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Grammatical outcomes of 3- & 6-year-old children who are hard of hearing

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Abstract

Purpose—Spoken language skills of 3- and 6-year-old children who are hard of hearing (HH) were compared to those of children with normal hearing (NH).

Method—Language skills were measured via MLU in words and percent correct use of finite verb morphology in obligatory contexts based on spontaneous conversational samples gathered from 185 children (145 HH; 40 NH). Aided speech intelligibility index (aided SII), better ear pure tone average (BE-PTA), maternal education, and age of amplification were used to predict outcomes within the HH group.

Results—On average, the HH group had MLUws that were .25-.5 words shorter than the NH group at both ages and they produced fewer obligatory verb morphemes. After age, aided SII and age of amplification predicted MLUw. Aided SII and PTA were not interchangeable in this analysis. Age followed by either PTA or aided SII best predicted verb morphology use.

Conclusions—Children who are HH lag behind their NH peers in grammatical aspects of language. Although some children appear to catch up, more than half the children who were HH fell below the 25th percentile. Continued monitoring of language outcomes is warranted since children who are HH are at increased risk for language learning difficulties.

It is well established that children who are hard of hearing are at risk for delayed spoken language outcomes (Delage & Tuller, 2007; Elfenbein, Hardin-Jones, & Davis, 1994; Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Moeller et al., 2010; Norbury, Bishop, & Briscoe, 2001). The presence of a hearing loss seems to be the most obvious risk factor influencing outcomes. A recent population-based study of children with mild to profound losses revealed that more severe hearing losses were associated with poorer global language outcomes (Wake, Poulakis, Hughes, Carey-Sargeant & Rickards, 2005). However, some studies suggest that **any** degree of hearing loss places children at developmental risk (Blair, Peterson, & Viehweg, 1985; Davis, Shepard, Stelmachowicz, & Gorga, 1981; Tharpe, 2008). This may be due to the fact that degree of hearing loss does not act alone in influencing outcomes; child, family, intervention, and environmental factors may combine with hearing status, resulting in protective effects or realized risk (Harrison & McLeod, 2010). Factors contributing to individual differences in outcomes have been explored in children who have cochlear implants (Geers, 2002, 2006; Geers, Brenner, & Davidson,

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2003), but comparable studies in large, well-defined groups of hard-of-hearing children are rare (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007).

Notably, in each of the outcome studies listed previously, some children who are hard of hearing achieve spoken language outcomes that are comparable to those of their normal hearing peers. It is not yet known what factors contribute to more positive outcomes, although the literature has entertained the possibility that early intervention (Yoshinaga-Itano, 2003; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998), the access to audible speech (Stiles, Bentler, & McGregor, 2012), and quantity and quality of speech in the home environment (Fitzpatrick, Durieux-Smith, Eriks-Brophy, Olds, & Gaines, 2007; Sarant, Holt, Dowell, Rickards, & Blamey, 2009) might offer protection against poor outcomes. In this paper we adopt a theoretical paradigm of examining risk and protective factors to understanding areas of vulnerability and predictors of grammatical development in children who are hard of hearing. For the purposes of this paper, we are defining “hard of hearing” (HH) as applying to children with better ear pure tone averages falling between 25 and 75 dB HL (mild through moderately-severe degrees) who use hearing aids rather than cochlear implants. Studies on this group of children are needed to inform theories about the ways in which inconsistent access to input may put children at long-term risk of delays in global language and grammatical development.

Evidence of Risk Factors for Poor Grammatical Outcomes

The presence of a hearing loss may lead to distorted or inconsistent access to language input. Having access to high quality, well-fit amplification may still not provide sufficient protection for some children or for selected aspects of language development. Children who are HH are unlikely to experience the same quality of auditory experience as children with normal hearing, given physiological limits imposed by the sensory deficit and, the negative effects of distance, noise, reverberation, and periods without amplification in everyday settings. Furthermore, limitations in hearing aid bandwidth reduce access to phonemes in the high frequency region of the speech spectrum (Stelmachowicz, Pittman, Hoover, & Lewis, 2002), particularly when spoken by female and child talkers (Stelmachowicz, Pittman, Hoover, & Lewis, 2001). Collectively, these factors may result in inconsistent access to structural details of the input, which could influence grammatical development (McGuckian & Henry, 2007). Whether it is due to the hearing aid or to the hearing loss, this inconsistent and distorted input places the child at risk for difficulty developing language, as measured by utterance length and use of grammatical morphology.

Prior work suggests that children who are HH are at risk of having shorter utterances, commonly considered a metric of overall syntactic skills particularly for children 4 and under (Brown, 1973, but see Eisenberg, Fersko, & Lundgren, 2001 and Klee, 1992 for alternative perspectives on interpreting low MLU), as compared to their normal hearing (NH) peers. Small studies that have reported MLU show that there are significant delays in utterance length by children who are HH (Brown, 1984; Ramkalawan & Davis, 1992). This is confirmed by more recent studies that presumably draw on earlier-identified populations with access to current amplification technology. Dutch-speaking HH children remained at the lower boundary of the 95% confidence interval for typically-developing children on MLUw from four through six years of age (Hammer, 2010).

Other studies show signs that children who are HH have general difficulty with morpho-syntax acquisition (Blamey et al., 2001; DesJardin, Ambrose, Martinez, & Eisenberg, 2009; McGuckian & Henry, 2007). One sign of delay is that studies matching on MLU tend to match children who are HH to much younger children with NH. For example, McGuckian and Henry (2007) matched the 7-year-old children enrolled in their study to children who were, on average, 3 years old. Likewise, Brown (1984) matched 9-year-olds who were HH to 4-year-olds with NH. Those studies in which children who are HH appear to catch up to their NH peers on MLU attribute that finding to the fact that MLU asymptotes around an utterance length of 5–6 morphemes or an age of 4–5 years old for conversational speech rather than to attainment of similar language skills (Blamey et al., 2001). For instance, despite finding that NH children and children who are HH have comparable MLU values, children who were HH scored below their NH peers on standardized language measures. Blamey et al (2001) suggested that this was due to the statistical properties of MLU and not to comparable skill levels, an observation that may also apply to Hammer's (2010) results. Differences in MLU between impaired populations and typical populations have been shown to persist into adolescence (e.g., Nippold, Mansfield, Billow & Tomblin, 2008, 2009) given appropriate sampling contexts. While findings of differences in MLU may not suggest specific difficulties with grammatical development after age 4, they do suggest global language delays.

