Research Article

# The Influence of Hearing Aid Use on Outcomes of Children With Mild Hearing Loss

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**Purpose:** This study examined the effects of consistent hearing aid (HA) use on outcomes in children with mild hearing loss (HL).
**Method:** Five- or 7-year-old children with mild HL were separated into 3 groups on the basis of patterns of daily HA use. Using analyses of variance, we compared outcomes between groups on speech and language tests and a speech perception in noise task. Regression models were used to investigate the influence of cumulative auditory experience (audibility, early intervention, HA use) on outcomes.
**Results:** Full-time HA users demonstrated significantly higher scores on vocabulary and grammar measures compared with nonusers. There were no significant differences between the 3 groups on articulation or speech perception measures. After controlling for the variance in age at confirmation of HL, level of audibility, and enrollment in early intervention, only amount of daily HA use was a significant predictor of grammar and vocabulary.
**Conclusions:** The current results provide evidence that children's language development benefits from consistent HA use. Nonusers are at risk in areas such as vocabulary and grammar compared with other children with mild HL who wear HAs regularly. Service providers should work collaboratively to encourage consistent HA use.

With the advent of universal newborn hearing screening (NHS) programs, it is now possible to identify hearing loss (HL) at birth and provide early intervention for children with mild HL. At the same time, these children are more likely to be missed on the NHS because the screen is not sensitive enough to detect HL in this range on a consistent basis without an unacceptable decrease in specificity (Davis et al., 1997; Gravel et al., 2005). Even if children with mild HL are identified by the NHS, they may not have their HL confirmed in a timely fashion or qualify for early intervention (White & Muñoz, 2008). Furthermore, there is ambiguity regarding appropriate clinical interventions for children with mild HL, particularly involving the need for audiological management (Fitzpatrick, Durieux-Smith, & Whittingham, 2010). This general uncertainty exists, at least in part, because of conflicting findings from the past and present literature: Some studies have reported negative effects of mild HL on developmental outcomes (Davis, Stelmachowicz, Shepard, & Gorga, 1981; Đoković et al., 2014), whereas other studies have suggested that mild HL has minimal or no effect on outcomes (Kiese-Himmel & Ohlwein, 2003; Porter, Sladen, Ampah, Rothpletz, & Bess, 2013; Wake et al., 2006). Limitations in past studies include grouping children with mild and unilateral HL together under the umbrella term of *minimal HL* and/or failing to consider the contributions of early intervention, aided audibility, or consistent hearing aid (HA) use to outcomes. Therefore, it is difficult to ascertain whether children with mild HL will benefit from intervention. The primary purpose of the current study was to investigate speech and language outcomes of children with mild HL, with the goal of providing valuable evidence to support clinical decisions about amplification and early intervention for this population. A secondary goal was to examine the timing of follow-up services for children with mild HL.

## *Outcomes of Children With Mild HL*

Children with mild HL may face unique and unexpected challenges (Blair, Peterson, & Viehwig, 1985; Davis,

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Elfenbein, Schum, & Bentler, 1986). In the study by Davis et al. (1986), school-age children with mild HL showed significant delays in vocabulary development compared with test norms. Davis et al. did not report when these children were identified with HL, but the children were presumably later-identified given that the study was conducted before universal NHS was implemented. Blair et al. (1985) evaluated children with mild HL (20–45 dB HL in the better ear) in first through fourth grade. Most of the participants were identified with HL after age 5 years. The children with mild HL performed within the average range in terms of academic achievement compared to the normative sample of standardized tests. However, they achieved lower scores on those same tests compared with same-age children with normal hearing from their school district. Thus, even though these children performed within normal limits for academics on the basis of standardized test measures, evidence suggests that they performed significantly below their classmates, and the gap increased compared with grade mates at higher grade levels.

Đoković et al. (2014) compared 144 children with mild bilateral HL (four-frequency pure-tone average [PTA] between 20 and 40 dB HL in both ears) with 160 children with normal hearing. The children with mild HL were later-identified (sometime between second and fourth grade in elementary school) and had no experience with amplification. They performed significantly more poorly compared with the control group with normal hearing on measures of morphosyntax and phonological short-term memory. There were no significant differences between groups on measures of vocabulary knowledge. Consistent with the findings by Blair et al. (1985), the mild HL group did not show significant delays compared to a normative sample on standardized tests.

Other studies suggest that language and emotional development are vulnerable in the early school years, but the gap between children with mild HL and those with normal hearing closes by adolescence. Bess, Dodd-Murphy, and Parker (1998) found that third-grade children with minimal HL (defined as unilateral, slight, or mild) scored significantly below their peers with normal hearing on standardized tests of academic achievement, but these differences were no longer significant by sixth and ninth grade. Although the performance of older students with minimal HL appeared to approximate that of their same-grade hearing peers, this reduction in the achievement gap may have been illusory, as almost one half of the ninth graders and more than one third of the sixth graders were retained for 1 year or more in school. Because the control group with normal hearing consisted of grade mates, not age mates, many of the children with minimal HL achieved grade-level performance in secondary grades at older ages and with more educational experience due to retention.

Despite the negative findings described above, considerable ambiguity about the benefits of providing intervention (amplification and/or early intervention) in this population persists. A number of studies suggest that mild HL does not put school-age children at risk for language delays (Briscoe, Bishop, & Norbury, 2001; Kiese-Himmel & Ohlwein, 2003; Norbury, Bishop, & Briscoe, 2001; Porter et al., 2013; Wake et al., 2006; Wolgemuth, Kamhi, & Lee, 1998). Wake et al. (2006) investigated differences between children with normal hearing and 48 children with slight or mild HL in first or fifth grade across several domains, including language and phonological short-term memory. Slight or mild HL was defined as a better ear low-frequency PTA (500, 1000, and 2000 Hz) and/or high-frequency PTA (3000, 4000, and 6000 Hz) between 16 and 40 dB HL. Children with slight or mild HL did not wear HAs. Phonological short-term memory was the only measure in which children with normal hearing performed significantly better than children with slight or mild HL; however, the HL group included primarily children with slight HL (i.e., 16–25 dB HL), with only 15 of the 48 children falling into the mild HL category (i.e., 26–40 dB HL). On the basis of these results, the authors concluded that children with mild HL do not require intervention to achieve grade-level performance but acknowledged that the results were not representative of children in the upper limits of the mild HL range.

Similar to Wake et al. (2006), Porter et al. (2013) investigated differences between children with normal hearing and 27 children described as having minimal HL, ages 4 to 9 years. This minimal HL group included children with (a) unilateral HL, (b) bilateral mild HL (bilateral thresholds between 20 and 40 dB HL at 500, 1000, 2000, and 4000 Hz), and (c) bilateral high-frequency HL (thresholds within normal limits at 2000 Hz and below and thresholds greater than 25 dB HL for frequencies above 2000 Hz). Twelve of the 27 children had bilateral HL, and five of the 27 children used amplification. The authors observed no significant differences between groups on receptive language, reading achievement, memory, or general academics. Teachers rated children with HL as having significantly more attention-related difficulties than children with normal hearing. Furthermore, children with amplification showed slower growth over time in teacher ratings of academic success and classroom behavior compared with children who did not wear amplification. The authors acknowledged that this finding, which was based on a small group of children, was counterintuitive. It is possible that children with mild HL received amplification due to greater developmental concerns compared with their peers, which might explain poorer performance for the children who wore amplification.

