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TITLE: Hearing Technology Use and Management in School-Age Children: Reports from Data Logs, Parents, and Teachers

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Abstract

Background: Consistency of hearing aid and remote microphone system use declines as school-age children with hearing loss mature. One indicator of hearing aid use time is data logging, another is parent report. Recent data suggest that parents overestimate their children's hearing aid use time relative to data logging. The potential reasons for this disparity remain unclear. Because school-age children spend the majority of their day away from their parents and with their teachers, reports from teachers might serve as a valuable and additional tool for estimating hearing aid use time and management.

Purpose: This study expands previous research on factors influencing hearing aid use time in school-age children using data logging records. Discrepancies between data logging records and parent reports were explored using custom surveys designed for parents and teachers. Responses from parents and teachers were used to examine hearing aid use, remote microphone system use, and hearing aid management in school-age children.

Study Sample: Thirteen children with mild-to-moderate hearing loss between the ages of seven and ten years and their parents participated in this study. Teachers of ten of these children also participated.

Data Collection and Analysis: Parents and teachers of children completed written surveys about each child's hearing aid use, remote microphone system use, and hearing aid management skills. Data logs were read from hearing aids using manufacturer's software. Multiple linear regression analysis and an intraclass correlation coefficient were used to examine factors influencing hearing aid use time and parent agreement with data logs. Parent report of hearing aid use time was compared across various activities and school and non-school days. Survey responses from

parents and teachers were compared to explore areas requiring potential improvement in audiologic counseling.

Results: Average daily hearing aid use time was approximately six hours per day as recorded with data logging technology. Children exhibiting greater degrees of hearing loss and those with poorer vocabulary were more likely to use hearing aids consistently than children with less hearing loss and better vocabulary. Parents overestimated hearing aid use by about one hour per day relative to data logging records. Parent-reported use of hearing aids varied across activities but not across school and non-school days. Overall, parents and teachers showed excellent agreement on hearing aid and remote microphone system use during school instruction but poor agreement when asked about the child's ability to manage their hearing devices independently.

Conclusions: Parental reports of hearing aid use in young school-age children are largely consistent with data logging records and with teacher reports of hearing aid use in the classroom. Audiologists might find teacher reports helpful in learning more about children's hearing aid management and remote microphone system use during their time at school. This supplementary information can serve as an additional counseling tool to facilitate discussion about remote microphone system use and hearing aid management in school-age children with hearing loss.

Key Words: children, hearing aids, assistive listening devices, pediatric audiology

Abbreviations: ICC = intraclass correlation coefficient; PPVT = Peabody Picture Vocabulary test; PTA = Pure-Tone Average; TONI = Test of Nonverbal Intelligence

Audiologists routinely recommend that children with hearing loss wear their hearing aids during all waking hours (referred to as “full time”). However, recent findings suggest that many children with hearing loss utilize their hearing aids less than full time, placing them at risk for poorer speech and language outcomes as compared to children who use their hearing aids on a full-time basis (Tomblin et al, 2014). Even for children with mild hearing loss, those who use hearing aids more than eight hours per day have better receptive vocabulary ability than children who use their hearing aids less than two hours per day (Walker et al, 2015a). Understanding how barriers to full-time hearing aid use change as children mature will likely improve efforts to increase the consistency with which their hearing aids are used and thus, improve outcomes for this population.

Advances in technology allow the estimation of hearing aid use time via an automatic feature built into most current hearing aids called data logging. This tool is used to estimate the average hours per day that an individual uses a device. In 2014, fitting- and wear-time data from over 6,600 hearing aid fittings for children and young adults with hearing loss (birth – 21 years of age) were recorded from devices at 44 different sites across the United States (Jones and Feilner, 2014). These data showed average hearing aid use time was approximately six hours per day (i.e., less than full time) . Furthermore, only one-third of the children used their hearing aids more than eight hours per day and 15% used their hearing aids less than 30 minutes per day. Low hearing aid use has also been shown in samples of young children (birth to seven years of age) with hearing loss (Muñoz et al, 2014; Walker et al, 2013) and in school-age children with hearing loss (Gustafson et al, 2015).

Recent studies suggest that daily hearing aid use time increases during the first seven years of life and that children with milder hearing loss and those with mothers having lower levels of education are at risk for low levels of hearing aid use (Muñoz et al, 2014; Walker et al, 2013). It is unclear if these trends of daily hearing aid use continue as children progress through primary school and into adolescence. Gustafson and colleagues (2015) characterized hearing aid use time based on four classroom observations for 38 children with mild-to-moderate hearing loss between six and 12 years-old. Compared to previous studies of factors influencing hearing aid use time in young children, this sample of school-age children also showed a similar relationship with degree of hearing loss – children with milder hearing loss were less likely to wear hearing aids during classroom instruction than those with poorer hearing. However, even when controlling for degree of hearing loss, children in fifth through seventh grade were less likely to wear their hearing aids than those in first through fourth grade. Collectively, these studies suggest that daily hearing aid use reaches maximal levels around age nine or ten years and then decreases for some children as they enter adolescence. Because Gustafson and colleagues characterized hearing aid use time based on four short classroom observations, more comprehensive information regarding hearing aid use time, as would be provided by data logging, might improve our understanding of daily hearing aid use in these older children with mild-to-moderate hearing loss.

