LSHSS

Research Article

Predictors of Hearing Aid Use Time in Children With Mild-to-Severe Hearing Loss

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Purpose: This study investigated predictors of hearing aid (HA) use time for children with mild-to-severe hearing loss (HL). Barriers to consistent HA use and reliability of parent report measures were also examined.

Method: Participants included parents of 272 children with HL. Parents estimated the amount of time the child used HAs daily. Regression analysis examined the relationships among independent variables and HA use time. To determine parental accuracy of HA use time, datalogging from the HAs was compared to the parents' estimates.

Results: Longer HA use related to older age, poorer hearing, and higher maternal education. Parental consistency ratings revealed similar findings—younger children and children with milder HL wore HAs less consistently than older children and children with more severe HL. Parents' estimates and datalogging were significantly correlated; however, results suggested that parents overestimate the amount of time their children wear their HAs.

Conclusion: Certain variables were significantly related to the amount of time children wore their HAs. Consistency rating scales provided insight into circumstances that were challenging for families. Use of both parent reports and datalogging may allow clinicians and researchers to obtain a general estimate of HA use time.

Key Words: children, hearing loss, amplification, hearing aids

As a result of universal newborn hearing screening, infants with hearing loss (HL) have earlier access than ever before to intervention. Recent data indicate that >95% of infants born in the United States are screened for HL at birth (Russ, White, Dougherty, & Forsman, 2010). Early confirmation of HL leads to early fitting of hearing aids (HAs) on infants (Spivak, Sokol, Auerbach, & Gershkovich, 2009), and age at fitting of amplification is predictive of speech perception, speech production, and spoken language skills (Sininger, Grimes, & Christensen, 2010). Furthermore, early identification and intervention have a positive impact on the speech and language outcomes of young children with HL (Carney & Moeller, 1998; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998).

In the era of early identification, it is typically assumed that children who achieve consistent, full-time use with their devices will have better outcomes than children who do not wear HAs consistently. However, few studies have explored this variable in young children or the family- and child-specific factors that influence consistency of HA use. Primary goals of the current study were to document HA use patterns and identify predictors of the amount of overall HA use time for children with mild-to-severe HL. Additional goals included identifying barriers to consistent use of amplification and examining the reliability of parent report of HA use.

To date, there is little research documenting the consistency of HA use in children. Moeller, Hoover, Peterson, and Stelmachowicz (2009) recently examined longitudinal parent reports of consistency of device use in a group of seven infants between the ages of 10 months and 28.5 months with mild-to-moderate HL. They administered a structured interview to mothers that evaluated the infants' daily habits with their HAs across a variety of environments (e.g., in the car, mealtimes, playing outside, etc.). Results indicated that HA

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use was inconsistent early in life and became more consistent with age. The authors intentionally chose not to include an estimate of average HA use time because of concerns regarding the reliability of these estimates. They were also unable to include an objective measure such as datalogging at the time of the study because it was not incorporated into the children's HAs. Datalogging is an automatic feature built into most current HAs (Mueller, 2007) that records the HA's performance over time, including average hours of use time per day. Availability of objective measures such as datalogging affords audiologists the opportunity to identify variables that predict the amount of time a child is using amplification. Recognizing which variables predict HA use time could help direct audiological counseling practices.

It is also likely that some situations may be more challenging for obtaining consistent device use, and these situations may vary by age. Moeller et al. (2009) explored possible challenges by asking parents to identify specific circumstances where it was difficult to keep the device on the child. Parent responses could be grouped into three categories: setting-specific issues, such as inclement weather or noisy environments; temperament/state challenges, such as fatigue, tantrums, or illness; and activity-related issues, such as nursing or playing alone. Even in the narrow age range that Moeller et al. investigated (10.5 to 28.5 months), challenges varied as a function of age. It seems likely that parents would encounter different challenges with device compliance as children enter preschool and early elementary school; however, there is no empirical evidence to support this claim. It may be useful for service providers and parents to recognize which situations pose challenges to consistent HA use across early childhood. This information can be used to counsel parents on realistic expectations as part of the HA adjustment process.

Unfortunately, relying on parent report to document daily HA use has its limitations, as discussed in Moeller et al. (2009). The primary limitation is the questionable accuracy of parents in estimating their children's average daily use time. There are no studies to date that have examined the reliability of parents as proxy reporters, although there are several studies that have explored the accuracy of adult HA users in reporting their own use time. Humes, Halling, and Coughlin (1996) monitored 20 adults with binaural HAs over a 6-month period using measures from a datalogging feature compared to participant report. They found a strong correlation ($r = 0.76$) between the average number of HA use hours indicated by objective datalogging measures and those reported by the research participants. However, on average, participants overestimated the amount of time they wore their HAs by ~4 hr per day. These findings suggested that although the absolute value of subjective estimates of overall use was not accurate, the relative difference between users' estimations appeared to be consistent, resulting in valid estimates of overall use time.

Taubman, Palmer, Durrant, and Pratt (1999) used a different approach to investigate subjective estimates of HA use time in adults. Participants included 24 adult HA users ranging in age from 50 to 90 years. Half of the participants (experimental group) were informed that their self-reported use time would be monitored using datalogging, and half were not (control group). There was a significant difference between the control group and the experimental group in the magnitude of difference between datalogging and self-reported use time, with the control group demonstrating a larger absolute difference between the two measures. Based on these findings, Taubman et al. concluded that clinicians and researchers should not rely on self-report estimates of average HA use time because they may be inaccurate. These conclusions may be overstated, however. Taubman et al. did not report on the correlation between self-report measures and datalogging. Working from the raw data in Table 1 from that study (Taubman et al., 1999, p. 303), it can be determined that the relationship between datalogging and self-report estimates for the whole group was highly correlated ($r = 0.72$). These results are consistent with the findings of Humes et al. (1996), in that the absolute value of estimates was inaccurate by several hours, but the correlation between objective and subjective measures was high. In other words, adults tended to overestimate their average overall HA use time, but that overestimation occurred to the same degree across all HA users.

It seems reasonable to predict that parents, serving as proxy reporters of children's average HA use time, may be less accurate than adult HA users at estimating the amount of time their child is wearing his or her HAs. There often will be occasions when parents are not present (e.g., daycare or at a friend or relative's house) and are possibly uninformed about the child's HA use. It is also difficult to estimate average daily use time in children because of fluctuating schedules. Parents will encounter situations where it is appropriate for the child to not wear HAs, such as nap time or bath time. Some of these situations would occur with younger children, suggesting that parents' accuracy in reporting HA use time will increase as children get older. The present study investigated the accuracy of parents' estimates of HA use time while also exploring variables that may predict which parents are more accurate reporters.

