. Does age of acquisition of the root word affect performance on the TMS for CI, HA, and TH kids?

Methods

All procedures of this study were approved by Texas Christian University Institutional Review Board.

Participants

Participants in this study were part of the Emergent Literacy and Language Acquisition (ELLA) Study, a longitudinal study of children with hearing loss (e.g., Lund et al., 2022). The subset of children included in this study included a group of children who had just complete first grade (G1) with hearing loss (n=50; 25 boys, 25 girls) and a group of children who completed G1 with typical hearing (n=21; 8 boys, 13 girls). Children who are DHH were the average age of 7.57 years (SD=0.32), and children with typical hearing were the average age of 7.23 years (SD=0.27). For the group of children who are DHH, the average maternal education was 17.09 years (SD=2.27). For the group of children with typical hearing, the average maternal education was 17.98 years (SD=1.86). No child in either group had been diagnosed with a language or learning impairment apart from hearing loss.

Of the children who are DHH, two subgroups were included: participants with HA, and participants with CI. Twenty five wore bilateral hearing aids, 20 wore bilateral cochlear implants, and 5 used a unilateral cochlear implant with a hearing aid in the unimplanted ear. The average age of initial hearing loss identification was 7.77 months (SD=12.66). For the children who wore hearing aids, the average age at the first amplification was 16.24 months (SD=16.82). For the children with cochlear implants, the average age at the first implantation was 23.24 months (SD=15.76). Hearing loss levels ranged from mild to profound in this study. All children used spoken language.

	CI (n=25)	**HA (n=25)**	**TH (n=21)**
Gender	Male: 9 Female: 16	Male: 16 Female: 9	Male: 8 Female: 13

Age in G1 (Years)	*M*= 7.5 *SD*= .373	*M*= 7.643 *SD*= .252	*M*= 7.23 *SD*= 0.267
Maternal Education	*M*= 17.4 *SD*= 2.061	*M*= 16.78 *SD*= 2.467	*M*= 17.98 *SD*= 1.86
Age of Identification (Months)	*M*= 2.702 *SD*= 5.681	*M*= 12.532 *SD*= 17.046	*Not applicable*
Age of Amplification (Months)	*M*= 23.24 *SD*= 15.76	*M*= 16.24 *SD*= 16.82	*Not applicable*
Level of Hearing Loss	Mild: 0 Mild to Moderate: 0 Moderate: 0 Moderately Severe: 2 Severe: 0 Severe to Profound: 6 Profound: 17	Mild: 1 Mild to Moderate: 9 Moderate: 6 Moderately Severe: 8 Severe: 1 Severe to Profound: 0 Profound: 0	*Not applicable*
Race/Ethnicity	White: 24 Asian: 1 Hispanic: 0 Black or African American: 0 Native Hawaiian/Pacific Islander: 0 Prefer not to answer: 0	White: 17 Asian: 2 Hispanic: 2 Black or African American: 3 Native Hawaiian/Pacific Islander: 1 Prefer not to answer: 0	White: 16 Asian: 1 Hispanic: 1 Black or African American: 2 Native Hawaiian/Pacific Islander: 0 Prefer not to answer: 1

Table 1. Demographic data of participants with TH and HL.

Procedure

The Test of Morphological Structure (Carlisle, 2000) was administered in addition to a battery of tests by speech-language pathologists during the ELLA Study. Administrators were trained to appropriately give assessments by ELLA study investigators. The Test of Morphological Structure (Carlisle, 2000) assesses morphological knowledge of derivational morphology. To administer the fill in the blank assessment, the examiner says a target word and reads a sentence for the child to complete. For instance, the examiner might say protect, and then read the open-ended sentence, “She wears glasses for...” It is expected that the child will change the word into the base or derived form of the word that will complete the sentence. In the case above, the target response would be protection. The TMS items were read aloud, and participants responded orally. Items were scored as one point for correct responses and zero points for incorrect responses, with a possible 28 points for each section. For this study, the authors utilized the raw scores of the derivation and decomposition sections of the assessment.

The raw scores from the derivation and decomposition sections of the TMS were analyzed holistically to answer the first and second research questions, comparing the derivation and decomposition performances of children with TH, HA, and CI.