One challenge in this line of research is estimating hearing aid use time accurately. Data logging technologies in hearing aids incorporate a wide range of processes including quantifying how long the hearing aid is turned on, estimating the time spent in different listening environments that are classified based on the acoustic input, tracking the programs used in estimated environments, and tracking user behavior such as changes to the volume control. The

accuracy of data logging has been challenged, in particular when attempting to quantify listening environments accurately (Lamarche et al, 2010). Data logging technology is also limited in the information it provides regarding overall use time. For instance, in most current hearing aids, data logging technology records the average number of hours per day that the device is turned on rather than providing time- and date-specific information. Not included in this single value of use time per day are the patterns of change over time (e.g., hearing aid use during the week vs. weekend, use during the school year but not during the summer months) or whether or not the hearing aids were in the child's ears while turned on. This latter issue is particularly important for older children, who are given the responsibility for their own hearing aids throughout the day and might fail to turn the devices off upon removal.

To supplement these limitations of data logging technology, reports of hearing aid use time have been gathered from parents. In general, parents tend to overestimate daily hearing aid use time by two to three hours per day when compared to data logging records (Muñoz et al, 2014; Walker et al, 2013; Walker et al, 2015b). Conflicting findings have been reported regarding factors that influence parent report. Walker and colleagues (2013) reported that parents of infants and young children estimated a longer amount of hearing aid use than data logging by an average of almost three hours per day, while parents of older children reached greater agreement with data logging than parents of younger children. However, a follow-up longitudinal study showed no influence of child age on agreement of parent report and data logging for children five months to nine years of age, but found parents of children with mild hearing loss overestimate hearing aid use to a greater extend than those with moderate or severe hearing loss (Walker et al, 2015a). Walker and colleagues (2015a) speculated that the marked overestimation from parents of children with mild hearing loss was due to lack of hearing aid use

afterschool and on weekends. In a sample of older school-age children, Gustafson and colleagues (2015) confirmed parent reports of classroom hearing aid use by visiting the classrooms of school-age children spanning six to 12 years of age. Ninety-five percent of parents of children in the first through fourth grade accurately reported whether or not their child wore hearing aids in the classroom; however, less than two-thirds of parent-reports of children in the fifth through seventh grade agreed with observer reports of hearing aid use. These findings suggest that parental overestimation might be more marked for older children than younger children. Based on findings reported in these three studies, it is unclear which factors influence parent overestimation or how clinicians should utilize parent reports of hearing aid use time to augment data logging records when counseling families of school-age children.

One previously unexplored source of information regarding hearing aid use is reports from caregivers other than parents. Obtaining parent reports, data logging records, and reports from other caregivers with whom the child spends time might assist audiologists in counseling families about the challenges of hearing aid use as the child matures. Because school-age children spend a majority of their days in classrooms, teacher reports of hearing aid use time might provide additional information to improve our understanding of hearing aid use and parent/data logging agreement in children. Comparing reports from parents and teachers might also be useful to monitor use of remote microphone systems. Early research showed that nearly 57% of children with hearing loss did not use their prescribed remote microphone systems, with younger children more likely to use remote microphone systems than older children (Brackett and Maxon, 1986). There is a paucity of recent research documenting the consistency of prescribed remote microphone system use in classrooms.

Reasons for limited device use in school-age children and adolescents is likely multidimensional. Not only do these older children face psycho-social difficulties related to hearing aid use (Elkayam and English, 2003; Keilmann et al, 2007), but reports of malfunctioning hearing aids ranging from 27-92% for school-age children and adolescents have been persistent for decades (Bess, 1977; Elfenbein et al, 1988; Gaeth and Lounsbury, 1966; Lipscomb at al, 1992; Most, 2002). Although responsibility to ensure proper operation of the hearing aids falls on a team of individuals (e.g., the educational audiologist, classroom teachers, parents, the child), audiologic counseling regarding hearing aid use and management (e.g., battery function, cleaning, listening checks) is typically directed to the parent, rather than the child (Elfenbein et al, 1988; Maxon and Smaldino, 1991). Considering the limited support children beyond elementary school receive in the area of device management during a time when their participation in this process is expected to increase, it is not surprising that hearing aid rejection becomes more common as students enter into the middle school age-range (Elfenbein et al, 1988; Lipscomb et al, 1992). Determining how teachers and parents view a child's ability to manage his or her hearing aids independently can assist clinicians in identifing areas in need of improved counseling for families with children in the elementary- and middle-school age range. Furthermore, including children in this counseling might help promote consistency of hearing aid use because of improved hearing aid functioning (Lipscomb et al, 1992).