Access to the speech stream has been identified as a critical factor influencing acquisition of grammatical morphology both for typical children (Slobin, 1985) and for children with specific language impairment (SLI; Leonard, 1989). The surface hypothesis (Leonard, 1989) proposed that children with SLI have difficulty acquiring grammatical morphemes that have low phonetic substance because these morphemes are more difficult to process and store. A logical consequence of this is that in order to acquire tense morphemes they need to be encountered more frequently by children with SLI in order for them to be fully stored. More recently Demuth and colleagues (Song, Sundara, & Demuth, 2009; Sundara, Demuth & Kuhl, 2011; Theodore, Demuth, & Shattuck-Hufnagel, 2011) have argued that young typical children are also influenced by audibility and co-articulatory contexts. Typical 2- and 3-year-olds are more accurate at production and grammaticality judgment tasks when the target morpheme falls at the end of the sentence and is not a part of a consonant cluster, presumably because this makes the morpheme easier to perceive. For a variety of reasons related to how often different types of morphemes are produced and where they fall in the sentence (Hsieh, Leonard, & Swanson, 1999), verb-related morphemes are more vulnerable to these changes than other morphemes. Indeed, discriminant analyses show that finite verb composite scores (*am, is, are*, third person singular *–s* as in *jumps [3s]*, and regular past tense *–ed* as in *played*) have good sensitivity and specificity for identification of children with SLI (Bedore & Leonard, 1998). This is presumably due to the fact that many verb-related morphemes are of low phonetic substance, are rare in the input, and, occur disproportionately in the middle of utterances (Hsieh et al., 1999), all factors that may also influence children who are HH. Such factors may make acquisition of these verb-related morphemes particularly taxing for children. Plurals, in contrast, were shown to occur more often than third person singular *–s* and are more often found in utterance final position, making them more audible despite sharing similar phonological properties with verb-related morphemes. Unlike children with SLI, who hear the morpheme but have difficulty storing that information, children who are HH may have difficulty perceiving the morphemes (Kortekaas & Stelmachowicz, 2000). Thus both groups would be predicted to have difficulty with morphemes that are low in phonetic substance and less common in the input (Hsieh et al., 1999). The prediction is that children with hearing loss are at risk in the area of verb morphology due to inconsistent and/or distorted access to input, whereas children with SLI may be at risk due to impaired language learning mechanisms.

McGuckian and Henry (2007) adopt a similar perspective to explain the pattern of grammatical morpheme deficits that are observed in children who are HH. They claim that these children have inconsistent access to the input because they sometimes hear and sometimes do not hear morphemes that are of low phonetic substance, including verb-related morphemes, such as contracted forms of BE, third person singular *–s*, and past tense *-ed*.

Unlike children with SLI, for whom audibility is not a concern, in children who are HH, access to the morphemes not only depends on the child's degree of hearing loss, but also on other factors such as, the gender of the speaker (Stelmachowicz et al., 2002), the listening environment, and the quality of amplification available to the child. Thus audibility once again influences language acquisition. Although more work is needed, recent evidence suggests that newer amplification technologies that provide better access to high frequencies enhance HH children's performance on recognition of high frequency phonemes (Glista et al., 2009; Wolfe et al., 2010) further highlighting the need to understand how input consistency influences language learning.

Morphology Use in HH Children

These predictions of difficulty with grammatical morphology appear to be consistent with the findings of those studies that have examined morpheme acquisition. Delays with morphemes are reported more often than typical use. Elfenbein et al. (1994) reported that children who are HH were 4.5 times more likely to make an error on plural, possessive, comparative and superlative morphemes as compared to their NH peers. In one of the most comprehensive studies, McGuckian and Henry (2007) studied the production of a wide variety of grammatical morphemes in a homogenous group of 7-year-old children with a mild-moderate hearing loss. The HH group was found to produce possessive -*s* & plural -*s* correctly less often than the younger NH control group matched on MLU. They found no differences between the two groups in use of morphemes traditionally included in a finite verb morphology measure, like am, is, are, third person singular –*s* or regular past tense –*ed*, but it is worth remembering that NH children were 3–4 years younger than their HH peers. Thus it would appear that the presence of even a moderate hearing loss increases the risk of delays in spoken language measured through the use of grammatical morphology or a more global measure like MLU. One might imagine that the degree of hearing loss as well as the child's age might influence the outcomes. Therefore, a goal of this study is to examine the contributions of age and degree of hearing loss on grammatical development in a large, homogenous group.

Finite verb morphology (FVM) has been examined extensively in children with SLI, but rarely in children who are HH. Limited hearing aid bandwidth and presence of noise may especially influence HH children's access to verbal morphology in the input; these forms in English have low phonetic substance, are often sentence medial and frequently involve fricatives. The few studies conducted to date on HH children suggest delays in preschool, but are in conflict about whether these resolve with age. Norbury et al. (2001) reported that 19 English-speaking HH children ages 5;9 to 10;7 were comparable to a group of NH controls in finite verb morphology. However, they also reported that 22% of their HH participants, the youngest participants in the study, demonstrated difficulty with verb tense marking. Similar results were found in Swedish-speaking HH children ages 5 – 9 years, with the youngest participants demonstrating difficulty (Hansson, Sahlen & Maki-Torkko, 2007). In comparison to NH five-year-olds, HH children were significantly less accurate in inflection of novel verbs. Dutch-speaking HH 4- to 7-year-olds were compared to NH 4-year-olds on FVM. The NH children were already at ceiling at this age. The HH children maintained borderline performance relative to the NH group across the entire age range examined, showing persistent difficulties in finite verb morphology (Hammer, 2010). While the Swedish and Dutch studies speak to the potential challenges of learning verb morphology, it may be difficult to generalize to English speaking children since many of the finite verbs are marked with bound morphemes that are whole syllables (-*te*, -*de*) or with free morphemes that cannot be contracted (*ben, zijn, hebben*, etc). Nonetheless, these studies suggest that four-to-five-year-old HH children are at risk, but are mixed about whether FVM production normalizes with age. Furthermore, previous studies lack the power to carry out regression analyses to identify protective factors that contribute to more positive outcomes.

Evidence of Protective Factors

Risk factors due to presence of a hearing loss may be balanced by a host of protective factors: higher quality input in the language environment; earlier access to amplification; a well fit hearing aid that gives sufficient access to speech (Stelmachowicz et al., 2001, 2002) and higher levels of maternal education (Fitzpatrick et al., 2007; Pressman, Pipp-Siegel, Yoshinaga-Itano, & Deas, 1999; Sarrant et al., 2009, Yoshinaga-Itano et al., 1998).