Researchers completed item by item analysis to answer the third and fourth research questions. To answer the third question, the audibility of each item was assessed. The 28 items on each part of the Test of Morphological structure were separated into subgroups according to the derivational morpheme additions. Participants’ responses were analyzed to understand whether the derivational morpheme sound audibility influences the performance of the three groups (HA, CI, TH). To answer the fourth research question, the researchers divided the Derivation and Decomposition sections of the assessment into two categories: shift words and transparent words. Each section of the TMS includes 14 shift words and 14 transparent words. The participants’ number correct for each question type was calculated on each section. Researchers utilized this data to analyze whether production change for shift words and transparent words affect performance on the TMS for children with TH, CI, and HA.

Researchers also identified the age of acquisition of each root word utilizing a database on the derivation and decomposition sections of the Test of Morphological Structure (Kuperman et al., 2012). For analysis, researchers grouped the seven earliest acquired words on each section into the bottom quartile, and the latest acquired seven words into the highest quartile to compare how participants performed relative to their grouping on earlier acquired and later acquired words to investigate the relationship between age of acquisition and performance for children with HL and TH.

Results

The first and second research questions asked if decomposition performance and derivation performance on the TMS differed between groups with CI, HA, or children with TH. To answer these questions, we conducted a repeated measures analysis of variance with group as the between-subjects variable and word type according to subtest (decomposition or derivation) as the within-subjects variable. Results revealed a main effect of subtest ($F(1,68) = 81.56$, $p < .001$) and of group ($F(2,68) = 6.565$, $p = .002$), but not an interaction effect of subtest by group ($F(2,68) = 2.087$, $p = .132$). Children, regardless of group, performed lower on the derivation subtest than on the decomposition subset. Post-hoc analysis of group effects with a Bonferroni correction for multiple comparisons revealed that children with CI differed significantly from children with TH ($p = .002$) but not from children with HA ($p = .468$). Children with HA also did not significantly differ from children with TH ($p = .085$). Children with CI were numerically the lowest performers across subtests, followed by children with HA, and children with TH performed the highest.

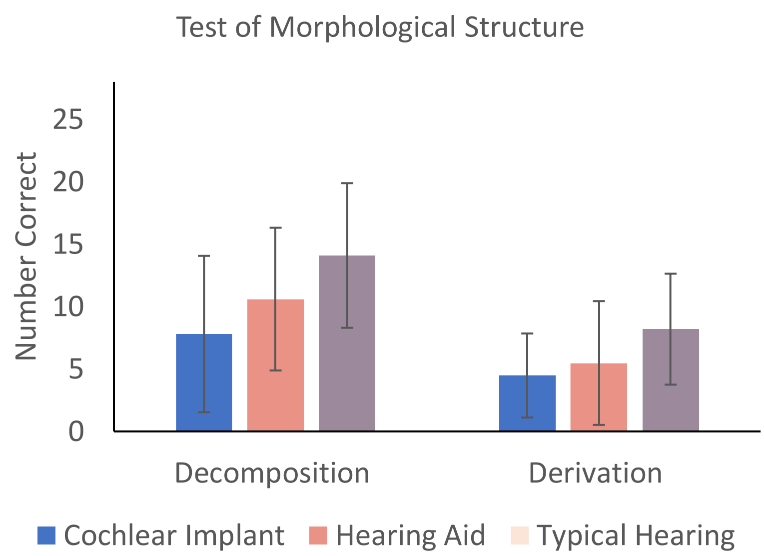

Figure 1. Mean performance on subtest by amplification type

The third research question asked if the audibility of a derivational morpheme sound influences performance differentially for children with CI, HA, and children with TH. To answer this question, number correct according to each morpheme type was calculated for each participant and entered into a one-way analysis of variance with performance on a particular morpheme as the dependent variable and with group as the between-subjects independent variable. Thus, performance on each type of morpheme and across the subtests was calculated separately. On the derivation subtest, there was a significant difference in performance between groups for the "th" morpheme ($F(2,68) = 4.386$, $p = .016$) and for the "ous" morpheme ($F(2,68) = 4.092$, $p = .021$). There was not a significant difference in performance for the morphemes "able", "ance", "er", "ity", or "sion" (p value ranged from .235 to .838). Post-hoc analysis of group effects with a Bonferroni correction for multiple comparisons revealed that on the "th" morpheme, children with CI differed significantly from children with TH ($p = .015$) but not from children with HA ($p = 1.00$). Children with HA also did not significantly differ from children with TH ($p = .125$). On the "ous" morpheme, children with CI differed significantly from children with TH ($p = .017$) but not from children with HA ($p = .771$). Children with HA also did not significantly differ from children with TH ($p = .250$).