The purpose of this study was to examine device use in young school-age children with mild-to-moderate hearing loss. In an effort to extend the findings of Walker and colleagues (2015) to older children, we examined degree of hearing loss, receptive vocabulary, and maternal education as potential factors influencing hearing aid use time as quanitified by data logging. It was also of interest to explore parent reports of hearing aid use compared to data logging records

during various activities on school days and non-school days. Finally, we compared parent and teacher reports of hearing aid and remote microphone system use during school instruction as well as parent and teacher ratings of the child's ability to manage his or her hearing aids.

Method

Participants

Child participants included five boys and eight girls between the ages of 7.27 and 10.61 years (M = 8.73 years, SD = 1.08 years). Hearing thresholds were measured prior to data collection using standard pure-tone audiometry at octave frequencies from 250 through 8000 Hz, including the interoctave frequencies: 3000 and 6000 Hz. All children exhibited mild-to-moderate sensorineural hearing loss in both ears (Figure 1). The thirteen children were all fitted with bilateral behind-the-ear hearing aids by an audiologist prior to their enrollment in this study. Hearing aids from three manufacturers were represented.

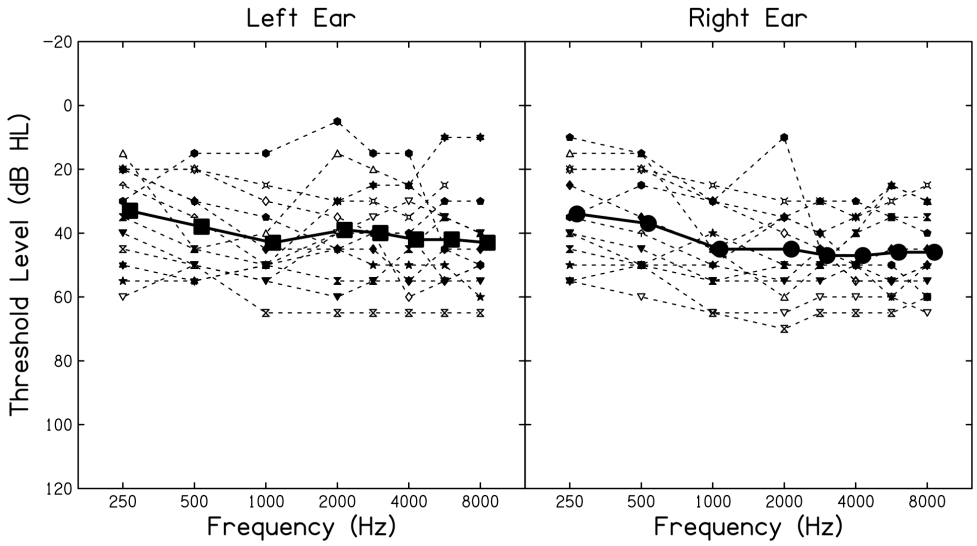

Figure 1. Individual (dotted lines) and mean (solid lines) hearing thresholds for the 13 children who participated in this study.

Demographic information about the child's audiologic background (e.g., age of hearing loss diagnosis, etiology of hearing loss) and educational experience as well as the mother's level of education was collected from each child's parent. Reported levels of maternal education were divided into categories previously used by Walker and colleagues (2013). All children spoke English as their native language and spent the majority of their day in a general education classroom. Parents reported no other known cognitive, motor, or sensory impairment. The Test of Nonverbal Intelligence (TONI-4) was used to confirm that each child in this study had average or above-average nonverbal intelligence based on published norms (Brown et al, 2010). That is, all participants exhibited a standardized score greater than 85. Child characteristics are shown in Table 1.

The parent accompanying each child to the research visit served as the parent participant. All parent participants were mothers (n=13). Parents were informed that the purpose of this study was to learn how much children use their hearing aids and other assistive technology and that their child's teacher would be asked to complete a survey about their child's hearing aid use. Parents were not informed that their child's data logging records would be accessed. The primary or homeroom teacher of each child (n=12) was identified by the parent and invited to participate in this study. The teacher of one child (HL9) was not contacted because enrollment in the study did not take place until summer vacation had begun. Teachers were informed that the purpose of the study was to examine how hearing aid use differs in the classroom as compared to at home; however, it was not explained that parents would be completing a similar survey. Children were recruited from Vanderbilt's pediatric audiology clinics and were paid $20 for their participation. Parents and teachers did not receive compensation for their participation. Informed consent and

assent were obtained according to the procedures required and approved by the Institutional Review Board at Vanderbilt University.

Table 1. Demographic information of child participants.