In spite of high prevalence rates, there are many gaps in the literature concerning children with mild-to-severe HL (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007). Recent estimates for childhood HL indicate that there is an average prevalence of 0.9% (range 0.4% to 1.7%) for mild HL or worse (pure-tone average [PTA] of 500, 1000, and 2000 Hz >25 dB HL; Mehra, Eavey, & Keamy, 2009). Given these data and the lack of information about the unique strengths, needs, and challenges of and for these children, 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 Outcomes of Children with Hearing Loss (OCHL) grant is a 5-year multicenter study that is being 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 reports on the results of two studies and addresses the following research questions:

Study 1

- Which child- and family-specific variables predict HA use time in children who are hard of hearing?
- What challenges do parents encounter with HA compliance across ages and situations?

Study 2

- Are parents accurate at estimating their children's average daily HA use time?
- Which child- and family-specific variables predict how accurate parents are at estimating their children's average daily HA use time?

STUDY 1

METHOD

Purpose

Study 1 sought to determine which child- and family-specific variables predicted the amount of time children wore their HAs, on average, during the week and on weekends. Study 1 also examined the variation of pediatric HA use across listening environments, as well as the challenges different situations pose for consistent HA use.

Participants. Participants were parents of 272 children with HL. The children included 127 females and 145 males who were between the ages of 0;5 (years;months) and 7;3 (M = 40.51 months; SD = 21.28 months). All of the families were participants in the longitudinal study on outcomes of children with mild-to-severe HL (OCHL). To qualify for participation, children had to present with a permanent bilateral HL (sensorineural, mixed, and permanent conductive) with a better-ear three- or four-frequency PTA no better than 25 dB HL and no poorer than 75 dB HL. 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.

Two-hundred eleven children were identified with HL at birth based on a failed newborn hearing screen (NHS), according to parent report. Of those 211 participants, the mean age at confirmation of HL was 7.36 months (SD = 13.97), and the mean age at fitting of amplification was 10.99 months (SD = 11.78). Sixty children were identified with HL later in life. Of those 60 children, 35 passed the NHS, 14 failed the NHS but there was no follow-up testing during the first year of life, four were not screened at birth, one had an inconclusive NHS, one had bilateral atresia, and five had an unknown status regarding NHS (due to international adoption or parental uncertainty). For one additional child, parents did not report if the child was identified with HL at birth or later. For those participants identified with HL after birth, the mean age at confirmation of HL was 27.28 months (SD = 17.1), and the mean age at fitting of amplification was 30.4 months (SD = 17.74). The mean better-ear PTA for the whole group was 49.58 dB HL (SD = 13.72). Two-hundred sixty-five children were fitted with wide dynamic range compression HAs and seven had bone conduction HAs. No participants had cochlear implants (CIs) at the start of the study, although six received CIs following study enrollment due to progression of the HL. At the time of data collection for Study 1, no children used CIs.

Data collection. Children and their families participated in an initial baseline visit followed by regular visits for up to 4 years. These visits occurred twice a year for children under age 2 and once a year for children older than age 2. At each visit, the child completed an audiologic assessment that included evaluation of HA function and administration of age-appropriate speech, language, and cognitive measures (see Appendix A for a summary of the OCHL test battery), and the parents completed a questionnaire and participated in a face-to-face interview regarding their children's HA compliance (described below). To avoid repeated measures, we included data from only one visit per subject in our analysis. For all analyses in Study 1, these data were from the initial baseline visit.

Audiologic assessment. A certified audiologist with pediatric experience completed all audiologic assessments. A test assistant participated in the 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 visual reinforcement audiometry, conditioned play audiometry, or conventional audiometry depending on the age of the child. All attempts were made to obtain ear-specific thresholds using insert earphones, circumaural headphones, or the child's own earmolds paired with insert earphones. Audiologists obtained soundfield thresholds if the child would not tolerate the testing with earphones or headphones. If a full audiogram could not be completed, the audiologist obtained a copy of the child's most recent unaided audiogram. The better-ear PTA was calculated for subsequent analyses.

HA verification measures. HA measurements included measures of total harmonic distortion, frequency range, and output sound pressure level at 90 dB SPL obtained in a 2-cc coupler following American National Standards Institute

S3.22 (ANSI, 2003). In addition, the audiologist conducted probe microphone measures to quantify the real-ear-to-coupler-difference (Bagatto et al., 2005). HA verification was then completed in a 2-cc coupler. We used Audioscan Verifit (v. 3.9, Dorchester, Ontario Canada) software to calculate aided and unaided speech intelligibility indices, using the standard male speech signal (carrot passage) presented at 65 dB SPL and 50 dB SPL, following ANSI S3.5 (1997). A swept pure tone at 90 dB SPL measured maximum output. The obtained fitting data were compared to prescriptive targets for Desired Sensation Level 5.0 (Scollie et al., 2005). These analyses are beyond the scope of the present analysis and are reported separately (McCreery, Bentler, & Roush, 2011).

Based on the results of the HA verification measures, parents received a report informing them if the settings of the HAs needed adjustment or if the HAs were in need of repair. Parents were also given the option of receiving a printout of the HAs' responses to share with their child's audiologist. Of the 272 children in Study 1, eight families were notified regarding problems with HA function. This low number is likely due to the fact that the families had been encouraged (via phone calls and postcards) to perform listening checks before scheduled research visits and to contact examiners if the HAs were not functioning appropriately. In these situations, visits were rescheduled for after the malfunctioning HA had been repaired.

HA provider survey. Each child's audiology service provider was encouraged to complete a survey that was designed to obtain information about the HA fitting audiologist's experience and clinical practices. The survey included specific questions regarding the HA fitting and verification methods used as well as the audiologist's comfort level with pediatric assessment and amplification procedures. For the 272 children in Study 1, we received 200 responses to the audiology service provider survey. Only 65 of these were unique audiologists; in other words, many of the same audiologists responded to the surveys because they served multiple children in the study. Based on the audiology survey responses, the vast majority of children (>90%) were fit using age-appropriate fitting and verification methods. Data on fitting and verification techniques, as well as quality of the HA fit for the participants, may be found in McCreery et al. (2011).

HA use questionnaire. At each visit, an examiner conducted an interview with the parent regarding pediatric HA use. Parents estimated the average amount of time their child used HAs per day during the week and on weekends. Parents also indicated consistency of use across contexts using a 5-point Likert scale that was adapted from a previous study on HA use in infants (Moeller et al., 2009). The examiner asked the parent to rate how often the child wore his or her HAs in eight different listening environments: in the car, at school, at daycare, during mealtimes, while playing alone, during book sharing, on the playground, and in public (e.g., at the zoo, in a store). The scale included the following ratings: 0 = *never*, 1 = *rare*, 2 = *sometimes*, 3 = *often*, 4 = *always*, and *not applicable*. The questionnaire also included an open-ended question, which asked the parent to identify any situations in which it was challenging to get the child to wear HAs. The HA use questionnaire is provided in Appendix B.