Taken together, these two studies (Porter et al., 2013; Wake et al., 2006) suggest that there is a further need for prospective studies that explore the effect of amplification on children with mild HL. The ambiguity in the research literature is due in part to the fact that children with mild HL are often grouped with children who have unilateral HL in studies describing language or academic outcomes (Porter et al., 2013). As a result, it is difficult to isolate the effects of mild HL on developmental outcomes. Until we have a better understanding of how bilateral mild HL affects outcomes, we lack the evidence to make recommendations regarding amplification for this population.

The mixed findings of previous studies also merit further examination because the effect of mild HL may depend on the aspect of language that is being measured. Wake et al. (2006) and Đoković et al. (2014) found significant differences between children with mild HL and peers with normal hearing on measures of phonological memory but not vocabulary. In contrast, Davis et al. (1986) described delays in lexical knowledge for children with mild HL (compared with test norms) and did not report on grammar or phonological processing skills. It is possible that reductions in audibility may have a stronger effect on domains of language involving structural aspects of language, such as phonology and morphology, and less of an effect on aspects of content. Leonard (1989) predicted a similar pattern in children with specific language impairment, described as the *surface hypothesis*. In this hypothesis, structural aspects of language with low phonetic content (e.g., third-person singular; "he walks") are predicted to be more vulnerable because of their short duration, limited perceptual salience, and low frequency in the language input. The surface hypothesis may explain some of the inconsistencies in findings across studies of children with mild HL, but additional research is needed to support this speculation.

### *Effects of Cumulative Auditory Experience*

Cumulative auditory experience—the culmination of audibility, HA use, and input over time—may moderate pediatric outcomes and is an issue that has rarely been described in the literature on children with mild HL (cf. Moeller & Tomblin, 2015). It stands to reason that children with HL will demonstrate optimal outcomes if (a) they are identified, fitted with amplification, and enrolled in intervention early in development during a period of optimal neuroplasticity (Sharma, Dorman, & Spahr, 2002); (b) the HAs provide adequate access to the speech spectrum (Koehlinger, Van Horne, & Moeller, 2013; Stika et al., 2015; Stiles, Bentler, & McGregor, 2012; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014); and (c) the HAs are worn on a consistent basis (Walker et al., 2013). Our hypothesis in the Outcomes of Children with Hearing Loss (OCHL) project is that children who are hard of hearing (including those with mild HL) will show individual differences in cumulative auditory experience. These individual differences in auditory access will have an effect on functional outcomes because timely intervention and consistent use of well-fitted HAs serve as protective factors against the negative consequences of reduced hearing.

With regard to intervention services, there have been no rigorous investigations on the effect of early intervention for children with mild HL. The positive influence of early intervention for a broader group of children who are deaf and hard of hearing is clearly supported in the literature (Moeller, 2000; Sininger, Grimes, & Christensen, 2010; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). As a result of this empirical evidence, the Joint Committee on Infant Hearing (JCIH) has issued a position statement advocating for screening by 1 month of age, confirmation of HL by 3 months of age, and intervention by 6 months of age (JCIH, 2007). However, on the basis of the expected prevalence, not all children with mild HL are identified during the newborn period. Ross et al. (2008) reported that newborn prevalence of mild HL is 0.16/1,000 live births on the basis of data reported by state Early Hearing Detection and Intervention organizations, but the actual prevalence is 0.36/1,000 live births (Watkin & Baldwin, 1999). The lower rate of identification is due in part to the fact that hearing screening protocols focus on detecting greater than mild levels of HL to reduce the number of false positives (White & Muñoz, 2008). In addition, even children with mild HL who are identified early may not qualify for early intervention. Approximately one half of the states in the United States do not include mild HL in eligibility requirements for Part C birth-to-3 services (Holstrum, Gaffney, Gravel, Oyler, & Ross, 2008). Further research is needed to determine whether receipt of early intervention serves as a protective factor relative to later outcomes (McKay, Gravel, & Tharpe, 2008).

In addition to a lack of information regarding the effectiveness of early intervention, we know little about the timing of service provision (i.e., age at confirmation of HL and HA fitting) for children with mild HL in the post–NHS era. Studies conducted prior to the NHS showed that children with mild HL experienced lengthy delays in confirmation of HL and HA fitting compared with children with more severe HL (Coplan, 1987; Harrison & Roush, 1996; Mace, Wallace, Whan, & Stelmachowicz, 1991). The OCHL team examined timing of service delivery for children with mild to severe HL who referred on the NHS (Holte et al., 2012) or who passed the NHS and were later-identified (Walker et al., 2014). Holte et al. (2012) reported findings that differed from those of past studies: Degree of HL did not influence timing of service delivery, and maternal education level was the only significant predictor of age at confirmation and HA fitting. Thus, as a whole, children with mild HL who were identified by the NHS were receiving follow-up services in as timely a fashion as children with more severe HL. On the other hand, Walker et al. (2014) showed that children with mild HL who passed the NHS and were later-identified were at risk for delays in service delivery. The current study seeks to provide more information about service provision in a group of children with mild HL. Delays in receipt of HA fitting and early intervention limit length of HA use and thus presumably decrease access to auditory input. Input, in turn, is a key component of the cumulative auditory experience that facilitates speech and language development.

Another important aspect of cumulative auditory experience relates to audibility. When HAs are fitted with best-practice verification methods, children with mild HL generally have good aided access to the speech spectrum via HAs. However, benefits of aided audibility for children with mild HL may not be obvious in certain situations (i.e., when the speaker and child are in close proximity to one another and/or the listening environment has minimal reverberation or background noise). In these ideal listening scenarios, children with mild HL may have adequate unaided audibility to perceive speech with little difficulty. Lewis, Valente, and Spalding (2015) recently found that children with mild and unilateral HL performed near ceiling on a sentence repetition task presented at +10 dB signal-to-noise ratio (SNR). Such scenarios are unlikely to take place in the real world, however, as distance, significant levels of background noise, and reverberation may all have a negative effect on speech perception and learning (Bradley & Sato, 2008). Thus, we lack clear evidence of how aided audibility influences functional speech perception outcomes for children with mild HL. It is important to note that recent studies with children with mild to severe HL support the premise that aided audibility relates to language outcomes (Stiles et al., 2012; Tomblin et al., 2014).

Stiles et al. (2012) examined the vocabulary abilities of children between the ages of 6 and 9 years who were hard of hearing and wore HAs. Aided audibility was a stronger predictor of performance than severity of HL (measured in PTA). The OCHL team showed that degree of HA benefit (measured by the aided speech intelligibility index [SII] after controlling for unaided PTA) had a similar positive effect on speech and language outcomes in preschool-age children regardless of whether they had mild or moderate to severe HL (Tomblin et al., 2014). Therefore, it is possible that children with mild HL may benefit from appropriately fitted HAs that give them maximal auditory access to the speech spectrum even though they are receiving less of a comparative improvement in audibility compared with children with moderate to severe losses.

Last, there is a third aspect of cumulative auditory experience: consistency of HA use. This topic has received even less attention than timing of intervention and aided audibility in the literature on children with HL. For example, Kiese-Himmel and Ohlwein (2003) reported on levels of acceptance of HA use and language outcomes for children with mild HL but did not describe how the two variables were related. Fitzpatrick et al. (2010) conducted a retrospective chart review of audiological services for children with minimal HL (mild bilateral or unilateral). Although the majority of children (91.4%) received a recommendation for amplification, fewer than two thirds consistently wore their devices. Fitzpatrick et al. did not report on speech or language outcomes for children in the study.