Child	Age (years)	Gender	Receptive Vocabulary Standard Score	Non-verbal Intelligence Standard Score	Better-Ear Pure Tone Average (dB HL)	Age of Diagnosis (years)	Age of Hearing Aid Fitting (years)	Current Grade Level
HL1	7.27	F	91	90	11.67	Birth	5.00	K
HL2	7.31	F	95	99	26.67	6.00	6.58	1st
HL3	7.58	M	112	109	25.00	5.00	6.33	1st
HL4	7.58	F	66	102	50.00	6.75	7.00	1st
HL5	8.38	M	87	110	45.00	3.00	4.00	2nd
HL6	8.39	F	96	114	38.33	4.00	4.33	2nd
HL7	8.63	F	85	99	48.33	5.33	5.33	3rd
HL8	9.29	M	96	106	41.67	3.00	3.33	3rd
HL9	9.47	F	69	87	46.67	5.00	5.00	3rd
HL10	9.57	M	99	100	28.33	Birth	2.00	3rd
HL11	9.68	M	97	92	60.00	5.33	5.50	3rd
HL12	9.70	F	86	117	51.67	5.00	5.00	4th
HL13	10.61	F	129	120	33.33	5.00	5.00	5th

Materials and Procedures

Data were collected from the children and their parents during one visit. Receptive vocabulary ability of each child was measured using the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007). Daily hearing aid use time was quantified using data obtained from hearing aid data logs and a parent survey designed for this study. During the visit, the child's personal hearing aids were connected to the manufacturer's fitting software to extract average use time of each device. If the length of time over which data logging was acquired was less than 90 days, a review of the participant's audiologic records for the prior 12 months was

completed to gather data logging information over a period of at least 90 days[1]. This additional chart review was required for three children. If values recorded were different between ears, the larger value was included in the analyses.

Parents completed a custom survey developed to assess patterns of device use across the lifespan and in various situations (see Appendix I). It was expected that the information provided about hearing aid use during early childhood might provide insight into which early-use patterns might have led to consistent use at a later age. To establish what types of hearing aids or remote microphone systems were available to each child, parents were asked to report on currently available hearing aids and/or remote microphone systems. We also asked parents to provide an overall estimation, as well as an in-depth report, of current hearing aid use or non-use during various activities for their child on typical school and non-school days. Finally, parents were asked provide an overall report of the child's level of independence in the hearing aid management process. Teachers were mailed a custom survey developed to parallel the parent survey. This survey addressed current hearing aid and other hearing assistive technology use in the classroom as well as the child's level of involvement in the management process (see Appendix II).

Results

Data Logging

All but one child participant had greater than 90 days of consecutive data logging information. One participant (HL6), who did not have data logging records from the most recent year in the audiologic chart, presented at the visit with only 27 days of data logging. Therefore,

[1] To account for differences in length of data logging across multiple recording periods, a weighted use-time value was calculated using the following formula: ([days_time1/total_days]*hours_time1) + ([days_time2/total_days]*hours_time2).

median data logging recording time was 283 days (range 27 - 2,118). Data logging indicated that children in this study used their devices for an average of 6.05 hours per day (SD = 4.78). Differences in data logging records between right and left devices were minimal (M = .25 hours, SD = .44). Four children (31%) had data logging records indicating >10 hours per day of hearing aid use. The relationship between daily hearing aid use time from data logging and child-related factors was examined using bivariate multiple linear regression. Table 2 shows correlations between the child-related factors (age, vocabulary, better-ear PTA, maternal education) considered in this study. Table 3 summarizes the descriptive statistics, correlations, and regression model results. As expected, daily hearing aid use time was moderately and positively correlated with better-ear pure tone average (PTA) of 500, 1000, and 2000 Hz, showing that children with greater degrees of hearing loss had longer hearing aid use time. A moderate, negative correlation between daily hearing aid use time and vocabulary suggests that children with lower vocabulary scores had longer hearing aid use times compared to those with higher vocabulary scores. The multiple linear regression model was significant, $F(4,12) = 5.216$, $p <$ .05, adj. R^2 = .584, revealing better-ear PTA (p =.064) and vocabulary (p =.056) as significant predictors. Child age and maternal education were not found to be significantly related to hearing aid use time.

Table 2. Correlations between potential child-related predictors considered as independent variables in regression models.

	Age	Vocabulary	Better-ear PTA	Maternal Education
Age	1	.101 (p = .743)	.449 (p = .449)	-.428 (p = .144)
Vocabulary		1	-.281 (p = .352)	.238 (p = .434)
Better-ear PTA			1	-.282 (p = .350)
Maternal Education				1

Table 3. Summary statistics, correlations, and summary of the regression model predicting daily hearing aid use time.

	Mean	SD	Correlation with Hearing Aid Use Time
Better-ear PTA	38.97	13.39	.728 (p = .005)
Age	8.73	1.08	.453 (p = .120)
Vocabulary	96.00	14.47	-.537 (p = .059)
Maternal Education	2.08	1.12	-.254 (p = .402)

	Multiple Regression Weights			
	B	SE_B	β	*p*
Intercept	-.328	9.771		.974
Better-ear PTA	.171	.080	.480	.064
Age	1.530	1.052	.346	.184
Vocabulary	-.155	.069	-.470	.056
Maternal Education	.604	.928	.141	.533

PTA = pure-tone average; SD = standard deviation; *B* = unstandardized regression coefficient; SE_B = standard error of coefficient; β = standardized coefficient

Parent Report

Parents overestimated current hearing aid use time relative to data logs by 1.34 hours per day, reporting an average use time of 7.39 hours per day (SD = 4.89). Figure 2 shows the distribution of average hearing aid use time as recorded from data logging and reported from parents. Parent report and data logging records revealed excellent agreement. The average measure intraclass correlation coefficient[2] (ICC) was .913 with a 95% confidence interval from .701 to .974; F(12,13) = 13.520, p<.001. We were unable to explore the relationship between early and current hearing aid use because children in this sample were identified with hearing loss and fit with hearing aids at an average age of 4.12 and 4.95 years, respectively. Specifically,

[2] The ICC provides an index of absolute agreement, with designations of <0.40 as poor to fair agreement, 0.41-0.60 as moderate agreement, and 0.81-1.0 as excellent agreement (Bartko, 1966).

no children were fit with hearing aids prior to age two years and only three children were fit prior to age four years. Table 4 shows data logging records and parent-reported hearing aid use or non-use during various activities on typical school and non-school days. Overall, hearing aid use was consistent across typical school and non-school days according to parents.