Statistical Analyses

To investigate the relationships among the independent predictor variables and the dependent response variables, we used linear regression models. The independent predictor variables were chronological age, gender, site (i.e., University of Iowa, Boys Town National Research Hospital, and University of North Carolina at Chapel Hill), maternal education level, and better-ear PTA. The dependent response variables were parent-report estimates of average HA use time during the week and on weekends. Due to the large number of maternal education categories collected, arbitrary ordinal levels were introduced in the data analysis. Details about the number of participants comprising each of the ordinal levels for maternal education are presented in Table 1. Dummy variables represented categorical variables in the statistical model. The selection of the best set of predictor variables was based on Pearson's product–moment correlation and Akaike's (1974) information criterion. Residual analyses were examined, and linear regression assumptions were appropriately satisfied. A quadratic effect for age was statistically significant and was included in the final model to account for the curvilinear relationship between chronological age and hours of use.

Data regarding HA use consistency across contexts and challenges to HA use were explored descriptively. In this section, participants were divided into three age groups: infants (0–2 years), preschool (3–4 years), and school age (5–6 years). The rationale for this division was motivated in large part by Moeller et al. (2009), who demonstrated that issues with infants/toddlers are somewhat unique. Thus, we felt that it was important to contrast children ≤2 years of age with older children. There are also reasons to suspect that school-age HA issues may differ from preschool, as children become more independent with their HAs (in contrast to

Table 1. Arbitrary levels for maternal education (N = 259).

Maternal education level	N
High school or less	39
Vocational school/some college	88
College	68
Graduate school	64

Note. Thirteen mothers did not report education level.

preschoolers, who may be dependent on a child care worker's HA knowledge). In further analyses, participants were divided into two groups based on better-ear PTA: (a) PTA <50 dB HL, and (b) PTA >50 dB HL. We separated the participants into two PTA groups as a further attempt to reduce the data to gain insight into factors that influenced HA use. The selection of 50 dB HL was the mean PTA of the group; it indicated an effort to compare children with mild-moderate degrees of HL to children with moderate-severe degrees of HL.

RESULTS

Descriptive Statistics and Multivariate Regression

Table 2 presents descriptive statistics summarizing the nominal independent and dependent variables. On average, parents reported that their child wore HAs ~10.5 hr per day during the week and ~10 hr per day on the weekend. A paired-samples *t* test indicated that HA use time was statistically significantly higher during the week than on the weekend, $t(269) = 4.45$, $p < .0001$.

The regression analysis indicated that chronological age ($p < .0001$), better-ear PTA ($p = .0002$), maternal education level ($p = .0066$), and site ($p = .0181$) had statistically significant effects on HA use time during the week. Longer HA use time was associated with older age, poorer hearing, and higher maternal education level. Table 3 presents the individual parameter estimates (β) and related statistics for each predictor variable. For example, the parameter estimates indicated that for every 10-dB increase in better-ear PTA, the predicted average HA use time increased by 0.50 hr, with all other predictor variables held constant, and for every 10-month increase in age, the predicted average HA use time increased by 0.71 hr, with all other predictor variables held constant. Note that the two chronological age variables must be considered simultaneously when interpreting the data. The quadratic effect of chronological age ($p < .0001$) had a small negative coefficient (–0.002), which indicates that although longer HA use time was associated with older age, the increase in hours of use was smaller at older ages than it was at younger ages. For example, the slope at 10 months of age was 0.2002-0.0015 × 10 = 0.18, and the estimated slope at 70 months of age was only half that amount at 0.09.

The results suggested that the children who were recruited from the Iowa site ($M = 9.83$, $SD = 3.50$) had significantly less HA use time than those recruited from the North Carolina site ($p = .04$). The mean difference of HA use time was ~1 hr. There were no significant differences between the North Carolina site ($M = 11.14$, $SD = 3.04$) and Boys Town ($M = 10.35$, $SD = 3.12$) or between Boys Town and Iowa. In addition, the results indicated that mothers who had obtained a college degree had children with the most HA use time compared to mothers with other educational backgrounds. Table 4 displays the mean and standard error of daily HA use time during the week for each level of maternal education. The largest mean difference (1.9 hr) was observed between children with mothers who had obtained a college degree and those with mothers who had obtained a high school degree or less. The remaining mean differences were <1 hr. There

Table 2. Summary of descriptive statistics for the linear regression analysis for Study 1.

Variable	*Mean*	SD	*Median*	*Min*	*Max*	N
Chronological age (months)	40.51	21.28	39.50	5.00	87.00	272
Better-ear PTA (dB HL)	49.58	13.72	50.00	16.25[a]	82.50[b]	267
Average daily HA use: week (hr)	10.48	3.23	11.25	0.00[c]	17.00	272
Average daily HA use: weekend (hr)	9.96	3.63	11.00	0.00[c]	17.00	270

Note. PTA = pure-tone average, HA = hearing aid.

[a,b]Thirteen children's PTAs fell outside the criterion range (25–75 dB HL). Due to unique audiological or medical circumstances (e.g., hearing loss in low or high frequencies only, fluctuation due to otitis media with effusion or enlarged vestibular aqueduct syndrome), the research team made some exceptions at both ends of the range.
[c]Two parents reported that their child never wore HAs during the week, and seven parents reported that their child never wore HAs on the weekend. Explanations for nonuse included not seeing benefit from the HAs and child's refusal to wear amplification.

Table 3. Summary of parameter estimates for the linear regression analysis for variables predicting parent report of daily HA use.

Parameter	*Estimate* (*β*)	*SE*	t	p *value*
Intercept	3.42	0.98	3.49	0.001
Chronological age	0.20	0.03	6.09	<0.001
Chronological age squared	–0.002	0.0004	–4.04	<0.001
Better-ear PTA	0.05	0.01	3.84	0.0002
Maternal education: High school or less	–0.90	0.55	–1.64	0.103
Maternal education: Vocational school/some college	0.20	0.44	0.45	0.651
Maternal education: College	0.94	0.46	2.02	0.044
Site: Iowa	–1.07	0.40	–2.64	0.009
Site: Boys Town	–0.14	0.40	–0.35	0.730
Gender: Female	0.26	0.34	0.77	0.443

Note. Site: University of North Carolina, Gender: Male, and Maternal education: Graduate school are not listed in the table. Those levels were used as the baseline reference level in the regression analysis.

Table 4. Daily HA use time in hours (based on parent report) during the week by chronological age, better-ear PTA, maternal education level, and testing site.

Variable	M	SE
Chronological age (N = 251)		
Infants (0–2;11)	8.24	0.37
Preschool (3;0–4;11)	10.91	0.30
School-age (5;0–6;11)	11.68	0.32
Better-ear PTA (N = 272)		
<50 dB HL	9.95	0.28
>50 dB HL	11.12	0.26
Maternal education level (N = 259)		
High school or less	8.92	0.62
Vocational school/some college	10.66	0.32
College	11.28	0.29
Graduate school	10.68	0.42
Testing site (N = 272)		
Iowa	9.83	0.39
Boys Town	10.35	0.32
University of N. Carolina	11.14	0.31

was no significant difference for HA use between female and male children.