Despite the lack of research linking HA use to outcomes, amount of HA use could be an important contributing factor in outcomes for children with mild HL. HA use varies widely in children who are hard of hearing (Jones & Launer, 2010; Muñoz, Preston, & Hicken, 2014). In particular, children with mild HL are less likely to wear their HAs than participants with greater degrees of HL (Walker et al., 2013). The poorer compliance rate of children with mild HL may be due to the parents' belief that their child hears well enough without amplification. This belief may be warranted in some cases. However, it is also possible that inconsistent HA use may have a negative effect on developmental outcomes due to reductions in exposure to input. The current study expands the evidence base on the issue of daily HA use and its influence on functional outcomes and thus informs clinical management regarding the importance of consistency of HA use in this population.

In summary, the current literature on oral communication outcomes in children with mild HL is inconclusive about whether these children are hindered by their reduced hearing levels. Untreated HL has been estimated to cost an additional $690,000 per child in the school years and result in an estimated $1.6 million in lifetime costs per individual (Johnson et al., 1993; adjusted for inflation). The findings from this study, albeit preliminary, have the potential to affect eligibility for early intervention services, educational practices, and medical and audiological care. If the data indicate a benefit of HAs for children with mild HL, more parents and audiologists may pursue amplification for these children and may be more likely to adhere to recommended levels of daily use. Early intervention and consistent use of HAs by children with mild HL may also improve academic and language outcomes for these children. Thus, the present findings may have important clinical implications for physicians, audiologists, and parents because they will advance knowledge regarding the benefits of amplification and intervention for children with mild HL.

Given the gaps in the research literature on outcomes for children who are hard of hearing, the National Institute on Deafness and Other Communication Disorders funded a collaborative research team to investigate the speech, language, academic, psychosocial, and family outcomes of children who are hard of hearing. The OCHL study is a 5-year multicenter project conducted by investigators representing three primary sites and multiple disciplines. The aims of the OCHL study are to examine background characteristics of the child and family and their interventions and explore how variations in these factors relate to functional outcomes. The current article specifically reports on results for a subset of children with mild HL in the OCHL study and addresses the following questions:

1. When do follow-up services (confirmation of HL, HA fitting, and early intervention) occur for children with mild HL as a function of NHS status? *It is predicted that children who pass the NHS initially will experience greater delays in follow-up compared with children who refer from screening.*
2. Are there differences in outcomes for children with mild HL as a function of amount of daily HA use? *We predicted that children with consistent daily HA use will demonstrate stronger performance on standardized language measures and speech perception tests compared with children who are part-time HA users or nonusers.*
3. Does cumulative auditory experience (i.e., age at confirmation of HL, level of audibility, amount of daily HA use, receipt of early intervention services) influence expressive morphosyntax and receptive vocabulary skills in children with mild HL? *We predicted that children who had HL confirmed at younger ages, had better audibility and greater amounts of daily HA use, and received early intervention will demonstrate higher scores on measures of expressive morphosyntax and receptive vocabulary compared with children*

*with later ages of confirmation, poorer audibility, lack of daily HA use, and no early intervention.*

# Method

## *Participants*

Thirty-eight children with slight or mild HL in the better ear participated. The children included 20 girls and 18 boys who were between the ages of 5 years, 10 months, and 7 years, 2 months, at time of testing ($M$ = 73.95 months, $SD$ = 11.58 months). All of the children and their families were participants in a longitudinal study on outcomes of children with mild to severe HL (OCHL). To qualify for participation in OCHL, children presented with a persistent bilateral HL (sensorineural, mixed, and permanent conductive) with a better ear three- or four-frequency PTA (BEPTA) of no better than 25 dB HL and no poorer than 75 dB HL. Exceptions were made to include children with bilateral high-frequency HL (thresholds greater than 25 dB at 3, 4, 6, or 8 kHz). Children with significant cognitive, visual, or motor impairments were excluded from participation. For all participants, at least one primary caregiver spoke English in the home. Children who used manually coded English or American Sign Language as their primary mode of communication were excluded from the study.

In the current analysis, only data from children with mild HL in the better ear were included. Participants were assessed at either 5 or 7 years of age. The range of BEPTA for the children with mild HL was 7.5 to 38.75 ($M$ = 28.72 dB HL, $SD$ = 7.12). The range of poorer ear PTA (PEPTA) was 10 to 61.25 dB HL ($M$ = 36.45, $SD$ = 10.19). Twenty-four of the participants presented with a slight or mild HL in both ears; 14 presented with a moderate HL in the poorer ear (ranging from 41.25 to 61.25 dB HL four-frequency PTA).

Twenty-eight of the participants were fitted with bilateral wide dynamic range compression HAs, one participant had a unilateral HA, and one was fitted with a soft-band bone-anchored HA. The latter two children had no amplification in the opposite ears. Eight children had no prior experience with HAs at the time of testing. Amount of HA use was determined in two ways: (a) parent report and (b) data logging (described in the Data Collection section). For 12 children, data logging was available at the test visit. For five children, data logging was available at the subsequent visit, which took place 1 year later. Given previous research indicating that amount of HA use shows little variability starting at age 5 years (Walker et al., 2015), we based group membership on the later data logging values for these five children. For 13 children, only parent report measures from the HA questionnaire were available for determining daily HA use.

Participants were divided into three groups on the basis of amount of daily HA use: (a) full-time users, (b) part-time users, and (c) nonusers. We considered full-time use to be 8.7 hr or greater on the basis of a median split of the HA use data; part-time use was between 2 and 8.3 hr. Nonusers were children who did not own a HA or whose parents indicated that the child did not wear the HAs. The full-time group comprised children who had the highest amount of use in this study. We acknowledge that some of the children in the full-time group wore HAs less than all waking hours (i.e., 12 hr). Thus, these arbitrary categories were less than optimal for real-world applications but enabled us to examine the effects of a continuous variable by dividing participants into categories that corresponded with the available data.

Using the criterion of 8.7 hr or greater for full-time use, 14 participants were categorized as full-time HA users ($M$ = 10.99 hr, $SD$ = 1.62, range = 8.7–13.42). Fifteen children were categorized as part-time HA users ($M$ = 5.58 hr, $SD$ = 1.92, range = 2.00–8.30). Nine children fell into the nonuser group. Eight of these children were not fitted with HAs. One child owned HAs but, on the basis of parent report, wore them only minimally (approximately 1 hr/day) and had not worn the HAs at all in the 2 months leading up to the test visit. In summary, among the 38 children with mild HL who were tested at 5 or 7 years of age, approximately 37% were categorized as full-time HA users, 39% were part-time HA users, and 24% were nonusers.