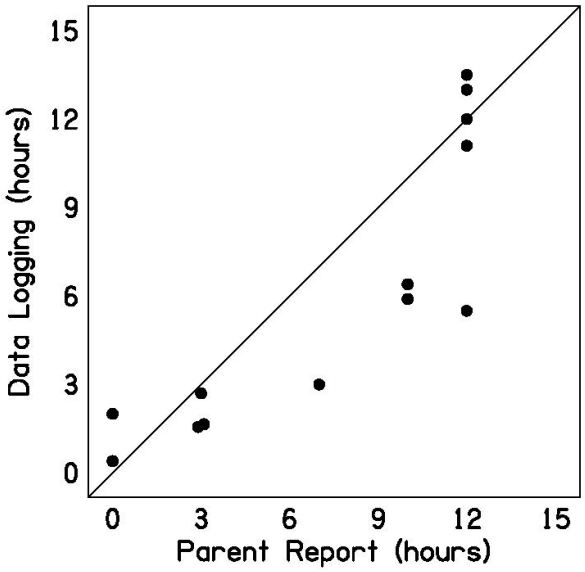

Figure 2. Daily hearing aid use time as recorded with data logging and reported by the parents of child participants.

Table 4. Data logging record and parent survey responses regarding hearing aid use on a typical school vs. non-school day. An X indicates typical hearing aid use reported during that activity.

Child	Data logging (hours)	As soon as s/he wakes up		During breakfast		In the car or on the bus		While completing homework		During social activities		While playing sports		During dinner		Between dinner and bedtime		While watching movies or TV
		Non-School	School	Non-School	School	Non-School	School	Non-School	School	Non-School	School	Non-School	School	Non-School	School	Non-School	School	Non-School
HL1	1.6				X	X	X										X	X
HL2	2.7						X											
HL3	0.4															X		X
HL4	5.9			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HL5	1.56						X											
HL6	3.0			X	X	X	X	X	X	X	X				X		X	X
HL7	13.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HL8	5.5	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X
HL9	12.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HL10	6.4	X	X	X	X	X	X	X	X					X	X			X
HL11	13.0	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X
HL12	11.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HL13	2.0																	

Teacher Report

Of the 12 teachers contacted, 10 (83%) returned completed surveys. All teachers reported spending the majority of the school day with the child (e.g., >6 hours). Table 5 shows responses to comparable questions from the parent and teacher surveys for the 10 children who had both surveys returned. Overall, parents and teachers showed good agreement when reporting hearing aid use or non-use during the typical school day. Ninety percent of the parents and teachers agreed on reports of hearing aid use or non-use during school instruction and lunch. All but one of the children who were reported by parents and teachers to use their hearing aids during school instruction typically arrived to school wearing their hearing aids, as reported by the teachers. Parents and teachers showed the least agreement (22-30%) for the child's personal management of the hearing aids – expression of desire for removal and responsibility for maintenance (i.e., battery changes, cleaning).

In this sample of children, parents of five children reported the use of a remote microphone system in at least some classes. Two parents reported that they were not sure whether or not their child used a remote microphone system. Six parents reported that their child did not use a remote microphone system in the classroom. Seven parent and teacher pairs (70%) were in agreement when reporting at least part-time use or non-use of a remote microphone system. One parent was unaware that her child was not using his remote microphone system in the classroom.

Table 5. Parent and Teacher survey responses regarding hearing aid and remote microphone system use on a typical school day.

Child	Hours Per Day Worn	Percentage of Day Worn	Child Expresses Desire to Remove HA		Child is Responsible for HA Management		HA use during transition to school in morning		Worn During School Instruction		Worn During Lunch		RM Use/Type		HA use during transition from school in afternoon	
	Parent	Teacher	Parent	Teacher	Parent	Teacher	Leaves Home	Arrives at School	Parent	Teacher	Parent	Teacher	Parent	Teacher	Leaves School	Arrives at Home
HL1	3-6	75%	Yes	Yes	Partially	Yes	Yes	Yes	Yes	Yes	No	No	Yes, in every class	No	Yes	No
HL2	3-6	70%	Yes	Yes	Partially	Partially	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No
HL3	< 1	100%	Yes	No	Partially	No	Yes	Yes	No	Yes	No	Yes	I am not sure	No	Yes	Yes
HL4	10-12	100%	Yes	No	No	Partially	No	No	Yes	Yes	Yes	Yes	Yes, only in some classes	Stand-alone RM, only in some classes	No	No
HL6	7-9	100%	Yes	No	Partially	Partially	Yes	Yes	Yes	Yes	Yes	Yes	I am not sure	Unknown type, only in some classes	Yes	Yes
HL7	>12	100%	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
HL8	>12	100%	Yes	No	Partially	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes, in every class	Personal RM, in every class	Yes	Yes
HL11	>12	100%	Yes	No	Partially	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes, in every class	Personal RM, only in some classes	Yes	Yes
HL12	>12	100%	No	No	Partially	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes, in every class	Personal + Soundfield RM, in every class	Yes	Yes
HL13	<1	0%	Yes	N/A	Partially	N/A	No	No	No	No	No	No	No	No	No	No