To assess whether maternal education level confounded either age or degree of HL, we analyzed a regression model removing maternal education. Confounding is typically considered to be present if the parameter estimates change by >10%. When maternal education was removed from the model, the parameter estimates for age and degree of HL each changed by <5%, thus indicating that there was no confounding relationship between maternal education and chronological age or degree of HL.

The regression analysis for HA use time during the weekend was similar to that for HA use time during the week, with the exception of a lack of significant differences in HA use time between sites. Maternal education level ($p = .0127$), better-ear PTA ($p < .0001$), and chronological age ($p < .0001$) had significant effects on HA use time on weekends. There was no significant difference between female and male children.

Consistency of Use: Unsupervised Versus Supervised Contexts

For data reduction purposes, ratings were combined into categories of *always*, *often/sometimes*, and *rarely/never*. A report of always was considered to be full-time use in that context.

Unsupervised context: Car. As seen in Figure 1, only 35% (37/105) of the parents of infants responded that their child always used amplification in the car, compared to 78% of parents of preschool (74/95) and of school-age (56/72) children. Table 5 displays use consistency in the car for the infant group in 6-month intervals. Consistent use in the car was the most limited at 12 months of age, with 54% (15/28) of parents indicating that HAs were rarely/never worn in the car and only 14% (4/28) reporting that their child always wore their HAs in that setting. However, there were improvements after 12 months of age, with 63% (22/35) of parents of 24-month-olds reporting that HAs were always worn in the car.

Supervised by caregiver: Public. As shown in Figure 1, most parents of preschool and school-age children reported that their child always used HAs in public settings (81%; 76/94, and 76%; 55/72, respectively); infants showed less consistency (67% *always* responses; 70/105). Only 50% (14/28) of parents of 12-month-old children reported consistent use in public, but consistency ratings improved to 83% (29/35) for 24-month-olds (see Table 5).

Supervised-by-other context: Daycare. There were similar patterns in the consistency of HA use in daycare settings (Figure 1). Infants (58% *always* responses; 29/50) were less consistent than preschoolers (38/48 = 79%) and

Figure 1. Ratings for consistency of hearing aid (HA) use in the car, in public, and at daycare in relation to age.

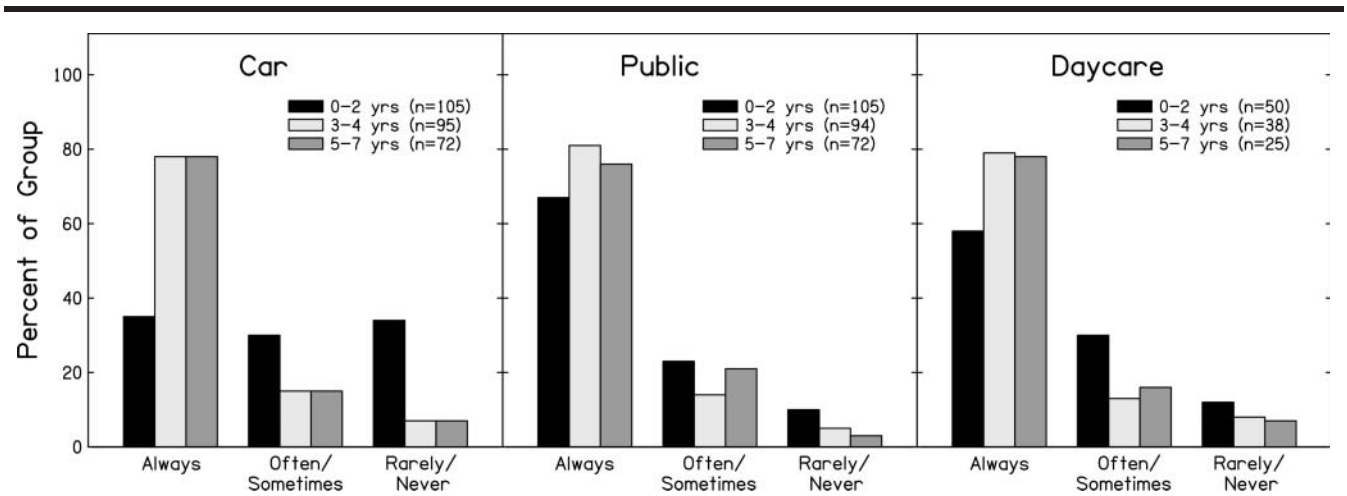


Table 5. Percentage of responses indicating full-time HA use in different contexts for infant age groups.

	Car		*Public*		*Daycare*	
Age	*%*	n	*%*	n	*%*	n
6 months	31	16	63	16	50	8
12 months	14	28	50	28	40	10
18 months	23	26	65	26	58	12
24 months	63	35	83	35	70	20

school-age children (22/29 = 76%). Within the infant group (Table 5), only 50% (4/8) of 6-month-olds and 40% (4/10) of 12-month-olds consistently wore their HAs at daycare, but consistency improved at later ages (58% of 18-month-olds [7/12] and 70% of 24-month-olds [14/20]).

Context by PTA: Public. Figure 2 shows the differences in consistent HA use between children with a better-ear PTA of <50 dB HL and children with a better-ear PTA of ≥50 dB HL. There was on average more consistent HA use in public for children who had a better-ear PTA of ≥50 dB HL. The largest difference in consistent HA use between the two groups was present at 5 years of age (better-ear PTA <0 dB HL: 64%; 14/22; better-ear PTA of ≥50 dB HL: 89%; 16/18).

Context by PTA: School. Consistent use at school varied as a function of better-ear PTA at selected ages. As seen in Figure 2, there was a large difference between 3-year-olds with milder hearing losses (<50 dB HL) and those with greater hearing losses (≥50 dB HL) (58%; 7/12, and 94%; 17/18, respectively). Compared to the 3-year-olds, 4- and 5-year-olds showed less of a difference between PTA groups and were reported to use HAs more consistently at school.

Open-Ended Responses: Specific Challenges to HA Use

Parents were asked during the interview to describe situations or environments that presented challenges to consistent HA use. Responses were classified into four categories: (a) child state (e.g., mood, illness, fatigue, temperament), (b) breaks in routine (e.g., different care provider, at home on weekends, after bath time), (c) loud events (e.g., movie theater, church), and (d) equipment issues (e.g., feedback from HA, discomfort from ear mold).

Parents of the infant group reported challenges to consistent HA use more often than parents of preschool and school-age children, especially in situations related to child state. Figure 3 illustrates that 39% (41/105) of parents of the infant group, 28% (27/95) of parents of preschoolers, and 11% (8/72) of parents of school-age children reported that child state was an obstacle to consistent HA use. Other, less prevalent challenges to HA use across all of the age groups consisted of breaks in routine, loud events, and equipment issues. Within the infant group, child state was more often reported as a challenge for children ages 12 and 18 months (14/28 = 50% and 14/26 = 54%, respectively), compared to 6-month-olds (3/16 = 19%) and 24-month-olds (10/35 = 29%).