We conducted one-way analyses of variance (ANOVAs) to determine whether there were any significant differences between groups (full time, part time, nonusers) in maternal education level, nonverbal cognition, BEPTA, PEPTA, and aided and unaided SII. Maternal education level was treated as a continuous variable (e.g., mothers with a high school diploma had 12 years of education). There were no significant differences between groups for maternal education level, $F(2, 35) = 0.20$, $p = .82$. Nonverbal cognition was measured using the Wechsler Preschool and Primary Scale of Intelligence–Third Edition (Wechsler, 2002) at age 4 years or the Wechsler Abbreviated Scale of Intelligence–Second Edition (Wechsler, 2011) at age 6 years. Performance on the Block Design and Matrix Reasoning subtests were compared in separate ANOVAs. Scores were converted into $z$ scores for analysis. There were no significant differences between groups for either Block Design, $F(2, 34) = 0.39$, $p = .68$, or Matrix Reasoning, $F(2, 34) = 0.67$, $p = .52$. One child in the nonuser group did not complete nonverbal cognitive testing; however, this child's language scores would suggest verbal and nonverbal cognitive skills within normal limits on the basis of performance on vocabulary and syntax measures. There was a significant difference between BEPTA, $F(2, 35) = 6.20$, $p = .005$, with follow-up tests indicating that the nonusers had significantly better hearing, on average, compared with the part-time users ($p = .004$) and the full-time users ($p = .04$). There was also a significant difference between groups for PEPTA, $F(2, 35) = 5.03$, $p = .005$. Nonusers had significantly better average PEPTA than part-time ($p = .01$) and full-time ($p = .05$) users. Of note, there was one participant in the nonuser group with hearing levels well within the average range (PTA of 7 dB in the better ear and 10 dB in the poorer ear). This participant had a bilateral high-frequency HL, with thresholds within the normal range out to 4000 Hz, sloping to 60 dB at 6000 Hz in both ears and 70 dB in the

**Table 1.** Average values (*SD*s) for maternal education level, nonverbal cognitive performance, better ear pure-tone average (BEPTA), and poorer ear pure-tone average (PEPTA) as a function of hearing aid use group.

| Group | Maternal education (years) | Block Design *z* scores | Matrix Reasoning *z* scores | BEPTA | PEPTA |
|---|---|---|---|---|---|
| Full time | 15.07 (2.30) | –0.16 (0.78) | 0.23 (0.94) | 29.52 (5.75) | 38.04 (8.75) |
| Part time | 14.73 (2.34) | –0.03 (1.02) | –0.07 (0.99) | 31.71 (5.95) | 40.00 (9.20) |
| Nonuser | 15.33 (2.40) | 0.22 (1.23) | –0.26 (1.11) | 22.50 (7.60) | 28.06 (10.04) |

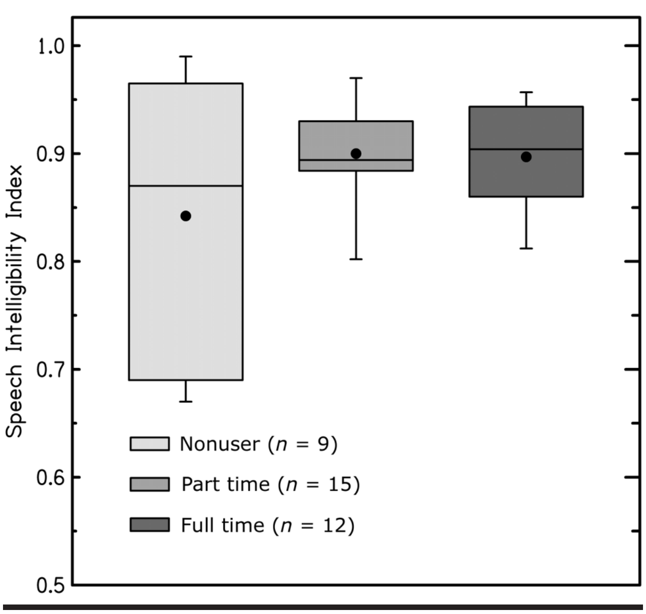
left ear and 75 dB in the right ear at 8000 Hz. Table 1 shows the average values for maternal education level, nonverbal cognition scores, and audiologic variables for the three groups.

The three groups were also compared with respect to audibility as measured by SII (see Figure 1). For children in the full-time and part-time use groups, aided SII was calculated because this value best represents the amount of access they had to the speech spectrum during daily activities. Unaided SII was calculated for the nonusers, with the exception of the one child who owned HAs. Results from an ANOVA indicated no significant differences in level of audibility among the three groups, $F(2, 33) = 1.90$, $p = .16$, $\eta^2 = .10$, although the variance in the nonuser group was considerably larger compared with that in the other two groups (as shown in Figure 1).

## *Data Collection*

As part of the OCHL study, children and their families participated in an initial baseline visit. This visit was followed by visits twice a year for children under age 2 years and once a year for children older than 2 years.

**Figure 1.** Box plot of aided or unaided speech intelligibility index values as a function of hearing aid use group. The central lines represent the median values, the filled circles represent the mean values, and the box limits are the 25th and 75th percentiles. The lower and upper fences are the minimum and maximum, respectively.




### Audiologic Assessment

A pediatric audiologist completed all hearing assessments. A test assistant participated in assessments as needed. The audiologist attempted to obtain air-conduction and bone-conduction thresholds at 500, 1000, 2000, and 4000 Hz at a minimum using conditioned play audiometry or conventional audiometry, depending on the age of the child. All attempts were made to obtain ear-specific thresholds utilizing insert earphones, circumaural headphones, or the child's own earmolds paired with insert earphones. If a full audiogram could not be completed, the audiologist obtained a copy of the child's most recent unaided audiogram. The BEPTA and PEPTA were calculated for subsequent analyses.

### HA Verification and Audibility Measures

The audiologist determined that HAs were functioning within manufacturer specifications using ANSI S3.22-2003 conformity measures of HA function. The SII (ANSI S3.5-1997) was calculated as a numerical estimate of audibility across the frequency range of speech. The SII is calculated by estimating the audibility of an average speech signal compared with the listener's hearing thresholds. The calculation is completed for a discrete number of frequency bands, which are each assigned an importance weight on the basis of the contribution of that frequency band to the average speech recognition score for a group of adult listeners with normal hearing. The audibility of each band is multiplied by the importance weight for that band. The weighted audibility of all bands is summed to create a number between 0 and 1 that describes the weighted audibility of the long-term average speech spectrum (LTASS), where a value of 0 indicates that none of the LTASS is audible and 1 represents complete audibility. The SII can be calculated for unaided or aided conditions. When aided, the audibility of the amplified LTASS signal through the HAs measured during verification is used for the SII calculation.

Simulated real-ear measures were used to calculate aided and unaided SII in cases where the response of the HA could not be measured in the child's ear. The audiologist initially conducted probe microphone measures to quantify the real-ear to coupler difference (RECD; Bagatto et al., 2005). An age-related average RECD estimated the acoustic characteristics of the child's occluded ear canal when the RECD could not be measured due to limited cooperation or participant noise. HA verification was then completed in the 2-cc coupler. Audioscan Verifit speech-mapping software (Cole, 2005) calculated unaided SII and aided SII at users' settings using the standard male speech signal (carrot passage; Cox & McDaniel, 1989) presented at average levels (60 or 65 dB SPL) following ANSI S3.5-1997. We computed indices of aided SII for the average level of input for 29 nine children who had been fitted with HAs. Eight of the children were not fitted with HAs; therefore, we computed indices of unaided SII on the basis of those children's pure-tone thresholds. One child used a soft-band bone-anchored HA; an SII was not calculated for this child.

Seven participants wore nonlinear frequency compression HAs, which is a signal-processing strategy that lowers and compresses a range of high-frequency speech energy into a lower frequency in order to improve audibility. For these children, filtered speech bands (3000, 4000, 5000, and 6300 Hz) were measured with the Audioscan Verifit software to determine the sensation level and location of each third-octave band used in the SII calculation after lowering. An algorithm was used to calculate the SII on the basis of the sensation level of the input frequency band at its output or compressed location (Bentler, Walker, McCreery, Arenas, & Roush, 2014). It is important to note that this method assumes that information that is lowered carries the same importance weighting for speech recognition as in cases without frequency lowering. However, it does not account for loss of spectral distinctiveness that may occur with nonlinear frequency compression.