For the decomposition subtest, there was a significant difference in performance between groups for the "th" morpheme ($F(2,68) = 11.548$, $p < .001$), the "able" morpheme ($F(2,68) = 3.247$, $p = .045$), the "ance" morpheme ($F(2,68) = 5.088$, $p = .009$), the "er" morpheme ($F(2,68) = 5.378$, $p = .007$), the "ity" morpheme ($F(2,68) = 6.615$, $p = .002$), the "ous" morpheme ($F(2,68) = 4.915$, $p = .010$), and the "sion" morpheme ($F(2,68) = 6.983$, $p = .002$). Post-hoc analysis of group effects with a Bonferroni correction for multiple comparisons revealed that on the "th" morpheme, children with CI differed significantly from children with TH ($p <.001$) and children with HA ($p = .019$). Children with HA did not significantly differ from children with TH ($p = .125$). On the "able" morpheme, children with CI differed significantly from children with TH ($p = .040$), but not from children with HA ($p = .529$). Children with HA did not differ significantly from children with TH ($p = .661$). On the "ance" morpheme, children with CI differed significantly from children with TH ($p = .008$), but not from children with HA ($p = 1.00$). Children with HA did not significantly differ from children with TH ($p = .077$). On the "er" morpheme, children with CI differed significantly from children with TH ($p = .012$), but not from children with HA ($p = 1.00$). Children with HA also significantly differed from children with TH ($p = .022$). On the "ity" morpheme, children with CI significantly differed from children with TH ($p = .002$), but not from children with HA ($p = .432$). Children with HA did not differ significantly from children with TH ($p = .091$). On the "ous" morpheme, children with CI differed significantly from children with TH ($p = .009$), but not from children with HA ($p = 1.00$). Children with HA did not differ significantly from children with TH ($p = .100$). On the "sion" morpheme, children with CI differed significantly from children with TH (*p* = .001), but not from children with HA (*p* = .088). Children with HA did not differ significantly from children with TH (*p* = .359).

Morpheme	**"th"**	**"able"**	**"ance"**	**"er"**	**"ity"**	**"ous"**	**"sion"**
Derivation	**.016**	.345	.739	.538	.838	**.021**	.235
Decomposition	**<.001**	**.045**	**.009**	**.007**	**.002**	**.010**	**.002**

Table 2. P values for effects of group on performance based on morpheme; bold indicates significant differences

The fourth research question asked if the production change for shift words versus transparent words affects performance differentially for children with CI, HA, and children with TH. To answer this question, we conducted a repeated measures analysis of variance with group as the between-subjects variable and subtest (decomposition or derivation) and word type (transparent or shift) as the within-subjects variables. Results revealed a main effect of subtest ($F(1,68) = 115.660$, $p < .001$) wherein decomposition performance was lower than derivation performance, of word type ($F(1,68) = 196.680$, $p < .001$) where shift performance was lower than transparent performance, and of group ($F(2,68) = 7.556$, $p = .001$). There was an interaction effect of subtest by word type ($F(1,68) = 21.004$, $p < .001$) but not an interaction effect of word type by group ($F(2,68) = 1.140$, $p = .326$). There was also not an interaction effect of subtest by word type by group ($F(2,68) = 2.450$, $p = .094$). Post-hoc analysis of group effects with a Bonferroni correction for multiple comparisons revealed that children with cochlear implants performed more poorly than children with typical hearing ($p<.001$) but not children with hearing aids ($p = .297$) and children with hearing aids and typical hearing did not significantly differ ($p =$

.077). The difference in the gap between transparent and shift performance was greater for the decomposition subtest than for the derivation subtest ($p < .001$).