Assuming that hearing aids are fit well and provide the expected benefits, early amplification should lead to greater access to language input and thus to better language outcomes. However, the influence of age of identification on outcomes may vary as a function of severity of hearing loss (e.g., Bess & Paradise, 1994; Wake et al., 2005). The assumption that earlier access to hearing aids promotes better outcomes needs to be further examined in reference to a well-defined group of hard-of-hearing children. Studies of language intervention and language outcomes often mix results from children with cochlear implants and children with hearing aids, making it difficult to clearly identify factors affecting outcomes for the HH group (e.g., Bow, Blamey, Paatsch, Sarant, 2004; Fitzpatrick et al., 2007, Sarant et al., 2008). Stiles et al. (2012) proposed that a measure of aided hearing, the Speech Intelligibility Index (SII), might provide a more realistic measure of how children access speech for use in language learning. SII is a weighted estimate of the amount of the speech spectrum that is audible above an individual's thresholds and may provide more information about access to speech while more commonly used measures, such as Pure Tone Average (PTA), do not. However, given that both PTA and SII are known to have limitations as predictors of speech recognition for children (McCreery & Stelmachowicz, 2011), it unclear if these variables will be significant predictors of morphosyntax. Empirical examination of this question is critical for answering clinical questions about how to decide who to monitor for speech and language development in this population.

We are unaware of studies examining MLU & grammatical accuracy in spoken language in relation to maternal education in this population, but maternal education has been considered as a potential predictor of outcomes on standardized tests in previous studies. Some find that it predicts language outcomes (Fitzpatrick et al., 2007; Sarrant, Holt, Dowell, Rickards, & Blamey, 2009) and others find that it does not (Pressman et al., 1999; Yoshinaga-Itano et al., 1998). Further investigation of the role of maternal education level on global language outcomes is warranted given these mixed results.

The small body of research on FVM and MLU in HH children suggests that this group is at risk for grammatical delays, especially at younger ages. However, all but one of these studies examined the development of children over the age of 5 years, and none included measures of aided audibility. The literature also is unclear about whether or not grammatical delays persist at later ages and for whom. Furthermore, wide individual differences in grammatical outcomes are observed, especially among younger children. Small sample sizes have limited the ability to identify how potential protective factors such as aided hearing or duration of auditory experience might explain individual differences in outcomes. There is a pressing need to examine grammatical outcomes in HH children both at younger and older ages to address these research gaps, and there is a need to explore these questions in larger samples so that protective and risk factors can be identified.

Research Questions

Thus we ask the following questions:

1. To what extent does the presence of hearing loss put children at risk of poorer grammatical outcomes than their NH peers and do these outcomes change with the age of the child?

   We predict that 3-year-old children who are HH will have shorter utterance lengths and less use of verb morphology as compared to NH age-mates. 6-year-old children who are HH may come closer to approximating the utterance lengths of their NH age-mates due to the psychometric properties of MLU in conversational speech. Persistent risk of language problems will instead be evident through deficits in the area of verb morphology use.

2. Is there evidence that known positive factors can mitigate the influence of hearing loss on grammatical outcomes?

   We predict that earlier age of amplification, higher aided SII, and higher maternal education will each influence child use of verb morphology and MLU in a positive manner, whereas greater degree of hearing loss will negatively influence grammatical outcomes.

Methods

Participants

All of the participants reported here came from a larger pool of 185 3- and 6-year-old participants from the Outcomes of Children with Hearing Loss project (OCHL; Holte et al., 2012). Participants who were HH were recruited through Early Hearing Detection and Intervention (EHDI) programs, educational, audiology or medical service providers, and school screenings in 17 states. Only children whose primary diagnosis was hearing loss of mild to severe degree were included in the HH sample; children with cochlear implants were excluded, although some children with progressive hearing loss received CIs after they were tested for this study. Children with significant cognitive, motor, or visual impairments or a diagnosis of autism were also excluded from participation. Children with NH were recruited by brochures and fliers placed at locations such as clinics, day cares and pediatric offices. To control for socioeconomic status (SES) variation, children with NH were recruited from the same zip codes as children who are HH. Only children who used English as the primary language at home were included in the HH and NH samples. The majority of the children in the sample were fitted with hearing aids. Three children with losses between 25–30 dB were not fitted with hearing aids.

In order to be included in these analyses, each participant was required to have a transcribed conversational language sample that had at least 50 utterances, in addition to a 3 or 4 frequency Better Ear Pure Tone Average (BE-PTA) taken within a year of the language sample. Three frequency BE-PTA are commonly used in audiological testing; however where possible a 4 frequency measure was employed to improve accuracy. Children with a BE-PTA of 80 dB HL or higher were excluded from this study. Following these criteria, 60 3-year olds who are HH (age range: 2;10 -3;8), 23 3-year-old children with NH (2;11-3;8), 40 6-year-olds who are HH (5;9-6;10) and 17 6-year-old children with NH (5;9-6;8) were included in our analyses. Table 1 provides information about the children and their families.

Data Collection & Analysis

Following initial recruitment, certified audiologists and speech language pathologists tested children over a 1–2 day period.

Hearing assessments—The audiologists performed audiometric testing on all children. Air conduction thresholds were obtained for each ear at 500, 1000, 2000, and 4000 Hz using conditioned play audiometry. If testing could not be completed, the child's audiologist provided a copy of the most recent reliable audiogram. Average values were computed for each ear. The lower average value, also known as the value for the better ear, was used as the better ear – pure tone average (BE-PTA) for subsequent analyses. Children in the HH sample presented with a permanent, bilateral loss in the mild through moderately-severe range. Only 4 children had BE-PTAs in the severe range (75–80 dB HL) and all remaining children had PTAs < 75 dB HL, defining the majority of the group as hard of hearing. All of the children with NH were confirmed to have hearing thresholds at or below 20 dB HL. Some 3-year-old children with NH underwent screening (i.e., passed at 20 db HL per ASHA standards) rather than full audiometric testing that included finding thresholds. Thus the BE-PTA reported in Table 1 may underestimate their hearing abilities.

Hearing aid and real ear measurements were obtained using the Audioscan Verifit (Cole, 2005) following ANSI protocol S3.22 (2003). Following these measurements, Audioscan Verifit software was used to calculate an aided audibility measurement (Bentler, Hu, & Cole, 2011) for stimuli presented at 65 dB, based on the Speech Intelligibility Index (SII; ANSI S3.5-2007) to estimate the proportion of the amplified speech spectrum that was audible to HH children when wearing their hearing aids. To calculate SII, the speech spectrum is divided into frequency bands and assigned individual frequency-importance weights based on each band's contribution to the intelligibility of speech. The weighted amount of audible information in each band is then summed to determine the SII. SII is reported on a scale from 0 to 1 in which 0 represents the entire speech spectrum as inaudible and 1 as completely audible. This number is frequently transformed into a percentage of audible speech (by multiplying it by 100), which is what we have done in this paper. Once again, measures were calculated for aided thresholds in both ears and the better measure was used in subsequent statistical analyses. For three HH children who were not fit with amplification, the unaided SII value was substituted for aided SII as an indicator of their access to speech. Examiners participating in the project were not involved in the process of fitting the hearing aids prior to testing. Parents were provided with a report that informed them of hearing aid functioning that they were free to share with their audiologist if they wished.

Information about the age at first amplification, maternal education level, and other family demographic information was provided by the parents through questionnaires and via medical/education chart reviews. Maternal education was coded categorically as 1) Completed High School or Less, 2) Some College, 3) Completed a Bachelor's degree, or 4) Postgraduate Training.

Formal language testing—Certified speech language pathologists and/or experienced examiners completed formal and informal language assessments for all children. All children were administered the *Comprehensive Assessment of Spoken Language* (CASL; Carrow-Woolfolk, 1999) for their age range. We report CASL syntax subtest scores in Table 1 to provide more information about language abilities for the reader.

The 3-year-old test battery included an articulation probe in which children were tested on their production of phonemes important for morphological production, /s, z, t, and d/. Six items tested use of /s and z/ word finally (e.g., *nose*, *house*) and six items tested the use of /t and d/ (e.g., *hat*, *bed*). Data on this probe is only available from 73 of the 87 3-year-olds. Examiners recorded correct production, distortions or substitutions (transcribed phonetically), or omissions of the final consonant for the words on the probe. Articulation skills were assessed for all 6–year-olds and for 3-year-old children who did not receive the probe by analyzing the use of word final consonants in their language samples and is described later under language sample analyses. This was completed to screen for the role of word final consonant production in the use of verb morphology. Children who produced word final /s, z, t, and d/ at least 75% of the time were considered to have ‘good’ articulation skills.

Language sample collection—The language data analyzed here were primarily gathered from conversational language samples that were designed to be age-appropriate. The 3-year-old children participated in a 15-minute language sample in which there was interaction between the child, a parent, and the examiner using playdoh and kitchen toys. To elicit a larger sample from the children, 3-year-olds also participated in a 5-minute picture description task with their parents, modeled after the Art Gallery procedure described by Adamson, Bakeman and Deckner (2004).

The conversational language samples gathered from the 6-year-olds differed from that of the 3-year-olds. The entire sample was conducted between the child and the examiner; parents were not present in the room. The playdoh portion of the sample lasted approximately 8 minutes and resembled the sampling for the 3-year-olds. The remaining 12 minutes included a conversational interview modeled after Hadley (1998). The conversational interview involves modeling of a narrative or personal experience by the examiner followed by questions to the child about similar situations. For example, the examiner might tell a story about an activity with their siblings and then ask the child if anything similar has ever happened to them. Natural, nondirective follow-up questions are used to keep the conversation going. The goal is to elicit a mix of narrative and explanatory topics within a conversational setting. The OCHL research team decided to exclude parents after age 3 to facilitate the use of this interview approach and potentially elicit more advanced language from the 6-year-olds.

Audio and video recordings of the language samples were made in controlled lab or clinical settings or in vans specially designed for the purpose of collecting language data. Audio was taken from a wireless microphone worn by the child or by a wireless or camera microphone positioned in close proximity to the child.

Transcription, coding, and reliability: All conversational language sample interactions were transcribed and coded following SALT conventions (Miller & Iglesias, 2010). All linguistic utterances, including partial repetitions and single-word responses, were transcribed and included. Vocalizations, grunts, and other noises were not counted as utterances. All samples were coded for grammatical morphology, including finite verb morphology (*full and contracted forms of BE, third person singular –s, and past tense –ed*). Each morpheme was marked as present or missing in an obligatory context following the protocols described on the SALT website. Transcribers allowed consistent articulatory errors to count as correct productions. For example if a child consistently produced a word final /s/ as a /ʃ/ then *3s* markers were counted as present in all cases that the /ʃ/ sound was produced. Although distortions of target sounds were observed in child samples, complete substitutions by unrelated sounds were not (e.g., using –eh for /s/). Two transcribers completed all of the transcriptions. One transcriber was a masters level clinician and the second transcriber was an undergraduate honors student. Reliability between transcribers was established for 10% of the language samples at a rate of at least 80% on each of the following criteria: utterance boundaries (*M*= 92%, range = 89–95%), words produced (*M*= 95%, range = 92–96%), coding for bound morphology (*M*= 88%, range = 85–90%).

For children who did not receive the articulation probe, articulation was assessed via the language samples. Transcripts were reviewed to identify contexts in which /s, z/ (N= 6 contexts) and /t, d/ (N = 6 contexts) should have been used in non-morphemic word-final contexts (e.g., *mouse, cheese, that, bad*). Like in the articulation probe, the final consonants of the target words in these utterances were then judged by an undergraduate in speech language pathology as correct, omitted, or distorted/substituted (transcribed phonetically). The undergraduate had completed a phonetics course and was blind to the hypotheses of the study. The student was trained by the first author using samples from children who had completed the articulation probe until agreement better than 90% was achieved on 3 consecutive samples. The percent correct use of final consonants in non-morphemic contexts was thus available either from words from the language samples or from single word articulation probes. This was completed to screen for the role of word final consonant production in the use of verb morphology.

Dependent Measures—Mean length of utterance in words (MLUw) was computed for participants with at least 50 utterances. Five additional children met all other selection criteria but were not included in analyses for failing to produce at least 50 utterances (3 3-year-olds who were HH, 1 3-year-old with NH, 1 6-year-old who was HH). This is worth noting because exceptionally short samples may be due to limited language skills. MLUw was chosen over MLU in morphemes (MLUm) as a conservative measure that would not penalize children if their articulation skills did not enable them to produce bound inflectional morphemes. Information about the length of the samples is shown in Table 1.

Given the length of the samples, many children did not have a sufficient number of contexts (3 or more, see Balason & Dollaghan, 2002) for analysis of individual morpheme use. Thus, to address the questions of use of grammatical morphology, a finite verb morphology composite (FVMC) was computed following the methods of Goffman and Leonard (2000). The percent correct use in obligatory contexts of full and contracted forms of *am, is, are, past tense -ed*, and *3s* was computed for every child who produced 4 or more opportunities for finite verb markers. To provide insight into the relative contribution of each morpheme, Table 2 provides information about the total number of opportunities and proportion of correct production for all children in a hearing/age group. For the FVMC analyses, we carried out two analyses. First, all children with 50 utterances and 4 contexts were included as representative of the outcomes of children who are HH as a whole. An additional 4 3-year-olds who were HH were excluded from these analyses for failing to produce a sufficient number of contexts for use of verb morphemes. Second, analyses were repeated only including children with good articulation skills. Using these more stringent criteria (50+ utterances, 4+ contexts, word final consonants > 75%) 43 3-year-olds who are HH, 23 3-year-olds with NH, 36 6-year-olds who are HH and 17 6-year-olds-with NH were included.

Results

Group Differences in Outcomes

MLU in words—To answer the first question we posed as to whether children who are HH show global language skills that are similar to their NH peers at 3 or at 6, we carried out a series of ANOVAs. First we examined MLUw. We carried out an ANOVA with hearing status and age group as independent variables and MLUw as the dependent variable. On average, children who were HH had lower MLUw values, $M = 3.06$, $SD = 1.13$, than their NH peers, $M = 3.43$, $SD = 1.21$, $F(1, 140) = 9.56$, $p = .002$, $\eta^2 = .06$. Both NH and HH groups had higher MLUw values at 6, *M* = 4.39, than at 3, *M* = 2.45; F (1, 140) = 192.92, p <.0001, η^2 = .58. While interpretation of age-related changes should be limited since this is a cross-sectional study, it is worth noting that there is no interaction between age and hearing status, suggesting that the gap between the HH and NH groups at age 3 is comparable to the gap observed for their 6-year-old peers. Table 3 shows the results for each group. The median HH child at both 3 and 6 had an utterance length that was similar to children at the 25^{th} percentile in the NH group. This helps to explain both why the effect sizes are modest and why group differences are consistently observed. Another way to think of risk is to consider what proportion of children fall more than 1SD below the mean of their NH peers. Approximately 43% of the children in each age group of the HH children fall more than 1SD below their NH peers on MLUw.

Use of verb morphology—Similar results were observed in the use of verb morphology when all children were considered (see Figure 1). An ANOVA with hearing status and age as independent variables suggested that, at both ages, children who were HH, *M* = .66, *SD* = .28 were less likely to use finite verb morphology correctly as compared to their NH peers, *M* = .84, *SD* = .22, F (1,136) = 16.02, p = .0001, η^2 = .11. Across both HH and NH groups, 6-year-old children, *M* = .90, were more accurate than 3-year-old children, *M* = .64; F (1,136) = 38.28, p <.0001, η^2 = .22. No interactions were observed. (See Table 3). This pattern of results held when only children with “good” articulation skills were included in the analyses, Age: F (1, 115) = 34.48, p <.0001, η^2 = .23, Hearing: F (1,115) = 10.93, p =. 001, η^2 = .09. No interactions were observed. Table 3 also shows the changes in MLUw and verb morphology that result from restricting the children who are analyzed based on articulation skills. Similar to the results seen in MLU, approximately 38% of the HH 3-year-old and 63% of the HH 6-year-old group fell more than 1 *SD* below the mean as compared to the NH peers. Thus these children are at risk at both 3 and at 6 in comparison to their peers when a sensitive measure is used to assess language outcomes.

Individual Differences in Outcomes

As can be seen in Figure 1, one of the reasons that effect sizes are small to moderate is that we observe a wide range of outcomes within the group of children who are HH. For instance, at both ages, we see children who are HH who use verb morphemes correctly less than 25% of the time and children in every group who are at 100% accuracy. Thus we ask to what extent can we explain the variability in the language outcomes on the basis of audibility and input-related measures only for the children who are HH. In other words, do better hearing, better audibility, and/or earlier identification serve as protective factors in the development of grammatical skills? As above, we analyze MLUw and FVMC for all children who are HH and then reanalyze FVMC for children who are HH and who have word final articulation scores better than 75% correct.

Global Language Development: MLU in Words

Stepwise linear regression analyses were carried out with MLUw as the dependent variable. Age was treated as a categorical variable given that we only have data from 3-year-olds and 6-year-olds; maternal education was divided into 4 categorical factors. Aided SII, BE- PTA, and age of amplification were continuous predictors. Age of amplification was chosen over other similar measures, such as age of identification, because 1) it was more precisely documented in children’s medical and educational records and 2) it represented the time at which children had improved access to the speech spectrum. For the 3 children who were never fitted with hearing aids, their age at time of testing was entered as a proxy value for age of amplification. Only children who had data available for all variables were included, resulting in 46 3-year-olds in the MLU analyses (40 for FVMC due to the 4 children with too few contexts) and 29 6-year-olds who were HH being included in the overall models and

30 3-year-olds and 25 6-year-olds for the regression model that was limited to children with good word final articulation skills. Table 4 shows correlations between the primary variables of interest included in the regression models.

The strongest predictor of MLUw was the child's age, accounting for more than half of the variance (adj R^2= .49) and entered first into the stepwise regression analysis. Aided SII (p =. 07) was a marginal predictor and accounted for approximately 1.4% more of the variance. Likewise, the age that a child was first fit with amplification was a marginal predictor (p =. 08) accounting for another 1.4% of the variance. Neither BE-PTA (p =.20) nor maternal education (p =.21) entered into the model. Even when aided SII was excluded from consideration, BE-PTA was not a significant predictor (p = .15). Table 5 shows the final regression model.

Grammatical Development: Verb Morphology Use

With regard to FVMC, age was again the best predictor (p <.0001, adj R^2= .24). BE-PTA entered the model next, accounting for 5% more of the variance (p = .02). If BE-PTA was excluded, aided SII also entered the model at this point, accounting for 4% of the variance (p = .03). BE-PTA explained slightly more variance and thus it was retained in the model. The age at which the hearing aid was first fitted (p =.82) and maternal education (p =.20) were not significant predictors of verb morphology use. Table 5 contains the final model.

If the analysis was restricted to only those children with word final articulation scores better than 75% on our screening measure, hearing no longer has predictive power. While age remained the best predictor (adj R^2 = .27, p <.0001), neither BE-PTA nor aided SII were good predictors (p >.12). It is worth noting that excluding children on the basis of word final articulation abilities resulted in 24 children being dropped from the analysis, reducing both power and variance. While the BE-PTA range remained similar, this reduced the range in terms of aided SII by 10 from the bottom end of the scale ($\text{range}_{\text{all}}$ =31–95; $\text{range}_{\text{good artic}}$ = 42–95) at least partially explaining why hearing was no longer the best predictor after age.

Discussion

Our first goal was to determine if the presence of mild to severe hearing loss places children at risk for delayed grammatical development. Consistent with our prediction, we observed that, as a group, children who are HH have lower MLUs than their NH peers. This group difference was also found for FVMC. The effect size for MLUw was small, indicating a high degree of overlap in each group: some children who are HH do have global language skills that are comparable to that of their NH children, while other children who are HH appear to have persistently poorer outcomes. Effect sizes for FVMC were moderate, suggesting larger gaps between HH and NH groups in the area of grammar than are observed in utterance length. No interactions were observed for either outcome measure suggesting that the gaps at age 3 are also present or possibly more detectable in the older cohort despite the fact that both MLUw and FVMC show ceiling effects in NH groups.

These results suggest the need for both optimism and caution. Many of the children at both ages (37–55%) performed comparably to age-matched peers with NH. The 3-year-old HH children, in particular, were most likely to have experienced early identification and intervention, suggesting possible contributions of these service delivery improvements to their language outcomes. The 3-year-olds were identified on average two years earlier than the 6-year-olds. While the quality and quantity of intervention was not a focus of this study, there are also clear differences in the amount of therapy received by the two cohorts. 94% of 3-year-olds received an average of 9.7 visits per month from a speech-language pathologist, teacher of the deaf, or both. 72% of the 6-year-olds received an average of 9.3 visits per month. At this point, we cannot draw firm conclusions about the protective nature of early intervention because the degree of variability in the 6-year-olds on the measures is quite different than the variability in the 3-yearold measures; as the longitudinal OCHL project moves toward completion this is a question worthy of further analysis.

However, the finding of significant between group differences on the grammatical measures at both ages suggests that some HH children (38%–63%) demonstrate persistent risk in this aspect of language development. These results are partially in support of the findings of Norbury et al. (2001). They found that the youngest participants in their study, who are most comparable to our own participants, demonstrated difficulty with verb morphology. Our findings indicate that between group differences did not resolve by age 6. Thus, both studies suggest a higher rate of difficulty with verb morphology in HH children than might be expected in the general population. Norbury et al.'s results also suggest that children may recover as they get older. Additional testing on these children as they continue to be followed by the OCHL project will address this question in the future. Our results underscore the importance of monitoring morpho-syntactic development in children who are HH. Future research should determine if interventions that focus on consistency of access to input are successful in protecting against the risk of language delay caused by a hearing loss.

Factors mitigating influence of hearing loss on language outcomes

A second goal of this study was to determine to what degree known positive factors mitigate the influence of hearing loss on grammatical development. Using regression models to explore potential explanatory factors, we found that once the child's age was accounted for, variables that related to auditory access to the input (audibility/aided SII, age at fitting) were the next best predictors of language outcomes. One way of operationalizing these findings is to reflect on the values of the coefficients. For every additional 10 points of SII gained due to a properly fit hearing aid, MLU goes up by .1 words. This benefit is essentially negated if a delay of a year is present in the time to fitting a hearing aid. Similarly, for every 10 dB loss of hearing (BE-PTA), a child's use of verb-related morphemes decreases 6 percentage points. Recall that for FVMC, BE-PTA and SII were both potentially significant predictors (with BE-PTA explaining slightly more variance) but could not both enter into the regression simultaneously. Stiles et al. (2012) reported that children with mild to moderately-severe hearing loss with an aided SII less than 0.65 demonstrated greater delays in vocabulary development than HH children with better aided audibility. The results of the current study provide support for this finding, suggesting that better aided audibility was associated with stronger global language skills and grammatical abilities in HH children. Although this suggests that stronger audibility may point toward improved access to input, this conclusion is tempered by the recognition that the aided SII measure does not reflect a child's audibility in noise. Children could have strong audibility, but have consistent exposure to noisy settings (e.g., day care). This circumstance would limit the protective effects of audibility in ways not captured by this study. Despite this caveat, the results support the protective value of optimizing audibility for young children who wear hearing aids.

In contrast to our predictions that improvements in the input quality might lead to improved outcomes, maternal education did not enter into the regression equations. There may be two reasons for the limited contribution of maternal education to outcomes of children with hearing loss. While maternal education has been shown to influence language development in typical children on a variety of measures, often vocabulary and complex syntax development have been the dependent measures rather than MLU (e.g., Hart & Risley, 1995; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Vasilyeva, Waterfall & Huttenlocher, 2008). Perhaps using other language measures would demonstrate an influence of maternal education. Second, although

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our sample size is relatively large, there may have been insufficient power to detect differences. Some of the children with the most severe losses came from families with high levels of education. We did not have sufficient power to detect interactions between predictors. It is worth noting that the NH groups were not included in these analyses, only children who were HH were examined, thus the fact that the NH 6-year-olds tended to be from higher SES families is irrelevant.

PTA vs. Aided SII—SII was a predictor of both MLUw and FVMC, while BE-PTA was only a predictor of FVMC. PTA often is taken to reflect the child's hearing abilities while aided SII reflects aided access to speech in quiet. Children with poorer PTAs tend to have lower aided SII values because of the relationship between the severity of the hearing loss and the ability to fit amplification effectively. Given the high degree of correlation between BE-PTA and aided SII ($r = -0.74$, $p < .05$), it is not surprising that only one entered into the equation for FVMC at a time. Both variables are important because it is possible to have limited aided audibility due to factors such as configuration of hearing loss, which are not accurately reflected by the PTA. We are left with the question of why both variables predicted FVMC while only aided SII predicted MLUw. One explanation might be that aided SII influenced the acquisition of a wider variety of vulnerable morphemes than were included in the FVMC. MLUw, as a measure, may be especially reliant on short free morphemes (e.g., *to, the*) that are also vulnerable in individuals with poor hearing and better captured by the SII frequency weightings. Children who are HH may have continued difficulty with free morphemes that occur in difficult to process prosodic structures (Gerken & McGregor, 1998; Gerken & McIntosh, 1993).

Another possibility is that the SII measure has important limitations when used to predict speech recognition in children and is in need of refinement (McCreery & Stelmachowicz, 2011), regardless of whether it is calculated on aided or unaided thresholds. The impact of aided SII on speech and language outcomes has not been systematically studied. The SII transfer functions used to predict speech recognition from audibility measures were derived based on adult data, and these functions are known to overestimate children's speech recognition (McCreery & Stelmachowicz, 2011; Scollie, 2008). In situations where acoustic speech cues are degraded, adults are able to rely on robust language abilities to compensate. These strategies are less available to children, who are still developing linguistic abilities. While SII uses weightings from a much broader range of frequencies than PTA, the weights for frequencies outside of 500, 1000 and 2000 Hz are relatively small, so even if those bands are completely inaudible, the change in SII is approximately 10%. For endings like /s/, SII has similar limitations as PTA as far as representing the audibility of grammatical morphemes. Children receiving altered input may rely on alternate cues from the speech stream that are not captured in the SII. The aided SII as applied in this study also reflects the child's audibility in quiet situations and may not accurately reflect the child's access to acoustic cues in everyday situations with competing background noise.

Age and Age of Amplification—Age at which the hearing aid is fit also provides a small boost to the outcome of MLU and not FVMC. One reason why this may be is that there is much more variability in FVMC in the 3-year-old group – the age group that has the least variability in age of amplification. Statistically this confounds age of amplification and child age, but from a more practical standpoint, it highlights the improvements that have been made in Early Hearing Detection and Intervention programs in the last 5 years. The 3-year-old group was identified and fit with hearing aids much earlier and had a shorter gap between age of identification and age of amplification than the 6-year-old group.

Conclusions from the literature regarding the contribution of age of identification to language outcomes are decidedly mixed (see Bess & Paradise, 1994). Early studies

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supported the finding that early identification is critical (e.g., Yoshinaga-Itano, 2003; Yoshinaga-Itano et al., 1998). More recent population-based studies found that the severity of the hearing loss, but not age at diagnosis, predicted language outcomes for a group of 89 children who were HH and between 7–8 years old. Instead, age at diagnosis only related to articulation scores and not to other language outcomes (Wake et al., 2005). It may be that certain measures are more sensitive to the effects of later identification, and predicted areas of vulnerability such as morphosyntax could be revealing in this regard. It is also possible that age of identification may interact with degree of hearing loss to differentially affect outcomes; early identification may contribute more in the case of moderately-severe hearing loss in contrast to mild hearing loss. Further studies using multivariate methods are needed to explore these hypotheses; our current data are insufficient to address questions of interactions between age at amplification and degree of hearing loss due to the differences in variability on the outcomes measures associated with child age.

Articulation—The overall findings did not change when children with and without good word final consonant production were considered. Children who are HH are likely to be less accurate at hearing and producing phonological forms that are implicated in English morphology (Bow et al., 2004; Moeller et al., 2010; Stelmachowicz et al., 2001, 2002). While only analyzing results from children with good word final articulation skills is a common and important control as a means of isolating morphological production difficulties, this is rarely done since it may underestimate the functional impairment faced by these children. In fact, articulation scores correlated well with morphology production abilities ($r = 0.53$, $p < .05$). Although the overall findings did not change when we restricted our analyses to only those children with good articulation skills, examination of Table 3 suggests that the overall mean MLU and FVMC of the HH children did improve. The pattern of results suggests that articulation skills may play a role in the degree of accuracy observed and should be considered as a potential factor in grammatical abilities in clinical settings, although it is also clear that articulation is not the only explanation for the grammatical deficits observed.

Summary and Conclusions—We found that, as a group, children who are HH do have persistent deficits in grammatical development. Having a hearing loss of any degree places children at risk for having a shorter MLU and being less capable of producing verb-related grammatical morphology. Some children do perform comparably to their NH peers, but current data leaves unclear what factors mitigate that risk. Despite the fact that the presence of a hearing loss places children at risk, the degree of hearing loss only minimally explains children's outcomes (aided SII accounted for about 1.5% of the variance in MLU and BE-PTA accounted for only 5% of the variance in FVMC). Additional research into how children who are HH make use of acoustic cues to maximize the input would be helpful for the purpose of optimizing clinical measures such as SII. Likewise, earlier access to amplification, and thus to high quality input, appears to serve as a small protective factor. Clinically it would be useful to have a clearer understanding of the factors that explain the relatively large amounts of variance remaining in both MLUw and FVMC so that children who are most at risk can be targeted for intervention. Investigations of factors such as amount of hearing aid use, background noise in the home, and amount of intervention are currently underway. In addition, SII and PTA are both static estimates of audibility in quiet situations that reflect how much sound reaches the ear under ideal circumstances. These measures do not reflect differences in how children might use the wide range of acoustic cues that are audible to support perception and learning (e.g., McMurray & Jongman, 2011). In this way, audibility may be a precursor to these processes, but by itself may not be sufficient to account for variability in selected outcomes.

Given the current data, it would seem that the language abilities of all children diagnosed as HH should be monitored throughout early childhood. Both MLU and use of verb morphology would be appropriate measures for tracking progress since they appear to be sensitive to differences across groups and have been shown to be robust measures in other populations. The finding that age of amplification was a predictor of MLU suggests that early identification programs are paying dividends in terms of language outcomes. Future research may want to consider how consistent use of amplification technology and quality of the hearing aid fit may be moderating these results. The interaction between articulation skills and language outcomes may be worthy of further exploration as well. While the main findings did not change, the data suggest that poor articulation skills may be an indicator of a child who is at risk of poor language outcomes.

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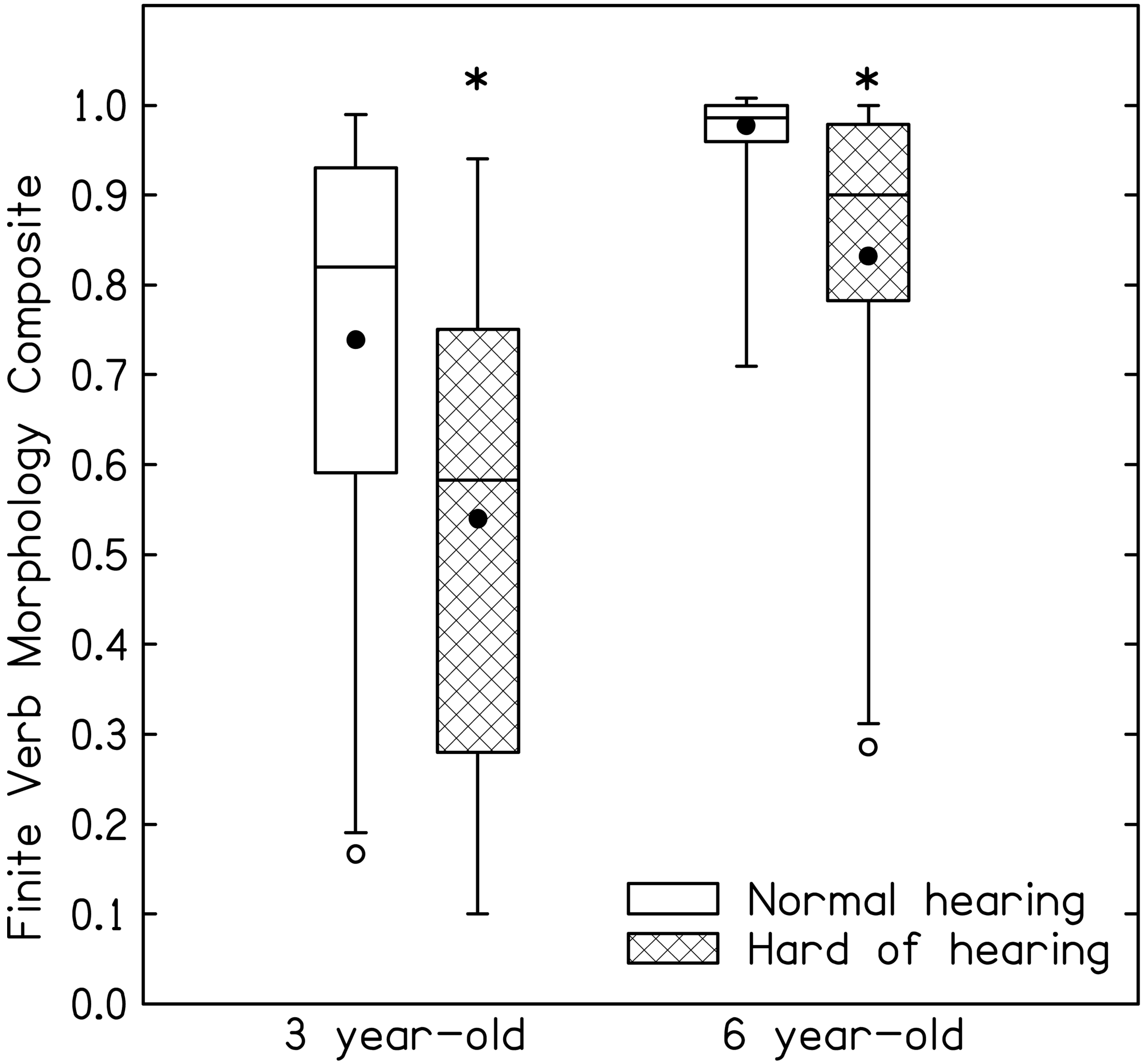

Figure 1.
The distribution of percent correct use in obligatory contexts of verb morphology (am, is, are, 3s, -ed) for 3- and 6-year-old children who are hard of hearing and normal hearing. Asterisks denote significant main effects (p < .005)

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Table 1

Demographic information about the participants and average number of utterances and obligatory contexts for finite verbs in the language samples.

Measure	3-year-olds				6-year-olds			
	NH (*N* = 23)		HH (*N* = 60)		NH (*N* = 17)		HH (*N* = 40)	
	M (SD)	**%**	***M (SD)***	**%**	***M (SD)***	**%**	***M (SD)***	**%**
Average age (yrs)	3.18 (0.26)		3.16 (0.24)		6.15 (0.26)		6.12 (0.24)	
Degree of hearing loss								
Normal: 0–20 dB		100				100		
Mild: 20–39 dB				22				25
Moderate: 40–59 dB				60				55
Moderate-severe: 60–79 dB				18				20
Audiological factors								
BE-PTA (dB HL)	15.67 (6.08)		48.57 (11.68)		5.06 (3.02)		46.09 (13.46)	
Aided SII	—		76.80 (14.03)		—		78.30 (14.54)	
Age (mos) aid fitted	—		11.43 (10.54)		—		34.28 (25.36)	
Language samples								
Number of utterances	147.29 (57.11)[a]		132.10 (55.12)[c]		203.88 (45.07)[e]		191.73 (49.86)[g]	
Number of obligatory contexts for FVM	27.41 (19.40)[b]		21.43 (16.16)[d]		58.35 (20.93)[f]		49.63 (23.47)[h]	
Language measures								
CASL Syntax	93.75 (13.33)		87.28 (13.51)		107.11 (16.46)		90.93 (23.25)	
Mother's education								
High school		23		23		6		21
Some college		18		19		12		37
Complete college		27		32		44		32
Post grad		32		27		38		10

Note.

[a]Range = 55–273.

[b]Range = 5–70.

[c]Range = 52–360.

[d] Range = 1–74.

[e] Range = 103–273.

[f] Range = 7–82.

[g] Range = 99–361.

[h] Range = 14–136.

CASL scores are standard scores for the age-appropriate subtests. Ranges are given for the measures related to FVM (use of contracted forms of *be* [*am, is, are*], third-person singular -*s*, and regular past tense -*ed*) in the language samples. HH = children who are hard of hearing; NH = children with normal hearing; BE-PTA = better-ear pure-tone average; aided SII = aided speech intelligibility index at 65 dB for the Carrot Passage (Cox & McDaniel, 1989); FVM = finite verb morphology; CASL = Comprehensive Assessment of Spoken Language.

Table 2

Number of contexts for production and proportion of correct production across all children within a hearing/age group.

		3-year-olds		6-year-olds	
		NH	HH	NH	HH
Full Copula BE	# Contexts	162	252	177	328
	Prop Corr	0.846	0.659	0.989	0.957
Full Auxiliary BE	# Contexts	29	64	24	72
	Prop Corr	0.828	0.641	0.958	0.931
Contracted Copula BE	# Contexts	287	664	362	757
	Prop Corr	0.847	0.517	0.989	0.918
Contracted Auxiliary BE	# Contexts	142	299	139	300
	Prop Corr	0.739	0.609	0.971	0.913
Third Person Singular -s	# Contexts	33	79	181	329
	Prop Corr	0.606	0.468	0.967	0.754
Past Tense -ed	# Contexts	16	31	109	200
	Prop Corr	0.750	0.548	0.936	0.745

Contexts = Number of opportunities for production

Prop Corr = Proportion of correct productions

Note: If it was phonologically possible to contract, omitted forms of BE were coded as contracted. Productions of BE were coded as contracted or full forms according to how they were produced. The distribution of morphemes is uneven, but consistent with expectations for conversational samples and the order of acquisition of Brown's morphemes. There are fewer opportunities in the NH groups because there are fewer children in the NH groups.

Table 3

Mean Length of Utterance (MLU) and Finite Verb Morphology Composite (FVMC) results. Group means (and standard deviations) along with the range are shown to illustrate the degree of variability present in each group.

		Full Group	
Group	**Lang Sample**	**3-year-olds**	**6-year-olds**
HH	MLU	2.33 (.66)	4.08 (.93)
		1.24–4.6	2.04–5.43
	FVMC	.54 (.26)	.83 (.20)
		.07–1	.28–1
NH	MLU	2.57 (.44)	4.69 (.76)
		1.44–3.27	3.0–5.83
	FVMC	.74 (.25)	.98 (.02)
		.17–1	.93–1
		Good Articulation Group	
HH	MLU	2.54 (.66)	4.23 (.86)
		1.61 – 4.6	2.66 – 5.43
	FVMC	.62 (.24)	.88 (.14)
		.07–1	.28–1
NH	MLU	2.58 (.45)	4.63 (.74)
		1.44–3.27	3.0–5.83
	FVMC	.76 (.22)	.98 (.02)
		.27–1	.93–1

Good Articulation Group = children with word final s, z ,t ,d > 75% correct

Table 4

Correlations between variables of interest for the regression models.

Variable	1	2	3	4	5	6
1. Age aid fitted	—					
2. BE-PTA	−.111	—				
3. Aided SII	.058	−.732*	—			
4. MLUw	.294*	−.186	.182	—		
5. FVMC	.154	−.296*	.239*	.619*	—	
6. Correct /s,z,t,d/	.118	−.253*	.334*	.334*	.512*	—

Note: MLUw = MLU in words. Only children who are HH are included.

* $p < .05$.

Table 5

Regression Models for MLUw and FVMC

	Predictor	Beta	Std Err	t-stat	pvalue	adj R^2	change in R^2
MLUw	Intercept	1.564	0.528	2.960	<.005		
Step 1	Age (Ref = 3 years)	1.897	0.239	7.929	<.0001	0.497	
Step 2	Aided SII	0.013	0.007	1.875	0.065	0.511	0.014
Step 3	Age aid fitted (mos)	−0.011	0.006	−1.764	0.082	0.525	0.014
FVMC	Intercept	0.769	0.145	5.287	0.000		
Step 1	Age (Ref = 3 years)	0.284	0.058	4.889	0.000	0.243	
Step 2	BE-PTA	−0.006	0.003	−.449	0.017	0.295	0.052

MLUw: F (3, 69) = 27. 59, p <.0001 R = .74, Adj R^2= .525;

FVMC: F (2,66) = 15.25, p <.0001, R =.562, Adj R^2=.295