**Speech-Language Assessment**

Examiners administered standardized tests of speech production, language, and phonological processing in a quiet testing room or a mobile testing van. The Goldman-Fristoe Test of Articulation–Second Edition (GFTA-2; Goldman & Fristoe, 2000) is a standardized measure of articulation in which examinees label single-word pictures. The Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4; Dunn & Dunn, 2007) is a standardized measure of receptive vocabulary in which the examiner says a word that describes one of the pictures on a page and the participant identifies the correct picture. The Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2004) Word Structure subtest is an assessment of expressive morphosyntax in which the examiner asks the participant to complete prompted sentences with picture stimuli. The Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) assesses phonological abilities in children ages 4 to 24. It provides a composite score for phonological awareness, which consists of performance on the Blending Words subtest (combining sounds to make words; e.g., "ham" and "er" make *hammer* and "t" and "oi" make *toy*) and the Elision subtest (separating words to form new words; e.g., saying *popcorn* without "corn" and *cup* without "k"). For 5-year-olds, the Phonological Awareness composite score also includes performance on the Sound Matching subtest; this score was removed from the calculation for the composite score to ensure that scores for 5- and 7-year-olds were comparable. Therefore, Phonological Awareness composite scores were based on the sum of two scores (Blending Words and Elision) for all participants. The CTOPP also provides a composite score for Phonological Memory, consisting of a combination of scores on Memory for Digits (repeating back numbers in forward order) and Nonword Repetition (repeating back nonsense words such as *zid*).

**Nonverbal Cognitive Assessment**

Subtests from the Wechsler scales of intelligence, specifically the Block Design and Matrix Reasoning subtests, were administered to measure nonverbal cognitive performance. Due to the longitudinal design of the OCHL study, three children received the Wechsler Preschool and Primary Scale of Intelligence–Third Edition at age 4 years and 34 children received the Wechsler Abbreviated Scale of Intelligence–Second Edition at age 6 years.

**Word Recognition Assessment**

The Computer-Assisted Speech Perception Assessment (CASPA; Mackersie, Boothroyd, & Minniear, 2001) was administered as a measure of word recognition in noise at age 7 years. Children heard recorded consonant–vowel–consonant words in 10-word lists. Lists were presented at 0° azimuth, with the steady-state noise presented at 55 dB SPL and the speech signal varying at levels of +10 and –5 dB SNR. Results are reported in the best-aided condition and scored for percentage correct at the phoneme and whole-word levels.

**HA Use Questionnaire and Data Logging**

As part of the visit, an examiner conducted with the caregiver an interview that pertained to pediatric HA use (see Walker et al., 2013, for a full description of the HA use questionnaire). Parents estimated the average amount of time the child used HAs per day during the week and on the weekends. Audiologists collected data-logging values for average use time per day from the manufacturers' HA programming software. If the data-logging values were different between ears, the larger value was included in data analyses.

**Statistical Analyses**

Because of unequal numbers of participants across tests, we conducted a series of ANOVAs to determine whether consistency of HA use influenced language and phonological processing. The alpha level was adjusted to .01 to control for multiple comparisons. The between-subjects variable was HA use group (full time, part time, nonuser), and the within-subject variables were standard scores on the GFTA-2 and PPVT-4, scaled scores on the CELF-4 Word Structure subtest, and Phonological Awareness and Phonological Memory composite standard scores on the CTOPP. A Bonferroni test was used for post hoc analysis. To investigate the relationships among the independent predictor variables and the dependent response variables, we utilized linear regression models. The independent variables included age at confirmation of HL, better ear SII (aided or unaided, if aided was unavailable), and amount of daily HA use as continuous variables and early intervention services as a dichotomous variable. The dependent variables were scaled scores on the CELF-4 Word Structure subtest and standard scores on the PPVT-4.

## Results

### *Research Question 1: Timing of Service Provision*

Twenty-three children (61%) referred on their NHS. Of those children, 21 children referred in both ears and two children referred in one ear. For those participants who referred on the NHS, the average age at first evaluation was 10.54 months (*SD* = 19.15), average age of confirmation of HL was 17.40 months (*SD* = 23.21), and average age at fitting of amplification was 21.17 months (*n* = 21, *SD* = 23.06). Sixteen of the 23 children qualified for early intervention according to parent report. Fifteen of those children received early intervention, starting at an average age of 6.82 months (*SD* = 4.06, *Mdn* = 6.00). One of the children received early intervention for reasons other than HL (i.e., feeding).

Fifteen children (39%) passed the NHS and were thus identified with HL after birth. Two of those children referred on the NHS in the birth hospital but passed the second-stage screen and were therefore considered to be later-identified. In the group of 15 participants who were later-identified with HL, parents reported that they first suspected the HL at 34.83 months on average (*SD* = 18.02). The average age at first evaluation was 37.75 months (*SD* = 15.93), average age at confirmation of HL was 45.53 months (*SD* = 11.49), and average age at HA fitting was 48.56 months (*n* = 9, *SD* = 12.64). Four children received early intervention, two due to reasons other than HL (i.e., speech or motor delays). Table 2 presents descriptive statistics regarding age at service delivery for children who referred on or passed the NHS.

### *Research Question 2: Group Differences in Outcomes*

#### Receptive Vocabulary

The results of the ANOVA were significant, $F(2, 35) = 5.77$, $p = .007$, $\eta^2 = .25$. Post hoc Bonferroni tests indicated that the full-time users had significantly larger receptive vocabularies compared with the nonusers ($p = .006$). There were no significant differences between the nonusers and the part-time users ($p = .31$) or the part-time and the full-time users ($p = .17$). Figure 2 displays the distribution of PPVT-4 standard scores as a function of HA use group.

#### Expressive Morphosyntax

The results of the ANOVA were significant, $F(2, 34) = 11.36$, $p < .001$, $\eta^2 = .40$. Post hoc tests indicated that the part-time users had significantly higher expressive morphosyntax scores compared with the nonusers ($p = .002$). The full-time users also performed significantly better than the nonusers ($p < .001$). There were no significant differences between the part-time and full-time users ($p = .84$). Figure 3 displays the distribution of CELF-4 Word Structure scaled scores as a function of HA use group.

#### Articulation

The results of the ANOVA for articulation were not significant, $F(2, 35) = 0.85$, $p = .44$, $\eta^2 = .05$. The nonuser group showed greater variance in GFTA-2 standard scores compared with the other two groups, as shown by the standard deviation for the nonusers in Table 3.

#### Phonological Awareness and Phonological Memory

The results of the ANOVA for phonological awareness approached significance, $F(2, 33) = 3.76$, $p = .03$, $\eta^2 = .19$. There was no significant difference between the nonusers and the part-time users ($p = .81$) or the full-time and the part-time users ($p = .25$). The results of the ANOVA for phonological memory were not significant, $F(2, 34) = 1.96$, $p = .16$. Table 3 shows the summary statistics for each ANOVA.

#### Speech Perception in Noise

Only children who were assessed at 7 years of age were included in this analysis (nonusers, *n* = 4; part-time users, *n* = 10; full-time users, *n* = 7). Due to small sample sizes for the CASPA, nonparametric statistical analyses were conducted using the Kruskal–Wallis test. The three

**Table 2.** Data for ages (in months) at service delivery for children identified by the newborn hearing screening (NHS) and children who were later-identified.

| | Identified by NHS (*n* = 23) | | | | Later-identified (*n* = 15) | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | *M* | *Mdn* | *SD* | Range | *M* | *Mdn* | *SD* | Range |
| Age at service delivery | | | | | | | | |
| First evaluation[a] | 10.54 | 2.00 | 19.15 | 0.5–60.0 | 37.75 | 44.00 | 15.93 | 2.5–60.0 |
| Confirmation[b] | 17.40 | 2.75 | 23.21 | 0.5–61.0 | 45.53 | 46.00 | 11.49 | 24.0–62.0 |
| Hearing aid fitting[c] | 21.17 | 6.00 | 23.06 | 2.0–67.0 | 48.56 | 51.00 | 12.64 | 30.0–66.0 |
| Early intervention[d] | 6.82 | 6.00 | 4.06 | 2.5–16.0 | 22.75 | 24.00 | 9.50 | 10.0–33.0 |
| Delays between follow-up services | | | | | | | | |
| First evaluation to confirmation | 6.86 | 0.75 | | 7.78 | 2.00 | | | |
| Confirmation to hearing aid fitting | 3.77 | 3.25 | | 3.03 | 5.00 | | | |

[a]NHS group, *n* = 20; later-identified group, *n* = 14. [b]NHS group, *n* = 22; later-identified group, *n* = 15; [c]NHS group, *n* = 21; later-identified group, *n* = 9. [d]NHS group, *n* = 14 (one due to reasons other than HL); later-identified group, *n* = 4 (two due to reasons other than HL).

Figure 2. Box plot of Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4) scores as a function of hearing aid use group. The central lines represent the median values, the filled circles represent the mean values, and the box limits are the 25th and 75th percentiles. The lower and upper fences are the minimum and maximum, respectively. The hatched area represents the average range for the normative sample.

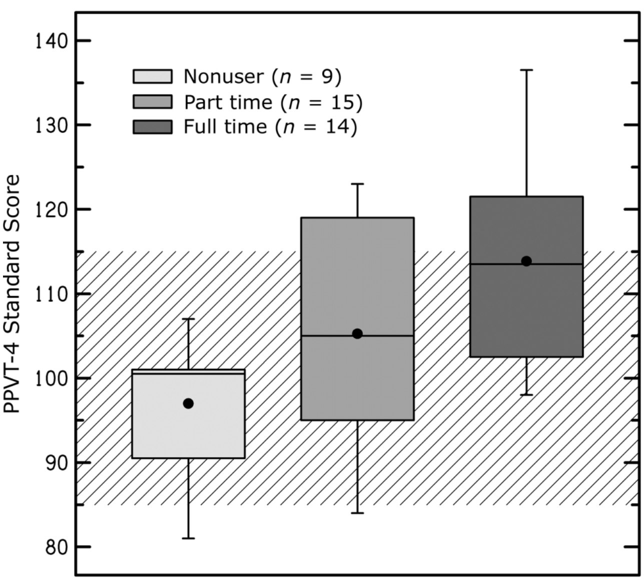
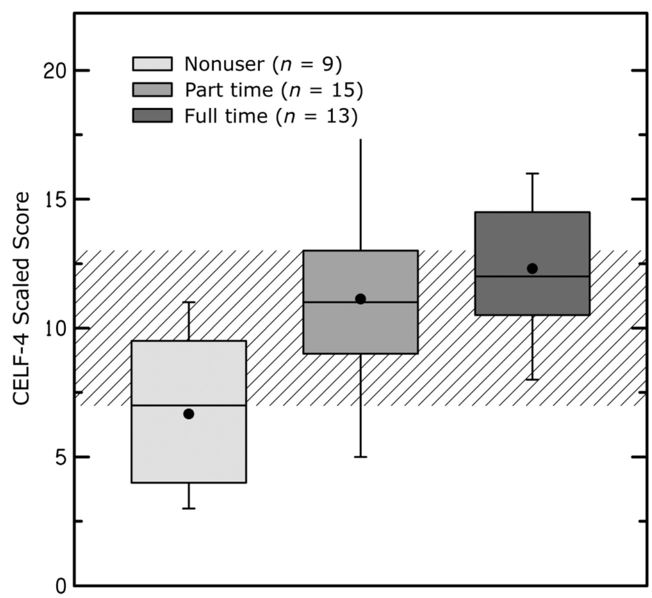



Figure 3. Box plot of Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4) Word Structure subtest scores as a function of hearing aid use group. The central lines represent the median values, the filled circles represent the mean values, and the box limits are the 25th and 75th percentiles. The lower and upper fences are the minimum and maximum, respectively. The hatched area represents the average range for the normative sample.




groups were compared on phoneme and whole-word correct performance at +10 and –5 dB SNR levels. Table 4 displays average scores on the CASPA in the various conditions. There were no significant differences between groups in any of the conditions (all *p*s > .07).

### *Research Question 3: Regression Analysis of Contribution of Cumulative Auditory Experience*

A multiple regression analysis was conducted to determine whether cumulative auditory experience (audibility, early intervention, HA use) influenced outcomes for children with mild HL. The outcome variables were CELF-4 Word Structure scaled scores and PPVT-4 standard scores. The predictor variables were age at confirmation of HL, better ear SII level, amount of daily HA use (treated as a continuous variable rather than a categorical variable), and participation in early intervention (with HL included as a reason for services). Aided SII was included for children who had HAs, and unaided SII was included for children in the nonuser group who did not have HAs. The participant in the nonuser group who did not wear his HAs was tested with his HAs on, and his aided SII data were included in the regression analysis. The participant who wore a bone-anchored HA was excluded from this analysis due to the difficulty in calculating aided SII with a bone-conduction device.

With CELF-4 Word Structure scores as the outcome variable, the overall regression model was significant, accounting for 35% of the variance. Amount of daily HA use ($\beta = .59$, $p = .003$) was the only predictor variable to contribute unique variance after controlling for age at confirmation, SII, and receipt of early intervention. Children with greater amounts of HA use tended to have higher scores in terms of expressive morphosyntax compared with children with lower amounts of HA use. With PPVT-4 scores as the outcome variable, the regression model was not significant, $F(4, 30) = 1.74$, $p = .17$. Only amount of daily HA use contributed unique variance ($\beta = .43$, $p = .04$) after controlling for the other predictors. Children with greater amounts of HA use tended to have higher receptive vocabulary scores. Table 5 shows results from the regression models.

## Discussion

The primary objective of this study was to describe the variability in cumulative auditory experience for children with mild HL when auditory experience is viewed in terms of audibility and amount of daily HA use. We also explored service provision in children with mild HL, including timing of identification and intervention.

The first research question examined timing of service provision for children with mild HL. The current results indicated that more than one half of the participants (61%; 24/38) were identified with HL on the basis of the NHS. It is worth noting that even for the children who referred on the NHS, many experienced a significant delay in confirmation of the HL (average age at confirmation was 19.5 months). This delay in confirmation is well outside of the JCIH

**Table 3.** Summary statistics for speech and language outcome measures in the full-time hearing aid user, part-time hearing aid user, and nonuser groups.

| Outcome variable | Nonuser | | Part time | | Full time | | Between groups | |
|---|---|---|---|---|---|---|---|---|
| | *M* (*SD*) | CI | *M* (*SD*) | CI | *M* (*SD*) | CI | $\eta^2$ | *p* |
| PPVT-4 | 97.0 (8.0) | [89.1, 104.9] | 105.3 (12.6) | [99.1, 111.4] | 113.9 (12.7) | [107.5, 120.2] | .25 | .007* |
| CELF-4 WS | 6.7 (3.0) | [4.8, 8.6] | 11.1 (3.0) | [9.7, 12.6] | 12.3 (2.5) | [10.7, 13.9] | .40 | <.001* |
| GFTA-2 | 92.4 (20.5) | [83.2, 101.7] | 99.3 (10.3) | [92.1, 106.4] | 99.2 (11.4) | [91.8, 106.6] | .05 | .44 |
| CTOPP PA | 94.8 (10.1) | [84.7, 104.8] | 101.7 (16.6) | [94.1, 109.3] | 111.1 (12.9) | [103.5, 118.8] | .19 | .03 |
| CTOPP PM | 85.3 (6.6) | [77.2, 93.5] | 91.1 (15.6) | [84.5, 97.6] | 95.5 (10.4) | [89.0, 102.0] | .10 | .16 |

*Note.* CI = 95% confidence interval; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition; CELF-4 WS = Clinical Evaluation of Language Fundamentals–Fourth Edition, Word Structure subtest; GFTA-2 = Goldman-Fristoe Test of Articulation–Second Edition; CTOPP PA = Comprehensive Test of Phonological Processing, Phonological Awareness composite; CTOPP PM = Comprehensive Test of Phonological Processing, Phonological Memory composite.

*Significance with alpha level at less than .01 (adjusted for multiple comparisons).

benchmarks for children who refer on the NHS (i.e., confirmation by 3 months of age). It is also much longer than data reported by Holte et al. (2012), in which the average age of confirmation for children in the OCHL study who referred on the NHS was 6.78 months. This delay in confirmation may be explained in part by results from Holte et al., in which parents reported that one of the primary reasons for delays in diagnosis was subjective observations that their child was responding to sound. This may be especially true in the case of parents of children with mild HL, who frequently observe responses to environmental sounds and speech. It is also possible that parents may interpret the use of the term *mild HL* as an indication that the magnitude of the HL is insignificant and that immediate follow-up is not critical (Haggard & Primus, 1999; Ross et al., 2008).

It is not surprising that children with mild HL who passed the NHS received services at older ages compared with the children who referred on the NHS. Once the first evaluation took place, however, confirmation of HL and HA fitting for the later-identified children took place in approximately the same amount of time, on average, as for the children who referred on the NHS (see Table 2). Thus, children with mild HL who are later-identified appear to be accessing services in a timeframe similar to that of children with mild HL who were identified early. In both cases, however, these children are experiencing longer delays in confirmation of HL and HA fitting than would be expected on the basis of the JCIH benchmarks of confirmation by 3 months of age (3 months after first evaluation or suspicion of HL, in the case of the later-identified group) and HA fitting 1 month after confirmation.

When all of the participants were examined, approximately one half (53%; 20/38) qualified for early intervention services. Of the children who qualified for early intervention services, 80% (16/20) participated for reasons involving HL. One explanation for the lack of early intervention for some of the children may be the delay in confirmation of HL; some children may not have had HL confirmed until after 36 months of age. As an alternative, some of the children may not have qualified for early intervention even if the HL was confirmed at a young age. Holstrum et al. (2008) highlighted the challenges of providing early intervention services for children with mild HL. As of 2008, a little more than one half of the states in the United States included specific language for eligibility into Part C/birth-to-three services for children with mild HL on the basis of the philosophy that these children may be at risk for future language and academic difficulties. The remaining states operate on a model in which the children must show evidence of delay before being deemed eligible to participate in services. Last, some parents could have adopted a "wait and see" approach to intervention in that they perceived that their child was meeting language development milestones and chose not to participate in early intervention. For this specific group of

**Table 4.** Summary statistics for Computer Assisted Speech Perception Assessment scores in the full-time hearing aid user, part-time hearing aid user, and nonuser groups.

| Outcome variable | Nonuser | Part time | Full time | Between groups | |
|---|---|---|---|---|---|
| | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) | $\chi^2$ | *p* |
| Phoneme (+10 SNR) | 90.0 (4.4) | 86.6 (6.7) | 92.7 (3.2) | 5.32 | .07 |
| Phoneme (–5 SNR) | 46.3 (25.2) | 46.0 (19.8) | 45.0 (18.9) | 0.01 | 1.00 |
| Word (+10 SNR) | 85.0 (12.9) | 70.0 (16.9) | 80.0 (6.3) | 2.31 | .32 |
| Word (–5 SNR) | 20.0 (17.3) | 17.5 (19.8) | 20.0 (21.0) | 0.21 | .90 |

*Note.* Scores reflect percentage correct in the best aided condition. SNR = signal-to-noise ratio.

**Table 5.** Summary of regression models with Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4) Word Structure (WS) and Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4) scores as dependent variables and age at confirmation, better ear speech intelligibility index (BESII), amount of daily hearing aid use, and receipt of early intervention as independent variables.

| | CELF-4 WS ($R^2$ = .35, $p$ = .01) | | | PPVT-4 ($R^2$ = .19, $p$ = .17) | | |
|---|---|---|---|---|---|---|
| **Independent variable** | **β** | **B** | ***p*** | **β** | **B** | ***p*** |
| Age at confirmation | .38 | 0.060 | .1700 | .01 | 0.004 | .9800 |
| BESII | –.16 | –7.420 | .3100 | –.04 | –6.230 | .8400 |
| Daily hearing aid use | .59 | 0.480 | .0038 | .43 | 1.310 | .0500 |
| Early intervention | .15 | 1.110 | .6200 | .03 | 0.720 | .9400 |

*Note.* β = standardized coefficients; B = unstandardized coefficients.

children, the latter explanation is not the case because only one child who qualified for early intervention did not enroll according to parent report. It is difficult to draw conclusions regarding the effectiveness of early intervention for children with mild HL given the small number of participants in this study. Future research needs to address the influence of early intervention/birth-to-three services on this population, including a larger sample of children.

The second research question explored outcomes as a function of amount of HA use. We predicted that children with mild HL who wore HAs on a full-time basis would demonstrate higher scores on measures of language and speech perception ability and that children with little or no HA use would demonstrate lower performance. The current results support this hypothesis. With the exception of articulation scores and speech perception in noise, test results across a variety of domains present a general picture in which nonusers demonstrate the lowest scores, full-time users demonstrate the highest scores, and part-time users are in the middle. This is despite the fact that the nonusers had significantly better unaided behavioral thresholds compared with the full-time and part-time HA users. On the basis of the present findings, we cannot definitively state that all children with HL in the mild range should be fitted with amplification. We can, however, make an argument for the need to monitor progress and optimize communication access for children with even slight degrees of bilateral HL. Children in the full-time HA group likely had the most consistent access to the auditory environment. This consistent access has a cumulative positive effect on functional language outcomes by elementary school. The results provide important evidence for parents and service providers on the effect of aided mild HL.

Although there was a significant difference between the full-time users and the nonusers on the PPVT-4, the average score for the nonuser group (97.0) was well within the average range for the normative sample of the test. This finding is consistent with results from the OCHL cohort as a whole: Another report on the entire sample of children who are hard of hearing showed a pattern of children performing, on average, within the normative range of the standardized tests but significantly lower than the OCHL control group with normal hearing (Tomblin et al., 2015). This pattern reflects an issue that has been discussed by other authors in the literature on mild HL (Blair et al., 1985; Đoković et al., 2014; Kiese-Himmel & Ohlwein, 2003), in which children with mild HL performed within normal limits on standardized language measures but significantly worse when compared with peers. In the present study, we made comparisons within the group of children with mild HL, but the end result is similar. Children with mild HL who were receiving consistent auditory access through full-time use of amplification significantly outperformed children who were not using amplification. Although all of the participants performed within the average range for the test norms, we can explain more variance in performance by taking into account differences in cumulative auditory experience for children who were otherwise homogeneous (i.e., had similar socioeconomic backgrounds, audibility levels, and nonverbal cognitive abilities).

Average scores on the measure of expressive morphosyntax present a different picture. Children in the nonuser group were below 1 *SD* compared with the test norms, with an average score of 6.7 (the mean for the normative sample of the Word Structure subtest is 10, with an *SD* of 3). In contrast, the average score for the full-time users was 12.3—almost 1 *SD* above the normative mean. For the nonusers, the apparent difficulty with using English morphological markers is consistent with findings by other researchers. For example, McGuckian and Henry (2007) showed that 7-year-old children with moderate HL demonstrated poor performance on measures of English morphology. Koehlinger et al. (2013) examined language samples of 3- and 6-year-old children in the OCHL cohort and found that children with more auditory access (i.e., better audibility and younger ages at HA fitting) produced more obligatory verb morphemes compared with children with less auditory access. As described at the beginning of this article, the current findings support the notion that grammar is particularly vulnerable to the effects of inconsistent auditory access, especially in the case of morphological markers that have short duration and reduced perceptual salience (e.g., third-person singular; "he walks"; Leonard, 1989). These results, in combination with others (Koehlinger et al., 2013; McGuckian & Henry, 2007), also highlight how early, consistent access to auditory information can serve as a protective mechanism for acquiring English morphological markers (as in the case of the full-time users).

Results did not indicate significant group differences for articulation, phonological memory, or speech perception in noise. The lack of differences on the articulation measure suggests that, as a whole, these school-age participants with mild HL had intelligible speech, with few speech production errors at the single-word level. By 7 years of age, children can make only three to four errors on the GFTA-2 to receive a standard score of 100. Approximately one half of the participants in the current study were 7 years of age at the time of testing. The mean standard scores for the children in the part-time and full-time user groups (99.3 and 99.2, respectively) suggest that the majority of participants had reached a ceiling level of performance in terms of speech production skills and were producing few articulation errors at the single-word level. This result is consistent with previous research by Elfenbein, Hardin-Jones, and Davis (1994), who found that children with mild HL could produce all phoneme types accurately, with the exception of fricatives, and were judged to be within normal limits for speech intelligibility. The confidence intervals and standard deviations in Table 3 also show, however, that children in the nonuser group showed more variance in scores compared with the other two groups, suggesting that some children in this group experienced difficulties with speech production skills at the time of testing.

It is interesting to note that there were no significant between-groups differences in terms of phonological memory (a composite of nonword repetition and digit span scores). Phonological short-term memory was the one area in which Wake et al. (2006) found significantly poorer scores in children with slight or mild HL compared with peers with normal hearing (average standard scores of 91.0 vs. 102.8, respectively). In addition, Briscoe, Bishop, and Norbury (2001) reported that nonword repetition scores in children with mild or moderate HL were comparable to those in children with specific language impairment. With the present findings, phonological memory was the only language measure in which the mean standard scores for all three groups were below the average score of the test norms. In particular, the children in the nonuser group had an average standard score of 85.3—1 *SD* below the mean of the normative sample. These results suggest that phonological processing may be depressed in children with mild HL relative to children with normal hearing, which is consistent with the findings of Wake et al. (2006) and Briscoe et al. (2001).

The lack of differences between HA groups on speech perception measures should be interpreted cautiously because the number of participants was low. However, these results are consistent with those of other studies (Lewis et al., 2015), which supports the notion that basic speech perception measures, even those presented in background noise, are not sufficiently sensitive for demonstrating differences in HA use in children with mild HL. Higher level tasks require children to exert more cognitive resources, and functional language measures such as receptive vocabulary and expressive morphosyntax may better reflect the subtle influence of consistent auditory access compared with word recognition measures, which do not adequately reflect the benefit of aided listening in everyday environments (Hillock-Dunn, Taylor, Buss, & Leibold, 2015).

The third research question sought to determine whether four variables related to cumulative auditory experience—age at confirmation, audibility, amount of HA use, and receipt of early intervention—predicted morphosyntactic and vocabulary scores. Our prediction was partially correct in that the overall regression model was significant for expressive morphosyntax but not receptive vocabulary. Again, the current findings may support applying the surface hypothesis (Leonard, 1989) to children who are hard of hearing. Our finding that the regression model was significant for expressive morphosyntax but not receptive vocabulary is intriguing, but additional research is needed to fully understand the effects of cumulative auditory experience on the development of form and content in children with HL.

After controlling for age at confirmation, audibility, and early intervention, only amount of daily HA use contributed unique variance to the regression for both expressive morphosyntax and receptive vocabulary. These results do not imply that early identification, intervention, and level of audibility do not matter, however. The regression model for expressive morphosyntax was significant and accounted for 35% of the total variance. The partial correlation for HA use was .52, which would account for approximately 26% of that variance. Therefore, there is additional shared variance among the predictor variables that is contributing to individual differences in grammatical performance. Early confirmation of HL allows for provision of early intervention services. Children who wore HAs full time presumably had more consistent access to the speech spectrum over time. Thus, all of these factors likely serve as protective mechanisms for children with mild HL and lend support to the idea that service providers and parents should be proactive in management decisions for this population. However, ultimately these results demonstrate that it is difficult to separate the effects of amplification and intervention on outcomes. The only definitive means for resolving this issue would be to conduct a randomized clinical trial with both early intervention and amplification as treatment conditions.

## Limitations and Future Directions

Although this article provides important outcomes evidence regarding intervention for children with mild HL, several limitations could be addressed through further research. The current study did not include measures of academic performance, such as reading or classroom behavior. Porter et al. (2013) included teacher and parent report questionnaires and found that teachers reported more attention-based difficulties in children with mild HL relative to children with normal hearing. Furthermore, Porter et al. found that teachers reported more behavioral difficulties for children with mild HL who used amplification compared with children without amplification. Future directions with the present cohort of children will include examination of teacher and parent questionnaires, such as the Screening Instrument for Targeting Educational Risk (Anderson, 1989) or the Speech, Spatial, and Qualities of Hearing Scale (Gatehouse & Noble, 2004). Such research may provide more insight into adults' impressions of the effects of audiological management for children with mild HL.

Another limitation is that we included children in early elementary grades only. Bess et al. (1998) found differences in reading and language skills at third grade but not at sixth or ninth grade, suggesting that children with minimal HL may catch up to peers over time. Our research group continues to follow the current cohort over time and is in the process of collecting data on academic, language, and speech perception skills in second through fourth grade. Thus, we will be able to determine whether cumulative auditory experience continues to play a role in outcomes over time and whether differences still exist as a function of HA use.

Last, we addressed timing of service provision for children with mild HL but did not discuss what factors explain individual differences in age at confirmation, HA fitting, or early intervention. The current study does not include all of the children with mild HL who participated in the OCHL project. Due to the accelerated longitudinal design of the study, only 5- and 7-year-olds were included in this article (see Holte et al., 2012, for a description of the research design). Future directions will include looking at the factors that predict timing and delays in follow-up services for children with mild HL who referred on or passed the NHS, including all of the OCHL participants with mild HL.

## Summary

Our findings provide evidence that cumulative auditory experience influences language outcomes for children with mild HL. On the basis of the current results, these children are at risk for delays, particularly in areas such as morphology and phonological memory. Children with mild HL who do not utilize amplification are at risk for delays in vocabulary and grammar compared with other children with mild HL who wear their HAs regularly. Early identification and intervention may act as facilitators toward achieving consistent HA use and optimizing language development potential. Fitting HAs and providing early intervention services in a timely fashion remain a challenge if children with mild HL are not referred by NHS. The evidence presented in this article shows that children's language development benefits from early and consistent HA use. Physicians and audiologists should work collaboratively to identify HL and fit HAs at an early age, enroll children in early intervention, and encourage consistent HA use because these services matter—even for children with mild HL.

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