

Supplementary Online Content

Tomblin JB, Oleson JJ, Ambrose SE, Walker E, Moeller MP. The influence of hearing aids on the speech and language development of children with hearing loss. *JAMA Otolaryngol Head Neck Surg*. Published online April 3, 2014. doi:10.1001/jamaoto.2014.267.

eMethods

eFigure 1. Participation rates across the project for each subcohort

eFigure 2. Piecewise regressions fitted to unaided and aided speech intelligibility (SII) scores

eReferences

This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods

The children who were participants in the current report were part of a larger longitudinal study of outcomes of children with mild to severe hearing loss (HL).

Sample Ascertainment

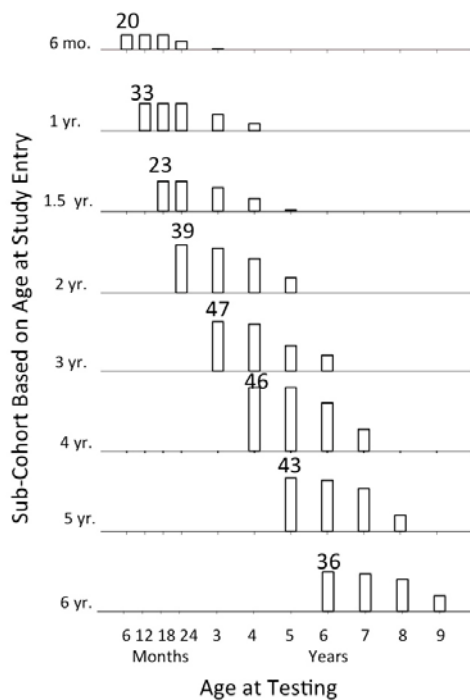
Children were recruited and seen in the home states of the three research teams (Iowa, Nebraska, and North Carolina) as well as in regions neighboring states adjacent to these states (eastern Kansas, southern Minnesota, northern Illinois, northern Missouri, and southern Virginia). The objective was to locate and approach all parents of children with mild to severe hearing loss within these catchment areas. In each case records maintained by the early hearing detection and intervention (EHDI) programs of children who had failed the new born hearing screening program in the were used. Through the EHDI programs, parents of newborns who had failed the screen and were within the age range of the study were contacted. Additionally, 6,800 recruitment brochures were sent to parents of children by audiologists, early intervention specialists, and educators who served children with hearing loss. These parents were encouraged to return a card indicating interest in the study and this resulted in 188 cards returned. Finally, the research center in North Carolina and in Nebraska served as primary clinical service providers in their region and these centers contacted all parents who were served in their centers. This method of ascertainment resulted in research participants who were volunteers and in many cases were being seen for clinical and/or educational management of a hearing loss.

Because the contacts were performed by these agencies it is not possible to determine the total number of parents who were contacted. Our research group received

responses from 430 parents. Of those, 72 children were excluded because the child did not meet the hearing criteria (bilateral loss with better ear four frequency PTA between 25 and 75 dB). An additional group of 39 children were found to have developmental disorders during the initial examination that would complicate interpretation of the hearing loss effects. This resulted in 319 children who qualified at enrollment. During the 5-year course of the study, 32 children dropped out of the study and 13 or were provided with cochlear implants. These latter children did contribute data prior to these events.

Overall Design

The overall study employed an accelerated longitudinal design in which children were enrolled over a span of 6.5 years (6 mo. to 7 years) and followed for at least 3 years.



eFigure 1 Participation rates across the project for each subcohort. Numbers indicate number of children enrolled at first observation.

Children between 6 mo and 24 mo were seen at 6 mo. intervals whereas children from 2 years of age were seen annually. eFigure 1 shows the distribution of observations made for children who were enrolled at different initial age levels and the number within each of these subcohorts who were observed subsequently. For the current study, children who were observed at either 3 or 5 years were selected. These children represented the majority of children in the cohort at ages where speech and language measures had been obtained.

Data Collection Method

All children along with at least one parent were seen at each visit by two examiners (and audiologist and a speech-language examiner). These visits were held on one day and typically lasted between 2 and 4 hours depending on the age of the child. The assessment protocols involved collection of information from the parent and the child. These assessments were performed either by the family coming to a laboratory at one of the three research sites or coming to a facility that was made available to the research team near the home of the child. Alternatively, particularly at the Iowa site, research vans were used to go to the child at their home. The data were all collected by trained examiners. Hearing data were obtained by certified audiologists. The behavioral data were obtained by individuals who were trained in speech-language pathology or education. All examiners were trained to a common protocol and one research coordinator reviewed video taped samples of the examinations in order to insure that procedures were similar across the sites.

Enrollment of Children with HL

Children with HL recruited via the methods above were entered into the research study if: (1) their chronological age was between 6 months and 7 years of age at the time of recruitment; (2) they had a better ear pure tone average of 25 dB through 75 dB; (3) the child had not received a cochlear implant; (4) were from homes where English was the primary language. Additionally, children with developmental disorders that were severe enough to limit the child's ability to perform in the various assessment tasks were enrolled and core demographic data

were obtained, but these children were not followed. Thus, these children were not considered as members of the cohort of children with HL.

In those instances where the child's hearing loss progressed beyond the 75 dB PTA, the child was retained and data gathered, unless the child received a cochlear implant. Thus, the children with hearing loss in this study had, at entry into the study, mild to severe bilateral hearing loss that may or may not have been managed with hearing aids. Furthermore, other factors that influence speech and language development such as English as a second language or significant developmental disabilities were minimized in order that the association of hearing loss with outcomes could be identified.

Computation of SII

The SII is a numerical estimate of the proportion of audibility across the frequency range of speech. It is calculated by estimating the audibility of an average speech signal compared to the listener's hearing thresholds or level of background noise, whichever is greater. The calculation is completed for a discrete number of frequency bands, which are each assigned an importance weight based on the contribution of that frequency band to the average speech recognition score for a group of adult listeners with normal hearing. The audibility of each band is multiplied by the importance weight for that band. The weighted audibility of all bands are summed to create a number between 0 and 1 that describes the weighted audibility of the long-term average speech spectrum, where a value of 0 indicates that none of the LTASS is audible and 1 represents complete audibility. Simulated real-ear measures were used to calculate aided and unaided SII. The audiologist initially conducted probe microphone measures to quantify the real ear-to-

coupler difference¹ An age-related average RECD estimated the acoustic characteristics of the child's occluded ear acoustic, when the RECD could not be measured due to limited cooperation or subject noise. Hearing-aid verification was then completed in the 2 cc coupler. Audioscan Verifit software² calculated aided SII at users' settings and unaided SII for the participants, using the standard male speech signal (carrot passage)³ presented at 65 dB SPL following ANSI S3.5 (1997). The obtained fitting data were then compared to the prescriptive targets of the DSL 5.0a. For children who used hearing aids with nonlinear frequency compression (NLFC), SII calculations were calculated using a method proposed by Bentler, Wu & Cole⁴ and used to predict speech recognition with NLFC in children and adults⁵. The alternative audibility calculation accounts for the shift in the location of each frequency in the output by measuring the sensation level of specific frequency bands used for the SII calculation in the output. Briefly, the sensation level of frequency bands in the hearing aid output was verified electroacoustically using filtered band stimuli from the Audioscan Verifit. The frequency bands are centered at 2, 3.1, 4, 5, and 6.3 kHz and correspond with bands used in the one third octave band method of the SII calculation. The sensation level of each band that occurs above the NLFC start frequency is entered into the SII calculation to provide an estimate of audibility for signals that have been spectrally altered.

Computation of rSII

An index of aided SII controlling for unaided SII was computed to reflect the gain in audibility from the hearing aid. Inspection of the of the relationship between aided and unaided SII as shown in eFigure 2 suggested that this relationship was not linear and thus a piecewise regression was fit using PROC NLIN in SAS. This routine tested whether

the data were better fit by two linear functions along with a knot defining the intersection of the two functions. This analysis showed that two linear functions with a knot at unaided SII of 0.16 modeled the data well. Thus, $rSII$ represented the difference from the obtained aided SII and a predicted aided SII based on the regression performed above or below the knot. For children with unaided SIIs below 0.16 predicted aided SII was $0.54 + 1.46 * (\text{unaided SII})$ whereas for children with unaided SIIs at or above 0.16 it was $0.74 + 0.21 * (\text{unaided SII})$.

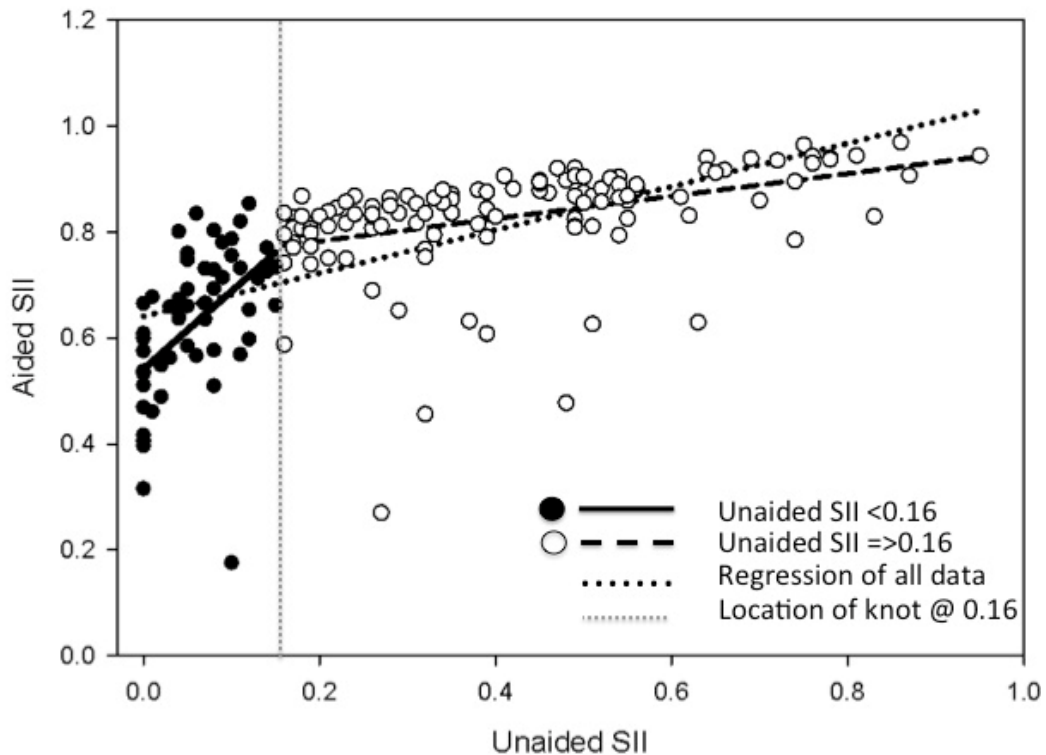


Figure 2. Piecewise regressions fitted to unaided and aided speech intelligibility (SII) scores where the knot was placed at unaided SII of 0.16 shown as a vertical dotted line.

Ear Canal Measurement.

Measured real ear to coupler differences (RECD) were used in the majority of cases across the project; however age-related averages were used when the RECD could

not be measured due to limited cooperation or subject noise. In this particular study the audiologists measured RECDs for 78% of ears and used age-related average RECDs for 22% for ears to calculate aided and unaided SII.

Hearing Aid Fit

We determined proximity to DSL targets by calculating the root-mean-square (RMS) of deviations from DSL targets at 500, 1000, 2000, and 4000 Hz. This “RMS error” of fit to target was considered to be adequate if the single error value was within 5 dB of DSL prescriptive targets, based on studies with adult HA users⁶. Using this standard, 57% of participants were considered to have adequately fit HAs, and 43% were considered to have less-than-optimal fits, based on the RMS error values. Examination of deviations from DSL targets indicated that when hearing aids deviated from target, they were typically underfit. The average deviation for the whole sample was approximately 6 dB (for a more detailed explanation of the quality of HA fittings in the OCHL cohort, see McCreery, Bentler, and Roush, 2013⁷).

eReferences

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