NOTE: HA = hearing aid; RM =remote microphone

Discussion

This study (1) investigated factors influencing hearing aid use in school-age children with hearing loss using data logging records, (2) examined hearing aid use patterns potentially contributing to poor agreement between parent report and data logging records of hearing aid use, and (3) explored the utility of teacher reports regarding children's hearing aid use, remote microphone system use, and device management skills.

As expected, our results are consistent with those of previous studies (Gustafson et al., 2015; Muñoz et al., 2014; Walker et al., 2013) showing children with milder degrees of hearing loss are less likely to wear hearing aids when compared to children with poorer hearing sensitivity. However, our data are not in agreement with the findings from Walker and colleagues (2015a) that showed children with better vocabularies wore their hearing aids more than children with poorer vocabularies. Instead, our results revealed that children who rarely wear hearing aids have better receptive vocabulary scores than those who are full-time users of hearing aids. Recall that, on average, children in the current study were older than those evaluated by Walker and colleagues. We speculate that children with better vocabulary skills might be more likely to discontinue hearing aid use as they get older. The rationale being that these children might be able to compensate for the missed or misheard words better than children with poorer vocabularies. We could not explore if children who were limited or non-users of hearing aids at the time of the study had been full-time hearing aid users earlier in life because the majority of children in this study were fit with hearing aids after four years of age.

In this study, parents overestimated hearing aid use as compared to data logging records by an average of 1.34 hours per day. Recall that previous studies included children who were generally younger than those enrolled in the current study and found parent report of hearing aid

use to overestimate data logging records from 2.19-3.36 hours per day (Muñoz et al, 2014; Walker et al, 2013; Walker et al, 2015b). Our findings suggest that parents of seven- to ten-year-old children with hearing loss show better agreement with data logging records than parents of younger children. In this study, parents reported that the day of the week (i.e., school or non-school day) and type of activity in which their children were involved did not impact their estimated hearing aid use time.

Probing discrepancies between hearing aid data logging records and parent report might facilitate discussions among parents and audiologists that target solutions to child-specific barriers to hearing aid and remote microphone system use. For instance, one mother reported that her child used his hearing aids >12 hours per day but data logging indicated only 5.5 hours per day of use. Discussion of this discrepancy revealed that her estimation was not accounting for the many hours per day her child spent playing sports without his hearing aids and prompted a subsequent discussion addressing his specific challenges with hearing aid use during sports-related activies. With a different family, the issue of parent-perceived benefit of device use arose from a discussion of discrepancies between parent report and the data logging record . Although near full-time use (10-12 hours per day) was reported by the parent, data logging records indicated that the child wore the hearing aids an average of 5.9 hours per day. A detailed discussion revealed that their family had recently taken several vacations during which hearing aid use was not enforced. While previous research in families with young children with hearing loss has shown counseling using data logging records to increase device use for some, but not all children (Muñoz et al, 2014), it is currently unknown if this type of counseling might improve device use in older, school-age children. It is possible that families of older children, who are

typically more involved with extra-curricular activities and spend time away from their parents each day, might benefit from this activity-specific counseling on device use.

The inconsistent reports of parents and teachers concerning a child's management of hearing aids at school reveals an area of care potentially under-addressed by audiologists and other providers. The proper management and use of hearing aids by students in this age range can be improved by a consistent emphasis on hearing aid wear and maintenance from a team of individuals that should include parents, teachers, audiologists, and the student themselves (Lipscomb et al, 1992). By providing explicit instruction about the hearing aid components and troubleshooting methods to both parents *and* children, audiologists are likely to promote students with hearing loss to become more independent hearing aid users. Results of this study suggest that teacher reports of the child's ability to independently manage the hearing aids could be useful in identifying which children require this support. Explicitly addressing plans for transitions toward independence of daily hearing aid management during and outside of school might prove useful to parents by empowering them to have more detailed discussions with their child's teacher(s) regarding management and use of hearing assistive technology in the classroom – discussions that should include hearing aid troubleshooting techniques. It is unknown if improved parent-teacher communication might increase the likelihood of full-time hearing aid use in children as they continue through school; however, educating teachers and students on hearing aid troubleshooting techniques can increase hearing aid use and satisfaction (Most, 2002). This is an important area for future research.