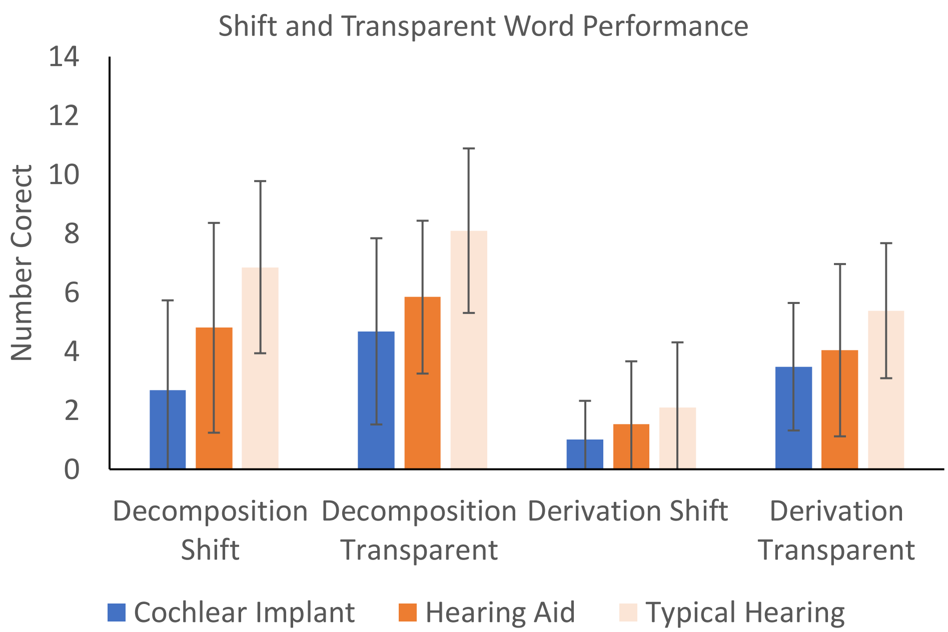

Figure 2. Mean performance on shift and transparent words by amplification type

The fifth research question asked if the age of acquisition of the root word affects performance on the TMS for children with CI, HA, and children with TH. To answer this question, we conducted a repeated measures analysis of variance with group as the between-subjects variable and subtest (decomposition or derivation) and age of acquisition (highest and lowest quartiles) as the within-subjects variables. Results revealed a main effect of subtest ($F(1,68) = .85.753$, $p < .001$), of age of acquisition ($F(1,68) = 639.268$, $p < .001$) wherein earlier acquired words have a higher performance, and of group ($F(2,68) = 8.841$, $p < .001$). There was an interaction effect of age of acquisition by group ($F(2,68) = 4.657$, $p = .013$) and of subtest by age of acquisition ($F(1,68) = 25.014$, $p < .001$). There was not an interaction effect of subtest by age of acquisition by group ($F(2,68) = .226$, $p = .798$). Post-hoc analysis of group effects with a Bonferroni correction for multiple comparisons revealed that children with cochlear implants performed more poorly than children with typical hearing ($p<.001$) but not children with hearing aids (p = .177) and children with hearing aids and typical hearing did not significantly differ (p = .062). The discrepancy between performances on early- versus late-acquired words was widest for children with typical hearing as compared to children with cochlear implants (p = .019) and children with hearing aids (p = .043). Both groups who were DHH did not significantly differ from each other (p = 1.00). The difference between early and late acquired items was greater for the derivation subtest than for the Decomposition subtest (where fewer children across groups answered items correctly).

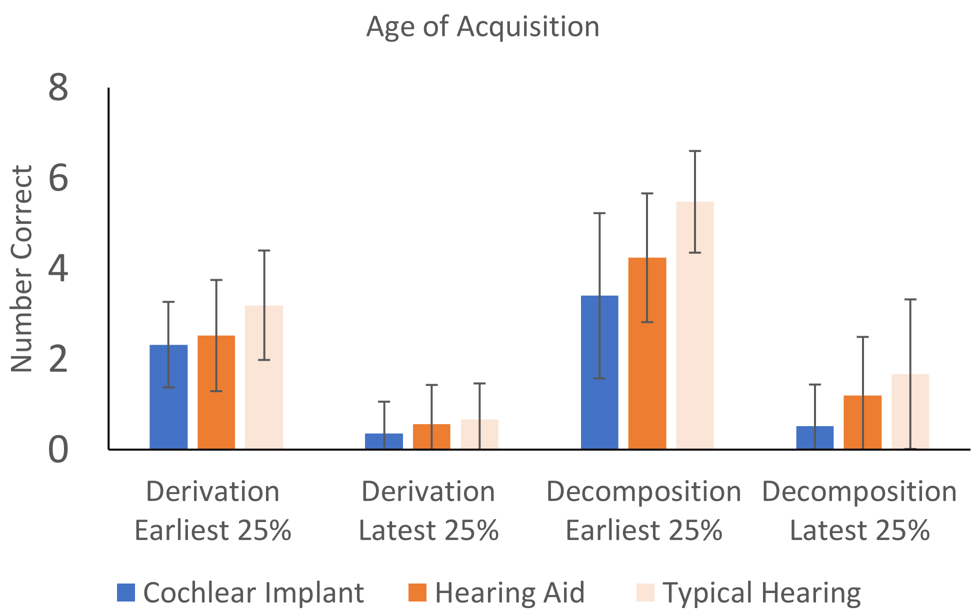

Figure 3. Mean performance on early and late acquired words by amplification type.

Discussion

The main purpose of this study was to compare derivational morphological knowledge of children who are DHH and children with TH in grade 1. Derivational morphological development in children who are DHH is critical to understand, as this knowledge directly impacts language and literacy development during school aged years.

The Test of Morphological Structure has not been administered to assess children who are deaf and hard of hearing, specifically with moderate to profound hearing loss, nor has there been intense study analyzing derivational morphology in children who are DHH. This study examined aspects of language that have yet to be intensely studied for children who are DHH.

The first and second research question addressed differences by group on the derivation and decomposition subtests of the TMS. On both subtests, children with CIs and HAs performed numerically lower than their peers with TH, and the difference between children with CIs and children who are DHH was statistically significant. In both the derivation and decomposition contexts, children who are DHH have lower accuracy on derivational morphology than children with TH. This reveals that even with amplification, children who are DHH perform lower on derivational morphology tasks. It is important to note that children, regardless of group, did better on the decomposition task. Decomposing words from the derived to base form is a derivational morphological skill that emerges in early elementary, which is reflected by the results of this study, with children who are DHH performing behind their peers (Carlisle & Flemming, 2003). The derivation task is expected to continue to develop as children progress through elementary school.

The third research question explored how audibility of a morpheme impacts derivational performance. Children who are DHH have significant differences in performance on less audible morphemes on the derivation task. Like in grammatical morphology, children who are DHH struggle more on the less audible derivational morphemes such as “th” and “ous.”. The derivation subtest results confirm the perceptual prominence theory, which states that the pattern of language development in CI and HA is affected by the audibility of the morpheme (Svirsky et. al., 2002).

On the decomposition subtest, there were significant differences by group on every morpheme on the TMS, regardless of audibility levels. This could be because decomposition is easier than derivation for children in first grade, so children with typical hearing performed significantly better on that subtest than children who are DHH. Future study could consider this more in depth.

The fourth research question examined how the production change for shift and transparent words impacted performance differentially for children who are DHH. Transparent words are easier for first grade children because the root word is phonologically intact in the derived form of the word (Carlisle, 2000). Shift words are known to be more difficult, as the root word changes phonologically in the derived form.

On both shift and transparent words on the TMS, children with CIs differed significantly from children with HA and TH. Numerically, children with CIs performed the lowest on each word type on both subtests, followed by children with HA, and children with TH performing the highest. Although transparent words are easier for children in first grade, children with CIs still struggled significantly, pointing to a foundational derivational morphological deficit on less complex words in addition to more complex derived words. This is important to address, as the ability to derive shift words builds on the ability to derive transparent words. If a child who is DHH cannot derive transparent words correctly, they likely will lag further behind on shift word derivation. This could directly impact their reading comprehension and word reading abilities, as shift and transparent derived words occur frequently in language.

The fifth research question addressed whether the age of acquisition of the root word affects performance by group. The earliest acquired quartiles of words on both subtests of the TMS are expected to be acquired at the mean age of 4.57 years. The latest acquired quartiles of words are expected to be acquired at the mean age of 9.12 years. The children in this study just finished first grade and were the average age of 7.46 years of age. Children with TH performed better on the earlier acquired words than the later words, which is appropriate for their age. However, children who are DHH, especially those with CIs, performed lower on earlier acquired words than later acquired words and performed lower than peers with typical hearing, reflecting that age of acquisition does impact derivational morphological performance for children who are DHH, specifically in earlier acquired words.

Limitations

This study had limitations that will direct future research endeavors. There was not significant diversity within the participants of the study, specifically race or ethnicity and maternal education, so the demographics of this study may not reflect the general population. For future study, it would be important to increase the diversity of the population.

Regarding derivational morphology, a limitation of this study would be the age of participants. Children who are in first grade are still acquiring the skill of derivational morphology, so the participants of this study regardless of hearing levels are not expected to have acquired this skill in completion. Although the knowledge of derivational morphology begins to develop in early elementary, significant growth and mastery occurs in mid-late elementary, specifically during grades 3 through 5. The results of this study reflect the gap in morphological knowledge in first grade, but likely not the true gap when children with typical hearing are expected to exhibit mastery, especially on the derivation task. Future studies should explore whether deficits in derivational morphology of children increase or decrease as they progress through school-aged years, specifically when they reach the 3rd through 5th grade window, as that is when mastery is typically developed.

The Test of Morphological Structure, the measure used in this study, was last updated in 2000. It is possible that certain items on the assessment are no longer relevant words for school-aged children. Certain sentence items seem to be grammatically incorrect or confusing for children (i.e. Reduction. The overweight man was trying to reduce). It would be beneficial to evaluate the relevancy and efficacy of the items on the TMS for future practice and study.

Conclusion

This study contributes important findings in morphology for children who are DHH. In addition to grammatical morphology, first grade children who are DHH have significant deficits in derivational morphology. This should be a target in speech-language therapy and in schools because derivational morphology has direct impact on numerous aspects of language development. If not acquired, children are at risk for prolonged delays in language skills such as expressive vocabulary and reading comprehension, which could lead to greater academic difficulty.

References

Boons, T., De Raeve, L., Langereis, M., Peeraer, L., Wouters, J., & van Wieringen, A. (2013). Narrative spoken language skills in severely hearing impaired school-aged children with cochlear implants. *Research in Developmental Disabilities*, *34*(11), 3833–3846. https://doi.org/10.1016/j.ridd.2013.07.033

Carlisle, J. F. (1987). The use of morphological knowledge in spelling derived forms by learning-disabled and normal students. *Annals of Dyslexia*, *37*(1), 90–108. https://doi.org/10.1007/bf02648061

Carlisle, J. F. (2000). (PDF) Awareness of the structure and meaning of morphologically complex words: Impact on reading. *Reading and writing*, *12*, 169-190.

Carlisle, J. F., & Fleming, J. (2003). Lexical processing of morphologically complex words in the elementary years. *Scientific Studies of Reading*, *7*(3), 239–253. https://doi.org/10.1207/s1532799xssr0703_3

Choi, W., Tong, X., Law, K. K.-S., & Cain, K. (2018). Within- and cross-language contributions of morphological awareness to word reading development in Chinese–English bilingual children. *Reading and Writing*, *31*(8), 1787–1820. https://doi.org/10.1007/s11145-017-9770-0

Cupples, L., Ching, T. Y., Button, L., Seeto, M., Zhang, V., Whitfield, J., Gunnourie, M., Martin, L., & Marnane, V. (2018). Spoken language and everyday functioning in 5-year-old children using hearing aids or cochlear implants. *International journal of audiology*, *57*(sup2), S55–S69. https://doi.org/10.1080/14992027.2017.137014

Davies, B., Holt, R., & Demuth, K. (2023). Children with hearing loss can use subject–verb agreement to predict during spoken language processing. *Journal of Experimental Child Psychology*, *226*, 105545. https://doi.org/10.1016/j.jecp.2022.105545

Davies, B., Xu Rattanasone, N., Davis, A., & Demuth, K. (2020). The acquisition of productive plural morphology by children with hearing loss. *Journal of Speech, Language, and Hearing Research*, *63*(2), 552–568. https://doi.org/10.1044/2019_jslhr-19-00208

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior research methods*, *44*(4), 978–990. https://doi.org/10.3758/s13428-012-0210-4

Kutlu, S., Ozkan, H. B., & Yucel, E. (2021). A study on the association of functional hearing behaviors with semantics, morphology and syntax in cochlear-implanted preschool children. *International Journal of Pediatric Otorhinolaryngology*, *148*, 110814. https://doi.org/10.1016/j.ijporl.2021.110814

Lee, J. W., Wolters, A., & Grace Kim, Y. S. (2023). The relations of morphological awareness with language and literacy skills vary depending on orthographic depth and nature of morphological awareness. *Review of Educational Research*, *93*(4), 528-558. https://doi.org/10.3102/00346543221123816

Levesque, K. C., Kieffer, M. J., & Deacon, S. H. (2019). Inferring Meaning From Meaningful Parts: The Contributions of Morphological Skills to the Development of Children's Reading Comprehension. *Reading Research Quarterly*, *54*(1), 63–80. https://www.jstor.org/stable/48557698

Levesque, K. C., & Deacon, S. H. (2022). Clarifying links to literacy: How does morphological awareness support children's word reading development? *Applied Psycholinguistics*, *43*(4), 921–943. https://doi.org/10.1017/s0142716422000194

Lund, E., Brock, N., & Werfel, K. L. (2022). Location effects on spoken language and literacy for children who are DHH. *Journal of Deaf Studies and Deaf Education*, 27(1), 48–61. 10.1093/deafed/enab030

Moeller, M. P., McCleary, E., Putman, C., Tyler-Krings, A., Hoover, B., & Stelmachowicz, P. (2010). Longitudinal development of phonology and morphology in children with late-identified mild-moderate sensorineural hearing loss. *Ear Hear* , *31*(5), 625–635. https://doi.org/10.1097/aud.0b013e3181df5cc2

Spencer, M., Muse, A., Wagner, R. K., Foorman, B., Petscher, Y., Schatschneider, C., Tighe, E. L., & Bishop, M. D. (2015). Examining the Underlying Dimensions of Morphological Awareness and Vocabulary Knowledge. *Reading and writing*, *28*(7), 959–988. https://doi.org/10.1007/s11145-015-9557-0

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. Supplement*, *189*, 109–112. https://doi.org/10.1177/00034894021110s522

Walker, E. A., Sapp, C., Dallapiazza, M., Spratford, M., McCreery, R. W., & Oleson, J. J. (2020). Language and Reading Outcomes in Fourth-Grade Children With Mild Hearing

Loss Compared to Age-Matched Hearing Peers. *Language, speech, and hearing services in schools*, *51*(1), 17–28. https://doi.org/10.1044/2019_LSHSS-OCHL-19-0015

Werfel, K. (2018). Morphosyntax production of preschool children with hearing loss: An evaluation of the extended optional infinitive and surface accounts. *Journal of Speech, Language, and Hearing Research*, *61*(9), 2313–2324. https://doi.org/10.1044/2018_jslhr-l-17-0406

Appendix A: Transparent and Shift Words on the Test of Morphological Structure

Derivation Subtest

Transparent	*Shift*
Warm/Warmth	Permit/Permission
Teach/Teacher	Express/Expression
Profit/Profitable	Protect/Protection
Appear/Appearance	Expand/Expansion
Four/Fourth	Revise/Revision
Perform/Performance	Major/Majority
Reason/Reasonable	Deep/Depth
Adventure/Adventurous	Equal/Equality
Active/Activity	Long/Length
Swim/Swimmer	Absorb/Absorption
Wash/Washer	Remark/Remarkable
Humor/Humorous	Human/Humanity
Assist/Assistance	Mystery/Mysterious
Glory/Glorious	Product/Production

Decomposition Subtest

Transparent	*Shift*
Grow/Growth	Wide/Width
Dry/Dryer	Discuss/Discussion

Vary/Variable	Describe/Description
Dense/Density	Five/Fifth
Fame/Famous	Elect/Election
Run/Runner	Strong/Strength
Differ/Difference	Decide/Decision
Agree/Agreeable	Popular/Popularity
Danger/Dangerous	Public/Publicity
Bake/Baker	Original/Originality
Guide/Guidance	Courage/Courageous
Continue/Continuous	Admit/Admission
Rely/Reliable	Reduce/Reduction
Accept/Acceptance	Divide/Division

Appendix B: Age of Acquisition of Root Words

Derivation Subtest

Earliest Acquired 25%	*Latest acquired 25%*
Wash: 4	Profit: 8.56
Swim: 4.17	Assist: 8.75
Long: 4.24	Express: 8.8
Warm: 4.65	Major: 8.8
Teach: 4.67	Absorb: 8.83
Human: 4.83	Permit: 9.47
Four: 4.93	Revise: 11.67

Decomposition Subtest

Earliest Acquired 25%	*Latest acquired 25%*
Dry: 4.11	Courage: 8.42
Run: 4.47	Reduce: 8.44
Five: 4.51	Public: 8.47
Strong: 4.58	Vary: 8.94
Danger: 4.61	Differ: 9
Grow: 4.79	Rely: 9.32
Bake: 5.5	Dense: 10.2