STUDY 2

METHOD

Purpose

Study 2 sought to examine the accuracy of parental estimates of average HA use time for children during the week. The accuracy was determined by comparing the parent-report

Figure 2. Consistent HA use in public and at school in relation to better-ear pure-tone average.

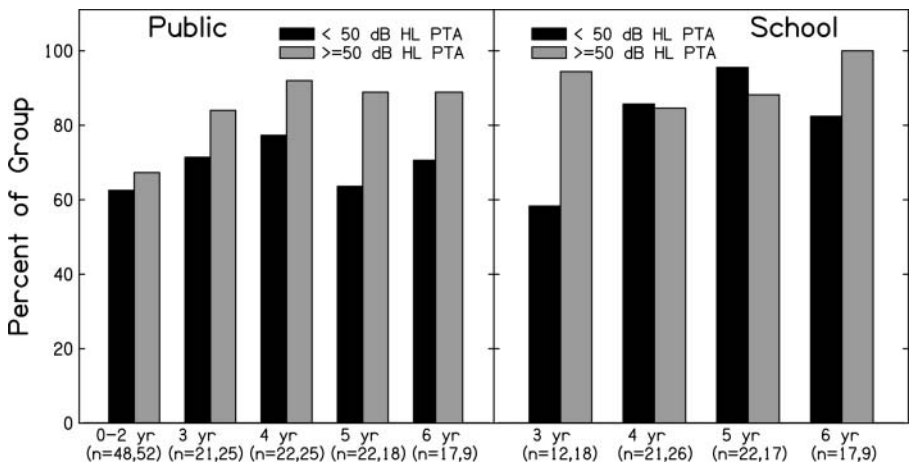
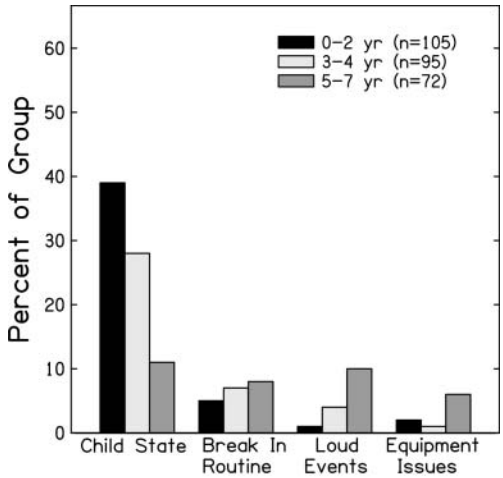


Figure 3. Reports about challenges to consistent HA use in relation to age.



data from the HA use questionnaire to objective datalogging measures that were acquired from the children's HAs. A secondary goal was to investigate variables that may predict parents' accuracy when estimating HA use time in children.

Participants and procedure. A subset of parents and children from Study 1 participated (n = 133) in this study. Audiologists began collecting datalogging information after data collection had commenced for some participants in the OCHL study. Once the OCHL audiologists began collecting datalogging, it was collected at each annual visit. However, for the present analysis, only the first datalogging measure was included. For 25 participants, datalogging was collected at the initial baseline visit; for 58 children, at the second visit; for 45 children, at the third visit; and for five children, at the fourth visit. The HA use questionnaire was administered to parents at the same visit. Families were unaware that the audiologist was using the datalogging feature during the course of the study. Because data for Study 2 were collected after the initial visit for most participants, the average age of the children was older than in Study 1 (M = 50.57, SD = 25.42). All 133 children had wide dynamic range compression HAs. Two participants received CIs before the audiologist obtained datalogging information, but continued to wear an HA on the contralateral ear. In both cases, parent estimates of average use time only referred to the HA and not the CI.

HA datalogging. Audiologists collected values for average use time per day by connecting the HAs to a HiPro box and using the appropriate HA software. If the values were different between ears, the larger value was included in the data analyses.

Statistical Analyses

To investigate the relationship between the subjective and objective estimates of daily HA use time, we conducted a Pearson's product–moment correlation. In addition, we used linear regression models to investigate the relationships among the independent predictor variables (gender, site, maternal education level, and better-ear PTA) and the dependent response variables (the time difference between parents' reports of HA use time and datalogging). As in Study 1, arbitrary levels were introduced to the data analysis due to the large number of levels within the categorical variable of maternal education. The selection of the best set of predictor variables was based on Pearson's correlation and Akaike's (1974) information criterion.

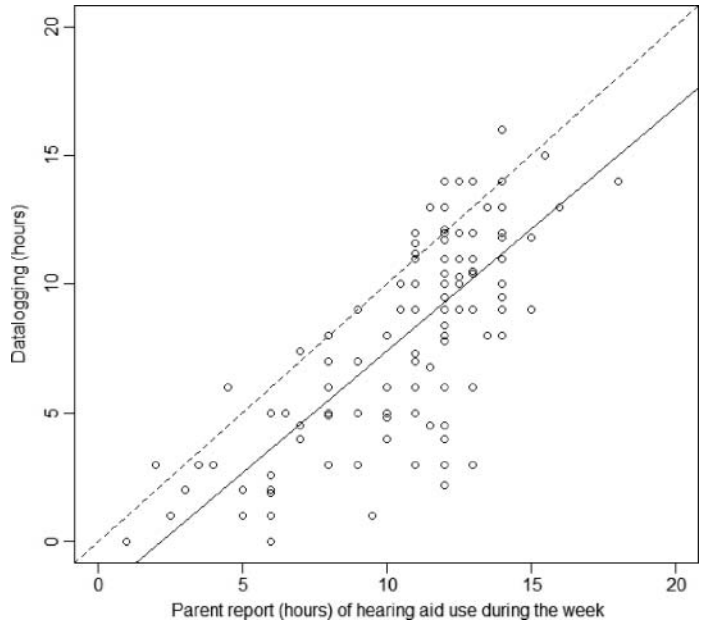
RESULTS

There was a statistically significant correlation (r = 0.76, p < .0001) between parent report and datalogging for HA use time during the week. Furthermore, HA use time reported by parents was significantly related to the time obtained from datalogging, $F(1, 131) = 177.31$, $p < .0001$. Parent report of HA use time explained a statistically significant proportion of the variance in datalogging (R^2 = 0.58). Every 1-hr increase in parent report of HA use time typically resulted in a 0.95-hr increase of HA use time from datalogging, indicating that parents typically overestimated the amount of time their children were wearing their HAs. For parents who reported daily HA use of 5 hr, the model average datalogging value was 2.69 hr, with the 95% confidence interval between 1.74 and 3.60 hr. As the parent report of daily HA use increased, the bias away from being equal to the datalogging also increased. For parents who reported 10 hr of HA use, the model average datalogging value was 7.40 hr, with the 95% confidence interval between 6.95 and 7.85. At 15 hr, the model average datalogging value was 12.12 hr, with the 95% confidence interval between 11.40 to 12.85 hr. Figure 4 displays the relationship between HA use time from parent report and datalogging.

Data indicated that 84% (112/133) of parents overestimated their child's HA use time, and 16% (21/133) either underestimated or were accurate in their estimations. On average, parents reported that their children wore their HAs for 10.84 hr per day (SD = 3.09), and datalogging values indicated that HAs were worn for 8.3 hr per day (SD = 3.87). This resulted in an average overestimation of 2.6 hr (SD = 2.52), but these differences ranged from an underestimation of 2 hr to an overestimation of 10 hr.

We also conducted linear regression models to investigate if child- or family-specific variables could predict the amount of time difference between parents' reports of HA use time and HA datalogging (dependent variable). Independent predictor variables included chronological age, gender, site, maternal education level, and better-ear PTA. Table 6 provides a summary of descriptive statistics of the independent and dependent variables. Only chronological age was found to have a significant negative effect on the

Figure 4. HA use time by parent report and datalogging. The solid line represents the regression line; dotted lines represent the 95% confidence intervals.



time difference between parents' reports and datalogging (p = .0008). The parameter estimate indicated that for a 1-year increase in chronological age, there was an estimated 0.03-hr smaller difference between parent report of HA use and datalogging. In other words, the older the child was, the smaller the expected difference would be between parents' subjective estimates of HA use and the objective datalogging measures. Table 7 displays the estimate for each parameter along with related statistics and p values.

DISCUSSION

In Study 1, we examined HA use time and the factors that predict average HA use time in children who are hard of hearing. A linear regression analysis indicated that three factors—chronological age, better-ear PTA, and maternal education level—influenced HA use time during the week and on weekends. A fourth factor, testing site, played a role in the amount of time children used their HAs during the week, but not on the weekends. On average, children at the North Carolina site wore their HAs for 1 hr longer than children at the Iowa site. It is unclear why there is a difference between the two sites; further examination of the data revealed no significant differences between the Iowa and North Carolina participants in terms of chronological age, better-ear PTA, age at fitting of HAs, maternal education level, or number of hours of services (for speech-language pathologists, teachers of the deaf/hard of hearing, or early interventionists).

Results showed that maternal education level influenced the amount of time children wore their HAs. In fact, there

Table 6. Summary of descriptive statistics for the linear regression model for Study 2.

Variable	*Mean*	SD	*Median*	*Min*	*Max*	N
Chronological age (months)	50.31	25.34	48.00	8.00	100.00	133
Better-ear PTA (dB HL)	52.17	14.85	51.00	15.00	105.00	130[a]
Parent report of HA use during week (hr)	10.84	3.09	12.00	1.00	18.00	133
Datalogging (hrs)	8.20	3.87	9.00	0.00	16.00	133
Difference between parent report and datalogging	2.65	2.53	2.00	–2.00	10.00	133

[a]Audiograms were not available for three participants.

Table 7. Summary of parameter estimates for the linear regression analysis for variables predicting the difference between datalogging and parent report of HA use.

Parameter	*Estimate* (β)	*SE*	t	p *value*
Intercept	3.52	1.08	3.24	<.01
Center: Iowa	0.37	0.47	0.77	0.44
Center: Boys Town	–0.03	0.74	0.03	0.97
Gender: Female	0.28	0.48	0.58	0.56
Mother's education: High school or less	0.73	0.82	0.89	0.38
Mother's education: Vocational school/some college	1.58	0.61	2.57	0.01
Mother's education: College	0.63	0.56	1.12	0.26
Better-ear PTA	–0.01	0.02	0.80	0.43
Chronological age	–0.03	0.01	3.47	<.01

was almost a 2-hr difference in reported HA use time between mothers with a college education and mothers with a high school education or less. It does not appear that this difference was the result of overestimation of HA use by mothers with more education or, conversely, underestimation by mothers with less education. The regression analysis in Study 2 indicated that maternal education level did not play a significant role in the difference between datalogging and parent-report estimates. The present findings are consistent with a recent study (Holte et al., in press) looking at the same cohort of OCHL participants, in which maternal education level was the only predictor variable that was significantly related to age at the first diagnostic audiology evaluation, confirmation of HL, and fitting of HAs (better-ear PTA, research team site, and gender were not significantly related to any of the dependent variables). Together, the findings from these studies highlight the need for continued counseling regarding the benefits of consistent HA use in children who are hard of hearing, especially those with milder degrees of HL and for families with lower levels of education. In addition, further study is needed to determine how counseling can be presented most effectively. Moeller et al. (2009) advocated for using experiential learning methods stating that simulations of aided and unaided HL and illustrations of developmental outcomes may be more informative than written resources. They stressed the importance of establishing clearer links for parents between consistency of HA use and development of speech and language skills. Elfenbein (1994) recommended that audiologists provide a combination of verbal and written material about the consequences of nonuse of amplification. At this point, no researchers have investigated the efficacy of counseling parents with regard to this topic.

The findings from the regression analysis demonstrated that older children tend to wear their HAs more frequently than younger children. The use of a rating scale for different listening environments highlighted the contexts that were problematic for maintaining consistent HA use, particularly for parents of young children, thereby supporting the findings of Moeller et al. (2009). Not surprisingly, many parents reported that HA use was rare in unsupervised contexts during the toddler years (12 months to 24 months). However, close examination of the data with infants demonstrates that the number of parents reporting challenges due to child state issues increased from 6 months to 18 months of age, but dropped again by 24 months. In addition, by the preschool years, a very high percentage of parents (78%) indicated that their 3- and 4-year-olds always wore their HAs in the car.

These results are important to convey to parents who are frustrated with trying to keep HAs on their young children. It may be valuable for parents to recognize that the challenges to maintaining consistent HA use are not unique to their child and will fluctuate with age, child-state issues, and different listening environments, but these difficulties are temporary in most cases. However, it is also critical for audiologists to be sensitive to the unique challenges associated with young children and offer support related to specific issues that are complicating HA use (Moeller, 2010). If parents realize that the challenges they are encountering are typical among caregivers and are not permanent, and if they can discuss alternative strategies and solutions that are tailored to the specific needs of their family, this information may provide the encouragement families need to persevere with trying to achieve full-time HA use.

It may also benefit families to receive specific training related to daily care and maintenance of HAs. Elfenbein (1994) reported on a group of 15 families who were participating in an educational program for parents of preschoolers with HL. More than 90% of the parents reported that they had received counseling about HA monitoring and troubleshooting, but only ~½ reported performing daily listening checks. Furthermore, ⅔ of the parents did not own moisture reduction kits, and ⅓ did not own basic equipment for monitoring HAs. The present study did not explore parental practices regarding equipment monitoring, but those data are currently being collected as part of the OCHL project. Future reports may address parents' knowledge on daily HA care and maintenance. It is hoped that this information will provide us with more evidence on how to effectively provide parents with specific information about troubleshooting

HAs. Perhaps if parents recognize the importance of good audibility for children's speech and language development, they will have a more vested interest in maintaining HA function and achieving consistent device use.

The severity of a child's HL also influences the amount of time children wear their devices, with parents of children with more severe losses reporting more daily hours of HA use time than children with milder losses. However, parents' responses on the rating scale indicated that there is a complex relationship between better-ear PTA, the age of the child, and the listening context. For example, at age 3, the largest difference between HA use in the two groups (mild-moderate, moderate-severe) occurred at school. Almost all parents of children with moderate-to-severe HLs reported that their children wore their HAs all the time at preschool. In contrast, a little more than half of the parents of children with mild-to-moderate HLs reported that their children wore HAs all the time at preschool. This may reflect a need for further education directed toward preschool teachers regarding the risks of minimal and mild HL (Daud, Noor, Rahman, Sidek, & Mohamed, 2010; Hicks & Tharpe, 2002; McFadden & Pittman, 2008).

By age 5, there does not appear to be much difference in HA use time at school between children with milder versus more severe HLs, but there is a large difference at that age in public situations, such as at the grocery store, the zoo, and so on. According to parents, 5-year-olds with more severe HL wore their HAs more in public situations compared to 5-year-olds with milder losses. It is possible that children with milder losses wear their HAs less often in public situations because they can follow some conversation without their HAs. In this situation, parents may be more amenable to letting their child not wear amplification. Previous studies have shown that school-age children with hearing impairment experience more difficulties with social isolation compared to peers with normal hearing (Davis, Elfenbein, Schum, & Bentler, 1986) and are more likely to be rejected by their peers (Cappelli, Daniels, Durieux-Smith, McGrath, & Neuss, 1995). It is unclear from this literature if these difficulties with socialization result in reduced HA use in public, particularly for children with mild HL who can function somewhat adequately without their HAs. Future studies should track consistency of use across listening situations to determine if this pattern exists as children enter elementary school and social pressure to "fit in" increases. These studies should include consistency ratings across different settings because this provides different information than parents' reports of overall use time. Both pieces of information are useful to service providers when guiding families through the HA process.

In Study 2, we explored the accuracy of parents' estimates of the average number of hours their child wore HAs during the week. Results indicated that parents are fairly accurate reporters of average HA use when accuracy is examined from a relative viewpoint and not absolute terms. Parents usually overestimated the amount of time their children wore HAs by ~2.5 hr; however, the significant correlation ($r = .76$) between parent report and objective datalogging measures indicates that most parents were overestimating by approximately the same degree. It is interesting to note how consistent the correlation in the current study is compared to other studies that have looked at this issue with adults reporting on their own HA use time. Humes et al. (1994) found the same correlation ($r = .76$) with 20 adults. The adults in that study overestimated the amount of time they wore their HAs by an average of 4 hr. Taubman et al. (1999) looked at the reliability of 24 adults in reporting HA use time with a correlation of .72, which is also consistent with the present findings.

Together, the results from Study 2 suggest that service providers should recognize that the majority of parents may overestimate HA use by a few hours. This appears to be especially true for parents of younger children, as chronological age was the only variable that predicted how accurate parents were in their estimates of use time. It seems reasonable to expect that it would be harder for parents to approximate the number of hours an 18-month-old would be wearing HAs compared to a 5-year-old. There are many more situations in which HAs would be removed (by the parent or the child) in the case of younger children, such as naps, riding in the car, or during temper tantrums, making it difficult to provide an accurate estimate of average wearing time. Therefore, use of objective measures like datalogging to monitor use of HAs is preferred with parents of younger children.

The findings from Study 2 also have implications for future studies, as we consider using datalogging or parent-report estimates as independent variables in multiple regression analyses of speech and language outcomes. It is assumed that children who use their HAs on a consistent basis will have better speech and language outcomes than children who are not full-time users, but daily use time has not been fully investigated as a predictor variable in outcomes of children who are hard of hearing. Given the results of the present study, it is likely that consistency of HA use contributes to outcomes by interacting with other variables such as degree of HL, quality of HA fitting, and maternal education level. Our future studies will employ multiple regression analyses to explore which of these variables are predictive of outcomes in the hard-of-hearing population, as well as the ways in which these variables may interact to influence outcomes.

Limitations and Future Directions

There are several important limitations that should be considered when interpreting the results of this study. In an attempt to control for various confounds, we excluded children with multiple disabilities; children who did not use English as a primary language; and children with profound deafness, unilateral HL, or CIs. These exclusionary criteria

limited our ability to generalize our results beyond this current subset of children who are hard of hearing. Future research may address the amount of daily HA use in a wider population of children. An additional limitation is that we did not include the measures of the quality of the HA fitting in our regression analyses. Although data were collected on HA fitting quality, this dimension of the work was judged to be beyond the scope of the current study and was reported elsewhere (McCreery et al., 2011). Future research will explore the influence of quality of fitting on consistency of use.

The primary goal of the OCHL project is to investigate outcomes of children who are hard of hearing. It is not an intervention study; therefore, another limitation is that we did not control for variables such as the quality of the HA fitting, counseling of parents with regard to HA use or troubleshooting, and quantity and quality of aural habilitation and intervention. The current findings serve as preliminary data on how much time young children are wearing HAs—a topic that has been neglected in the pediatric aural habilitation literature. These data indicate that although many parents consider their children to be full-time HA users, there are still a significant number of children who do not wear their HAs on a consistent basis. Consistency of HA use and its potential influence on children's outcomes deserves continued attention in future research.

There were six children who received CIs following enrollment in the OCHL study. These children continue to be followed on an annual basis, consistent with participants who still use HAs, but data are not collected on the amount of time they wear their CIs. Furthermore, CIs do not have datalogging capacities like HAs. An important future direction would be to apply these same research questions to children with CIs and investigate differences in use time among children with unilateral, bilateral, and bimodal configurations. It would also be useful for audiologists to have access to datalogging information for CIs as well as HAs.

Conclusion

Our findings provide evidence that several child- and family-specific variables, including chronological age, severity of HL, and maternal education level, were significantly related to the amount of time children wore their HAs based on parents' estimations of daily use time. Parental ratings regarding consistency of HA use across different listening environments supported the regression analysis, as younger children and children with milder HLs wore their HAs less consistently than older children and children with moderate-to-severe HL in a variety of contexts. Parents also reported on challenges to maintaining consistent HA use, with child state issues (e.g., temper tantrums, illness, fatigue) being the most commonly reported concern. Finally, our findings suggest that although most parents overestimated the amount of time their child wore his or her HAs, the positive correlation between parents' subjective estimates and objective measures using datalogging was high. The relative difference between parents' estimations appears to be consistent, but these estimates are mediated by the age of the child. Therefore, clinicians should rely on datalogging and consistency ratings to monitor HA use whenever possible. When it is not possible to obtain datalogging measures, clinicians should be aware that parents will usually overestimate average use time, particularly in the case of younger children.

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APPENDIX A (P. 1 OF 2). OCHL TEST BATTERY

Domains assessed	*Measurement instruments*	*Age at test (months)*
Presymbolic communication	Communication and Symbolic Behavior Scales: Temptations	18
	Communication and Symbolic Behavior Scales Caregiver Questionnaire	18
Vocal development landmarks	Vocal Development Landmarks (created for study)	6, 12, 18
Language measures		
	Spontaneous Language Sample	36, 72, 96
Vocabulary (receptive & expressive)	MacArthur Bates Communicative Development Inventory (MBCDI) Words & Gestures (8 to 18 mos)	12, 18
	MBCDI Words & Sentences (19 to 30 mos)	24
	MBCDI Upper Extension (31 mos and up)	36
	Peabody Picture Vocabulary Test-4	60, 84, 108
	Weschler Abbreviated Scale of Intelligence (WASI) vocabulary	72, 84, 96, 108
Verbal reasoning	Preschool Language Assessment Instrument-2	60
Global rec-exp measure	Mullen Scales of Early Learning	12, 24
	Comprehensive Assessment of Spoken Language 3-4 Core	36, 48
	Comprehensive Assessment of Spoken Language 5-6 Core	72
	Comprehensive Assess. of Spoken Language 7-10 Core	96
Narrative	Candy Stealing Story	84, 108
Elicitation of mental state stories	Explanation of Action Movies	84, 108
	Theory of Mind measures (Standard False Belief Tasks)	60, 72
Morphology	Clinical Evaluation of Language Fundamentals-4 Word Structure	60, 84
	Morphological Elicitation Procedure (created for study)	36, 48
Speech production measures		
Speech production	Goldman-Fristoe Test of Articulation	36, 60, 84, 108
	Open & Closed Set Test (D. Ertmer)	24
	Conditioned Assessment of Speech Perception and Production (Ertmer & Stoel-Gammon, 2003)	24
Speech Intelligibility	Beginner's Intelligibility Test	60, 84
Academic measures		
Phonological processing & memory	Comprehensive Test of Phonological Processing (CTOPP)	60, 84, 108
Phonological awareness & print knowledge	Test of Preschool Early Literacy (TOPEL)	48
Print knowledge	TOPEL	60
Word attack	Woodcock Reading Mastery Test-R (WRMT-R) Word Attack	72, 96
Word recognition	WRMT-R Word Identification	72, 96
Reading comprehension	WRMT-R Reading Comprehension	72, 96
Spelling	Weschler Individual Achievement Test (WIAT)-II-A	84, 108
Math reasoning	WIAT-II-A	84, 108
Hearing function, audibility and speech perception		
Audiologic evaluation	History, Audiogram (VRA) + Tymps	Every visit
	History, Audiogram (CPA) + Tymps	Every visit
	History, Audiogram (Conventional) + Tymps	Every visit
	Electroacoustic Analysis 60/90 Curves	Every visit
Hearing aid function	Aided Speech Intelligibility Index (Verifit SII)	Every visit
Audibility	Hearing Aid Checklist	Every visit
Hearing aid use	Little Ears Questionnaire	12, 18, 24
Speech perception	Parent's Evaluation of Aural/Oral Performance of Children (PEACH)	18, 24 (depending on Little Ears score)
	Early Speech Perception (ESP) lo-verbal	24
	ESP	24, 36
	Phonetically Balanced Kindergarten (PBK)	60, 72
	Computer-Assisted Speech Perception Assessment (CASPA)	84, 96, 108
	Multisyllable Lexical Neighborhood Test (MLNT) & Lexical Neighborhood Test (LNT)	48
	Speech Spatial Qualities (SSQ) - revised	48, 72, 96

APPENDIX A (P. 2 OF 2). OCHL TEST BATTERY

Domains assessed	*Measurement instruments*	*Age at test (months)*
Psychosocial, behavioral and family measures		
Cognitive skills	Weschler Preschool & Primary Scale of Intelligence (WPPSI)	48
	Weschler Abbreviated Scale of Intelligence (WASI)	72, 96
	Head to Toes Task	72
	Vineland Adaptive Behavior Scales	12, 24, 36, 48
	Friendship Interview	72, 96
Social skills	Child Behavior Checklists (CBCL)	24, 48, 72, 96
Behavior	Teacher Report Forms (TRF)	48, 72, 96, 108
	Adult Perceptions II	60
Parenting and discipline	Family Activities Checklist & Parent Issues Checklist	48, 72, 96
Family activities	Infant Behavior Questionnaire	12
Child temperament	Early Childhood Behavior Questionnaire	36
	Children's Behavior Questionnaire - short version	48, 72
	Social Competence & Behavior Evaluation Scale	60, 84, 108
School Behaviors (teacher report)	Teacher Predictions of Peer Nominations	84, 108
	Direct and Indirect Aggression Scale - Teacher	84, 108
	Direct and Indirect Aggression Scale - Parent	84, 108
	Screening Identification For Targeting Educational Risk (SIFTER – preschool & school age)	36, 48, 60, 72, 84, 96
Family background and intervention measures		
Intervention program measures	OCHL Service Provider Survey (SPS)- Audiology	Every visit
	OCHL SPS 0 to 3 years	Each visit 6–35 m
	OCHL SPS Preschool	Each visit 35–59 m
	OCHL SPS School-Age	Each visit 60 m +
Family background & satisfaction	OCHL Family Interview	6 months after every visit
Family quality of life	Beach Center Family Survey	24, 48, 72, 96

APPENDIX B. HEARING AID USE QUESTIONNAIRE

Subject #: _____ D.O.B._____ Date Completed: _____

1. Hearing Aid Make: _____ 2. Model: _____ 3. Type: _____

4. Fitting: monaural _____ binaural _____ 5. FM use: home _____ school _____

6. During the first year after your child was fit with hearing aids, how many hours a day did she/he wear them?
   _____ Hours _____Child was fit less than 1 year ago

7. Current use time:

8. How many **hours a day** does your child currently wear the aid(s)?
   Monday-Friday _____
   Saturday-Sunday _____
   Data Logging: Right_____ Left _____

9. When your child wakes from sleep (morning or nap), how much time does she/he require before the hearing aid goes on? _____

Put an X in the boxes below to indicate how consistently your child uses HAs in the situations listed:

Situation	Never (0)	Rare (1)	Sometimes (2)	Often (3)	Always (4)	N/A
10. Car						
11. PreSchool/School						
12. Day Care						
13. Meal Time						
14. Playing Alone						
15. Book Sharing						
16. Playground						
17. Public (store, zoo, restaurant)						

18. Are there any particularly challenging times or situations for you or the child for keeping the hearing aid(s) on?
   _____