Fifty percent of teachers reported that the children with hearing loss in this study did not use a remote microphone system in the classroom. Although consistent with previous research (Brackett and Maxon, 1986), this finding should be interpreted with caution. Unlike the Brackett

and Maxon study, it is unknown if the use of a remote microphone system was recommended for children in the present study. Considering the recommendation that all children with hearing loss be considered as potential candidates for remote microphone systems in classrooms (e.g., Johnson, 2010; Salathie et al., 2010; American Academy of Audiology, 2008), documenting the consistency of use of prescribed remote microphone systems with a large sample size is an important area for future research.

There are several limitations that must be considered before extending the results of the present study to a broader population of school-age children with hearing loss. In contrast to previous research, our results showed no effect of maternal education level on hearing aid use time. These conflicting findings are likely due to the small sample size examined in this study and to the tendency of our children to come from families where maternal education levels were relatively high (i.e., only 38.4% of child participants had mothers who had completed only high school or less). It is important to note that even for these children with mild-to-moderate hearing loss who had primarily mothers with college educations, 69% of children used their hearing aids <10 hours per day. Children included in this study all had hearing loss of moderate degree or less and were from a narrow age-range of school-age children who were all mainstreamed into general education classrooms; thus, findings might not extend to older school-age children, those with more severe degrees of hearing loss, or children with speech, language, academic, or other developmental difficulties. Future research should include a larger sample of children with hearing loss across a broader age range to determine if findings from this study persist in a more generalizable sample.

Finally, like other studies that have documented agreement between parent report and data logging records, this study design assumed that use time recorded by data logging

technology represented an accurate estimate of the child's daily hearing aid use. However, limitations of hearing aid data logging technology prevent us from knowing the actual degree of logging accuracy in the current study. That is, for example, the hearing aid could be turned on but not seated in the child's ear or could be turned off while being worn. Data logging technology in modern cochlear implant processors can be considered to provide more accurate estimates of device use than data logging in hearing aids, as cochlear implant use time is not recorded unless the processor is communicating with the internal device (Mauger et al, 2014). This safeguard removes the possibility of data logging records that overestimate actual use (i.e., when the device is on but not in the child's ear). Until hearing aid data logging technology can provide this type of accurate recording, it remains an imperfect tool for estimating daily hearing aid use, highlighting the benefit of evaluating hearing aid use time from multiple sources.

Conclusions

In summary, this study supports that parent reports are largely consistent with data logging records of hearing aid use time in school-age children with mild-to-moderate hearing loss. Variable use time observed across children was explained by differences in degree of hearing loss and vocabulary skill level. Although the reported use or non-use of hearing aids in the classroom was consistent between parents and teachers, teachers and parents were not in agreement regarding the children's management of their hearing aids. Audiologists and other service providers might find teacher reports of hearing technology use in students a helpful additional counseling tool when working with families of children with hearing loss.

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Appendix I.

Patterns of Amplification Use
Parent Questionnaire

We know that children with hearing loss can range from "no use" to "full-time use" when it comes to hearing aids. We also understand that there are a variety of reasons why children may not wear hearing aids. Please answer the following questions as accurately as possible so that we can better understand your child's current and past patterns of hearing aid use/non-use.

Section A

For which ear(s) does your child have hearing aids?
- ☐ Left ☐ Right
- ☐ My child does not have hearing aids.

Does your child use an FM system at school? (select one)
- ☐ Yes, in every class
- ☐ Yes, only in some classes
- ☐ No
- ☐ I am not sure if he/she uses an FM system at school

If your child <u>does not</u> have hearing aids, please answer the next two questions.

Has a professional ever recommended hearing aids for your child: ☐ Yes ☐ No

If hearing aids were recommended, please share why your family decided not to obtain hearing aids at that time:

If your child has hearing aids, please complete the remainder of the questionnaire.

At what age did s/he first receive hearing aids? _____
(Please list in years and months)

Section B

The following questions refer to your child's hearing aid use patterns <u>between birth and two years</u> of age.

When your child was young (birth to 2 years old), how many hours per day did he/she wear hearing aids?
- ☐ <1 hour ☐ 7-9 hours
- ☐ 1-2 hours ☐ 10-12 hours
- ☐ 3-6 hours ☐ >12 hours
- ☐ My child did not have hearing aids at this time

Which types of activities did he/she <u>most</u> often wear the hearing aids (for example, tummy time, bath time, meals, car trips)?

_____

Which types of activities did he/she <u>least</u> often wear the hearing aids (for example, tummy time, bath time, meals, car trips)?

_____

This scale was developed for use in a research study.
See Gustafson, S.J., Ricketts, T.R., & Tharpe, A.M. (2017). DOI: 10.3766/jaaa.16042 for further details.

Section C

The following questions refer to your child's hearing aid use patterns between two and four years of age.

Before your child started school (2-4 years old), how many hours per day did he/she wear hearing aids?

☐ <1 hour ☐ 7-9 hours
☐ 1-2 hours ☐ 10-12 hours
☐ 3-6 hours ☐ >12 hours
☐ My child did not have hearing aids at this time

Did your child wear his/her hearing aids during all activities between two and four years of age? ☐ Yes ☐ No

During which types of activities did he/she most often wear the hearing aids (for example, reading, group play, lunch)? _____

During which types of activities did he/she least often wear the hearing aids (for example, reading, group play, lunch)? _____

If your child was enrolled in daycare or preschool during this time, please provide a brief description of the number of hours per day and number of days per week he/she spent at daycare or preschool.

_____

_____

_____

If your child attended daycare or preschool, did your child wear hearing aids while he/she was there? ☐ Yes ☐ No

Section D

The following questions refer to your child's current hearing aid use patterns.

On a typical school day (Monday-Friday), how many total hours per day does your child currently wear hearing aids?

☐ <1 hour ☐ 7-9 hours
☐ 1-2 hours ☐ 10-12 hours
☐ 3-6 hours ☐ >12 hours

On most days, my child leaves for school wearing his/her hearing aids. ☐ Yes ☐ No

On most days, my child comes home from school wearing his/her hearing aids. ☐ Yes ☐ No

My child wears his/her hearing aids during activities outside of school (for example, sports, family time). ☐ Yes ☐ No

Which types of activities does he/she most often wear the hearing aids (for example, school, movies, restaurant, playground/park)? _____

Which types of activities does he/she least often wear the hearing aids (for example, school, movies, restaurant, playground/park)? _____

This scale was developed for use in a research study.
See Gustafson, S.J., Ricketts, T.R., & Tharpe, A.M. (2017). DOI: 10.3766/jaaa.16042 for further details.

Does your child ever express a desire to remove his/her hearing aids, either by telling you or removing the hearing aids him/herself? ☐ Yes ☐ No

If so, please explain the situation(s):

My child is responsible for his/her own hearing aid management (for example, replacing batteries, cleaning device if needed, putting them away at night).
☐ Yes
☐ Partially
☐ No

Has the number of hours per day that your child wears his/her hearing aids changed over the last 6 months? ☐ Yes ☐ No
If so, please explain how: _____

Place a check mark next to activities, if any, for which your child wears hearing aids on a typical school day.

As soon as s/he wakes up		During breakfast	
While getting ready for school		In the car/bus on the way to school	
During school instruction		During lunch	
During after-school activities at school		While completing homework	
During social activities outside of school		While playing sports	
During dinner		Between dinner and bedtime	

Place a check mark next to activities, if any, for which your child wears hearing aids on a typical non-school day.

As soon as s/he wakes up		During breakfast	
During lunch		In the car	
While watching TV/movies		While completing homework	
During social activities		During sports	
During dinner		Between dinner and bedtime	

If there are any other comments you wish to share with us about your child's hearing aid use/non-use, please note them here:

This scale was developed for use in a research study.
See Gustafson, S.J., Ricketts, T.R., & Tharpe, A.M. (2017). DOI: 10.3766/jaaa.16042 for further details.

Appendix II.

Patterns of Amplification Use
Teacher Questionnaire

We know that a student with hearing loss can range from "no use" to "full-time use" when it comes to hearing aids. We also understand that there are a variety of reasons why a student may not have hearing aids. Please answer the following questions as accurately as possible so that we can learn about current patterns of hearing aid use among school children with hearing loss.

How many hours per day do you spend with this student?

_____

To the best of your knowledge, does this student have hearing aids? ☐ Yes ☐ No
If no, please skip to Section B.

Section A

On a typical school day, what percentage of the time spent with

_____

you is this student wearing his/her hearing?

Which types of activities does he/she most often wear hearing aids (for example, reading, lesson, recess, lunch)?

Which types of activities does he/she least often wear hearing aids (for example, reading, lesson, recess, lunch)?

On most days, this student arrives at school wearing his/her hearing aids. ☐ Yes ☐ No

On most days, this student leaves school wearing his/her hearing aids. ☐ Yes ☐ No

This student wears his/her hearing aids during activities outside of the classroom (e.g. recess, field trips). ☐ Yes ☐ No

Does this student ever express a desire to remove his/her hearing aids, either by telling you or removing the hearing aids him/herself? ☐ Yes ☐ No

If so, please explain the situation(s):

This student is responsible for his/her own hearing aid management (that is, replacing batteries, cleaning device if needed).

☐ Yes
☐ Partially
☐ No

Has the number of hours per day that this student wears his/her hearing aids changed over the last 6 months? ☐ Yes ☐ No

If so, please explain how:

_____

Place a check mark next to activities for which this student wears his/her hearing aids on a typical school day.

Breakfast		Lunch	
Teacher-led instruction		Group-work in class	
Silent work		Music class	
After-school activities		PE or sports	

Section B

Does this child use an FM or Roger system at school? (select one)
☐ Yes, in every class
☐ Yes, only in some classes
☐ No

Which type of FM system does this child use? (select all that apply)
☐ Personal FM/Roger
☐ Sound field FM/Roger
☐ Stand alone (not attached to hearing aids)
☐ I am not sure

If there are any other comments you wish to share with us about this student's hearing aid use/non-use or this student's hearing abilities, please note them here: