Published in final edited form as:
Otol Neurotol. 2013 December ; 34(9): 1703–1710. doi:10.1097/MAO.0000000000000190.

Do Audiologic Characteristics Predict Outcomes in Children with Unilateral Hearing Loss?

Judith E. C. Lieu, MD, MSPH[1], **Roanne K. Karzon, PhD**[1,2], **Banan Ead, MA**[1], and **Nancy Tye-Murray, PhD**[1]

[1]Department of Otolaryngology-Head and Neck Surgery, Washington University School of Medicine, St. Louis, Missouri, USA

[2]St. Louis Children's Hospital, St. Louis, Missouri, USA

Abstract

Objective—To determine whether audiologic characteristics of unilateral hearing loss in children were associated with language, cognitive or achievement scores.

Study design—Case-control study

Setting—Pediatric otolaryngology ambulatory practice

Patients—Cases (n=109) were children aged 6–12 years with permanent unilateral hearing loss; controls (n=95) were siblings with normal bilateral hearing.

Interventions—Audiologic characteristics measured included side and severity of hearing loss, and word recognition scores in quiet and in noise.

Main outcome measures—Cognitive abilities were measured using the Wechsler Abbreviated Scale of Intelligence; reading, math and writing achievement was measured with the Wechsler Individual Achievement Test-Second Edition-Abbreviated; and oral language skills were measured with the Oral Written and Language Scales.

Results—Children with unilateral hearing loss had worse verbal cognitive and oral language scores than children with normal hearing, but no differences in achievement scores. Children with profound unilateral hearing loss tended to have worse cognitive scores and had significantly lower oral language scores. Higher word recognition scores in quiet of the normal hearing ear were associated with higher cognitive, oral language, and reading achievement scores. Higher word recognition scores in noise were slightly correlated with higher oral language scores.

Conclusions—As expected, children with unilateral hearing loss had worse language scores than their siblings with normal hearing with trends toward worse cognitive scores. Children with profound unilateral hearing loss tended to have worse outcomes than children with normal hearing or less severe unilateral loss. However, there were no differences in outcomes between children with right or left unilateral hearing loss.

Keywords

unilateral hearing loss; children; language development; audiometry; educational measurement

---

Corresponding author: Judith Lieu, MD, MSPH, 660 S. Euclid Ave., Campus Box 8115, St. Louis, MO 63110, Phone 314-747-8205, FAX 314-454-2174, lieuj@wustl.edu.

INTRODUCTION

In 1984, Bess and Tharpe published a study of children with unilateral hearing loss (UHL) reporting "more problems than previously supposed."[1] Their seminal work challenged the widespread belief that no handicap would arise from UHL and spawned many other studies. Notably, other studies published prior to 1984 had also suggested that children with UHL might have problems in school[2, 3] and documented problems with sound localization.[4, 5]

The audiological consequences of UHL are well-documented. Lack of binaural input results in increased difficulty understanding speech in the setting of background noise,[6] conditions of favorable and unfavorable listening conditions,[6, 7] and difficulty with sound localization.[1, 4, 8] Studies in adults and children with UHL,[7, 9] including conductive UHL,[10] all show that deficits of binaural hearing negatively affect self-perceived quality of life and auditory function.

An increasing body of research suggests that UHL is a risk factor for speech-language delay. Infants, toddlers and preschool children with UHL have delayed speech and language compared to age-appropriate norms.[11–13] Two small studies showed few differences between school-aged children with UHL and normal-hearing (NH),[14, 15] whereas a larger study found significant oral language deficits in children with UHL compared to NH siblings.[16] When 46 of the children with UHL in the latter study were followed longitudinally, oral language scores improved significantly over time, but parent- or teacher-identified problems with school performance did not lessen.[17] Although UHL may have a significant negative impact on speech and language development in young children, the impact on adolescents is still uncertain.

Most of the extant literature regarding children with UHL have reported that a significant proportion have problems educationally. In the 1980s, 22–35% repeated at least one grade (compared to 2–3.5% for the public school population), and 12–41% received additional educational assistance.[8, 18, 19] During one academic year in Colorado, 36% of children with UHL were in individualized educational program/plans (IEPs).[13] In several studies, teachers reported lower academic performance among children with UHL compared to NH.[20–22] Two studies reported lower verbal cognitive scores in children with UHL, especially those with right-sided and severe-to-profound UHL.[1, 23] Socioeconomic factors, such as maternal educational and family income level, also impact language scores in children with UHL.[16]

The mechanisms through which UHL affects school performance remain unclear, but are thought to be related to impaired sound localization and binaural summation. Children with difficulty localizing sound may expend effort to locate the sound rather than to comprehend the spoken language. Loss of binaural summation may decrease incidental learning because background noise interferes with overheard speech. Severity of UHL may affect the quality and quantity of the auditory signal from the impaired ear and thus impair language development on a graduated scale. Based on theories of a "right ear advantage," right-sided UHL would be associated with greater disadvantage in learning language compared to left-sided UHL.[24]

A systematic review of the literature showed that previous studies suffer from small sample sizes and few controls.[25] Variables related to child, family and socioeconomic status are known to be strongly associated with speech-language outcomes and literacy.[26–28] The present study was designed to 1) incorporate larger sample size; 2) use rigorous, sibling controls to better account for family, parental, and socioeconomic factors that could affect educational outcomes; and 3) explore characteristics of the hearing loss itself that might affect outcomes. Our objectives were to determine whether audiologic characteristics of UHL were associated with language, cognitive or achievement scores. Specifically, was the side or severity of hearing loss, or word recognition scores in quiet or noise associated with test scores? The implication of finding associations is that improving the audiologic performance of children with UHL might in turn improve their academic performance.

STUDY POPULATION AND METHODS

We conducted a case-control study of children with UHL compared to sibling controls with NH. Institutional Review Board approval through the Human Research Protection Office at Washington University School of Medicine was obtained prior to commencement of this study. All parent and child participants signed written informed consents and pediatric assents, respectively.

Participants

Children aged 6–12 years were recruited from the pediatric otolaryngology clinics at St. Louis Children's Hospital/Washington University School of Medicine and several regional school districts.

Inclusion criteria—Children were eligible if they had UHL, defined as an average threshold of any three consecutive frequencies (e.g., 500, 1000, and 2000 Hz; or 2000, 4000 and 6000 Hz) ≥ 30 dB hearing level (HL) in the affected ear. NH in the other ear was defined as a pure tone threshold average (PTA) of 500, 1000, and 2000 Hz < 20 dB HL, and threshold at 4000 Hz < 30 dB. The hearing loss had to be considered 'permanent' (i.e., no medical or surgical treatment planned that could bring hearing to normal levels before leaving elementary or primary school).

Exclusion criteria—Children were excluded if they were not 6–12 years old at the time of assessment; had ongoing temporary or fluctuating conductive hearing loss, such as due to otitis media or tympanic membrane perforation; or had a medical diagnosis associated with known cognitive impairment (e.g., Down syndrome, congenital cytomegalovirus infection) or known cognitive impairment per parental report.

Siblings of children with UHL, 6–12 years of age at the time of assessment, were eligible to be control participants if they had NH in both ears, and did not have any of the exclusion criteria listed above.

Research procedures

Subject demographic information, parental socioeconomic data, subject concurrent and past medical history, and subject educational or school history was obtained through parental questionnaire and interview. Each child underwent a brief otolaryngologic examination, and occluding cerumen was removed before audiologic measures were obtained. The children then underwent audiologic, language, cognitive, and achievement testing with breaks as needed.

Characteristics of UHL and Audiologic Measures

Severity of hearing loss was categorized as follows: Mild = PTA < 40 dB HL; Moderate = PTA 40 to 69 dB HL; Severe = PTA 70 to 89 dB HL; and Profound = PTA ≥ 90 dB HL. Word recognition scores (WRS) using CID W-22 word lists were obtained in quiet and in noise. WRS in quiet were obtained monaurally through headphones at 40 dB sensation level (SL) relative to their PTA or at the participant's most comfortable loudness level (MCL) if recruitment became a problem for those with more severe hearing impairments. WRS in noise were obtained at +5 and 0 dB signal-to-noise ratio (SNR) in the soundfield with 8-

talker speech babble. Words were presented through a speaker at 0 degrees azimuth, with two speakers presenting the noise at 30 degrees from midline on each side of the participant.

Standardized outcomes measures

Cognitive ability was measured using the Wechsler Abbreviated Scale of Intelligence (WASI).[29] It provides the three traditional Verbal, Performance, and Full scale IQ scores. Achievement was measured using the Wechsler Individual Achievement Test-Second Edition-Abbreviated (WIAT-II-A).[30] The WIAT-II-A includes standardized scores for reading, math, and writing. Oral language skills were measured with the Oral Written and Language Scales (OWLS).[31] The standardized subtests of Listening comprehension, Oral Expression, and Oral Composite were measured. All scores were standardized for age, with a mean of 100 and standard deviation (SD) of 15.

Statistical analysis

Descriptive statistics were obtained for each group, and included means and standard deviations, medians and interquartile ranges, and frequency counts. Bivariate analyses examined the outcomes associated with patient demographic, baseline clinical, and audiologic variables. Student's t test or one-way ANOVA were used for continuous variables. Correlations were tested with the Pearson *r* test. Chi-square or Fisher exact tests were used for categorical variables. Bivariate analysis of other outcomes involved calculating the odds ratio (OR) and 95% confidence interval (CI). A two-tailed alpha level of 0.05 was considered statistically significant. A Bonferroni correction for each family of standardized outcomes was applied to adjust for multiple comparisons, decreasing the two-tailed alpha level to 0.05/3 = 0.0167 for achievement and language, and 0.05/7 = 0.007 for cognition. Statistical analysis was performed using SAS version 9.2 software (Cary, North Carolina).

RESULTS

A total of 109 children with UHL and 95 sibling controls with NH were recruited; 107 children with UHL and 94 controls completed testing for this study, except for four children with UHL and four controls that did not complete the language testing. The demographic and clinical characteristics of all recruited participants are summarized in Table 1. The children with UHL were slightly younger than controls, spoke their first two-word phrase later, and had a higher prevalence of head trauma. Otherwise, the groups were similar. Overall distribution of race and ethnicity approximated the distribution in the metropolitan area: 76% white, 16% black, 4% Asian, 0.5% American-Indian, 3% mixed or not stated, and 6% Hispanic or Latino. Level of maternal education was high overall; 44% of mothers had completed a bachelor's degree or higher, 35% had enrolled in some college or achieved an associate's degree, and 13% had graduated from high school or achieved a GED. Few mothers had not completed high school (7%). The majority (75.9%) came from families with incomes > 200% of the federal poverty level (FPL), while 9.4% were from families with incomes at 100–200% FPL, and 14.8% came from families <100% of FPL.

Table 2 summarizes the characteristics of the children with UHL in this study. Most had profound UHL, and slightly more right ears than the left ears were affected. UHL was identified at a mean age of 4.6 years (SD 2.6 years); the mean duration of known hearing loss was 4.0 years (SD 2.7 years). Parents relayed that their children's hearing loss was congenital or hereditary in about one-third. "Congenital/hereditary" etiologies to which UHL was attributed included congenital cytomegalovirus infection, atresia of the external auditory canal, congenital cholesteatoma, malformations of the cochlea, and enlarged vestibular aqueduct. "Other" etiologies which parents shared included viral infections, a vaccination, and possibly autoimmune. Thirty-one children (28%) did not have any work-up done for etiology; most of these children had never been evaluated by an otolaryngologist for their hearing loss. The most common diagnostic test done was CT and/or MRI of the temporal bones.

We were able to review 73 CT scans and 24 MRIs, of which 34 (46%) CTs and 8 (33%) MRIs were "abnormal". The most common CT abnormality to which UHL was attributed was an enlarged or prominent vestibular aqueduct in 15 (20%), followed by seven (10%) with a cochlear malformations, four (5%) with an ossicular abnormality, three (4%) with a transverse temporal bone fracture, three (4%) with atresia, and three (4%) with meningitis. Several children had more than one abnormal CT finding. The only MRI abnormality associated with hearing loss was an enlarged endolymphatic sac in two (8%) children. The other MRI abnormalities were sinus disease or T2 signal abnormalities.

Audiological characteristics

Table 3 summarizes the comparisons of WRS in quiet and in noise between children with UHL and NH, and children with right versus left UHL. Although WRS in quiet in the better hearing ear showed no difference, children with UHL had worse WRS in both noisy conditions compared to children with NH. Whereas children with right UHL had nearly identical WRS at +5 dB SNR to children with left UHL, they had better WRS at 0 dB SNR. Figure 1 shows the variation in WRS in noise according to the severity of hearing loss. There were no differences in WRS at +5 dB SNR. However, the WRS at 0 dB were statistically different based on severity of hearing loss ($F[4] = 3.46$, $p = .0094$), and post hoc analysis showed significant differences between NH and profound UHL only.

Cognitive, achievement and language scores

The cognitive scores for each group are summarized in Table 4, while Table 5 shows the achievement scores and Table 6 shows the oral language scores. There were trends toward lower Vocabulary, Verbal and Full scale IQ scores for children with UHL than for children with NH. When comparing the proportion of children whose scores were at least one standard deviation below the mean (i.e., scores < 85), there was a trend toward more children with UHL having lower vocabulary and Full scale IQ scores. Unlike the cognitive scores, there were no significant differences in reading, math or writing achievement scores between groups. In contrast to achievement scores, mean oral language scores were all significantly lower for children with UHL compared to children with NH. These language scores are similar to those reported before in a subset of this sample population.[16] Age of identification and duration of hearing loss were not associated with language, cognitive, or achievement scores (data not shown).

Association of audiologic characteristics and standardized scores

Cognitive, achievement, and language scores, compared based on severity of the UHL, showed a trend toward lower full scale IQ scores with more severe UHL ($F[4] = 1.96$, $p = .1028$), but no difference in verbal or performance IQ. There were no significant differences in the reading, writing or math achievement scores based on severity of UHL. In contrast, more severe UHL was associated with a trend toward lower listening comprehension scores ($F[4] = 2.10$, $p = .0827$), and significantly lower oral expression ($F[4] = 3.00$, $p = .0198$) and oral composite scores ($F[4] = 3.35$, $p = .0112$).

WRS in quiet, WRS in noise, and differences between the WRS at +5 and 0 dB SNR were correlated with the oral language, cognitive and achievement scores. There were slight relationships between the WRS in quiet of the impaired ear and Oral Expression and Oral Composite language scores (Pearson $r = 0.263$ and 0.261, $p = .0002$ for both, respectively).

Similarly, there were slight associations between WRS at +5 dB SNR with Oral Expression and Oral Composite language scores (Pearson $r = 0.200$ [$p = .0052$] and 0.237 [$p = .0009$], respectively). The WRS in quiet of the better hearing ear was slightly associated with verbal IQ, Full scale IQ, and reading achievement scores (Pearson r = 0.226 [$p = .0013$], 0.217 [$p = .002$], and 0.212 [$p = .0026$], respectively). Current or past use of amplification was not associated with any differences in cognitive, achievement or language scores.

The associations of WRS in quiet of the better hearing ear were evaluated further by comparing the children with WRS > 90% and ≤ 90%. Children with WRS >90% had significantly higher verbal (105.1 vs. 99.1, t = 2.58, $p = .01$) and full scale (104.1 vs. 98.9, t = 2.36, $p = .02$) IQ scores, Oral Composite (96.3 vs. 89.5, t = 3.12, $p = .002$), and reading achievement (103.6 vs. 98.4, t = 2.29, $p = .02$) scores.

Tables 4, 5 and 6 also display the comparisons of the cognitive, achievement, and language scores of children with right and left UHL. None of the comparisons revealed any significant differences between children with right or left UHL.

Socioeconomic factors associated with, cognitive, language and achievement scores

We examined the effect of two socioeconomic status variables on scores—FPL and maternal educational level (coded as less than high school, high school or GED, some college or associate degree, and bachelor degree or higher). Higher maternal educational level was associated with higher verbal ($F[4] = 10.49$, $p = <.0001$), performance ($F[4] = 8.52$, $p = <.0001$) and full ($F[4] = 11.38$, $p = <.0001$) IQ scores; reading ($F[4] = 6.90$, $p = .0002$), math ($F[4] = 6.90$, $p = .0002$), and writing ($F[4] = 6.24$, $p = .0005$) achievement; and oral expression ($F[4] = 9.37$, $p = <.0001$) and oral composite ($F[4] = 5.81$, $p = .0008$) language scores. Similarly, higher family income was associated with higher verbal oral ($F[3] = 9.27$, $p = .0001$), performance ($F[3] = 7.89$, $p = .0005$) and full ($F[3] = 10.82$, $p = <.0001$) IQ scores; reading ($F[3] = 8.78$, $p = .0002$), math ($F[3] = 5.92$, $p = .0032$), and writing ($F[3] = 9.04$, $p = .0002$) achievement; and oral expression ($F[3] = 10.08$, $p = <.0001$) and oral composite ($F[3] = 9.02$, $p = .0002$) language scores.

Because multiple factors affected the cognitive and language scores, we used multivariable linear regression to model the influence of UHL with other variables simultaneously. Table 7 shows that UHL continued to be a significant predictor of verbal and full IQ scores while controlling for maternal education level. Table 8 shows the effect of UHL on oral language scores while controlling for full IQ, age, and maternal educational level. Age was included because a longitudinal study of children with UHL showed increase in scores with time.[17] UHL continued to be a significant predictor of oral expression and oral composite scores, and trended toward significance for listening comprehension. WRS in quiet and noise were not independent predictors of any of the cognitive or language scores. The models shown in Table 8 explained 28% of the variance in scores for listening comprehension, 55% of the variance for oral expression, and 47% of the variance for oral composite scores.

DISCUSSION

In this study we evaluated the potential educational and speech-language impact of UHL using sibling controls to minimize the family (including genetic), parental, and socioeconomic factors that potentially influence these scores. Despite this rigorous control, children with UHL trended toward lower mean vocabulary, verbal sum and full scale IQ scores. They also had lower mean oral language scores, consistent with an earlier report of a subgroup of this study population.[16] These effects were robust to multivariable analysis, showing that UHL remains an independent predictor of cognitive and language scores even when other covariates are accounted for. However, achievement scores in reading, writing, and math were not different between the two groups.

As expected, children with UHL demonstrated poorer word recognition scores in quiet in their affected ear, as well as more difficulty with word recognition in the midst of noise. This finding is consistent with earlier studies and is generally considered to be the source of listening difficulty within a noisy classroom. Incidental learning, or opportunities to overhear information from diverse sources, is more limited for children with hearing loss, including UHL. The decrease in incidental learning may result in impoverished vocabulary, language rule formation, and generalized knowledge about the surrounding environment. The audiologic consequences of UHL are compounded in children because speech perception is known to undergo maturation through adolescence.[32] Other auditory skills, such as intensity discrimination and temporal resolution, develop prior to maturation of speech perception and reorganize periodically to form the efficient pathways of adult speech perception.[32, 33] Noise levels that interfere minimally with speech perception in adults can interfere substantially in the speech perception of children. Thus children require significantly greater SNRs to understand speech than adults.[8, 34, 35] Even children with NH make more errors with speech recognition in the presence of classroom noise compared to quiet conditions. Children with UHL may seem to be inattentive or even unresponsive to teachers because they require relatively higher SNRs to comprehend instructions, commands, or questions than NH peers. Language deficits that result can interfere with reading and writing and thus can have a negative impact on literacy. However, this finding provides a potential avenue for intervention, if word recognition scores can be improved by training. All of these difficulties have been observed in children with mild-to-moderate bilateral hearing losses.[36]

Contrary to prior studies which noted differences between children with right and left UHL,[1, 23, 35] we did not find any right or left ear differences on cognitive, achievement, or language outcomes. Similarly, we did not find differences between children with right or left UHL in WRS in the setting of background noise. When severity of the UHL was examined as possible predictor, only the oral expression and oral composite language scores were affected by severity. Although this result is similar to the suggestion of poorer outcomes in children with profound UHL reported by Bess and Tharpe, [1] severity of UHL explained only 6% of the variation in both language scores.

In contrast, maternal educational level and family income, variables that evaluate socioeconomic status, were highly associated with nearly all of the standardized scores measured in this cohort. Notably, maternal educational level explained 15% of the variance in Full scale IQ scores and 13% of the variance of oral expression language scores. These results are consistent with the findings that disparities in socioeconomic status influence cognitive and language development in children.[26]

Limitations of this study include the single time point assessment and the limited age range of study population. We do not know whether vocabulary, language, and IQ deficits in this age group will continue into adolescence and adulthood, and whether they might affect rates of post-secondary education or occupational choices. There is also a possibility that use of FM systems or hearing aids may have affected outcomes in those who used them. However, only a minority of the study population ever used any amplification, and even fewer continued to use amplification of any kind.

In summary, children with UHL had worse language scores than their siblings with normal hearing with trends toward worse cognitive scores. Children with profound UHL tended to have worse outcomes than children with NH or less severe UHL. However, there were no differences in outcomes between children with right or left UHL.

Acknowledgments

Funding and support: This work was supported by NIH grants K23DC006638 and UL1RR024992, and by the St. Louis Children's Foundation/Children's Surgical Services.

Abbreviations

FPL	federal poverty level
NH	normal hearing
PTA	pure tone average
SNR	signal-to-noise ratio
UHL	unilateral hearing loss
WRS	word recognition score

REFERENCES

1. Bess FH, Tharpe AM. Unilateral hearing impairment in children. Pediatrics. 1984; 74(2):206–216. [PubMed: 6462820]
2. Keller WD, Bundy RS. Effects of unilateral hearing loss upon educational achievement. Child Care Health Dev. 1980; 6(2):93–100. [PubMed: 7357689]
3. Stein DM. Psychosocial characteristics of school-age children with unilateral hearing loss. J Acad Rehabil Audiol. 1983; 16:12–22.
4. Humes LE, Allen SK, Bess FH. Horizontal sound localization skills of unilaterally hearing-impaired children. Audiology. 1980; 19(6):508–518. [PubMed: 7425955]
5. Newton VE. Sound localisation in children with a severe unilateral hearing loss. Audiology. 1983; 22(2):189–198. [PubMed: 6847534]
6. Bess FH, Tharpe AM. An introduction to unilateral sensorineural hearing loss in children. Ear Hear. 1986; 7(1):3–13. [PubMed: 3512353]
7. Giolas TG, Wark DJ. Communication problems associated with unilateral hearing loss. J Speech Hear Disord. 1967; 32(4):336–343. [PubMed: 6074893]
8. Bovo R, Martini A, Agnoletto M, et al. Auditory and academic performance of children with unilateral hearing loss. Scand Audiol Suppl. 1988; 30:71–74. [PubMed: 3227285]
9. Newman CW, Jacobson GP, Hug GA, Sandridge SA. Perceived hearing handicap of patients with unilateral or mild hearing loss. Ann Otol Rhinol Laryngol. 1997; 106(3):210–214. [PubMed: 9078932]
10. Priwin C, Jonsson R, Magnusson L, Hultcrantz M, Granstrom G. Audiological evaluation and self-assessed hearing problems in subjects with single-sided congenital external ear malformations and associated conductive hearing loss. Int J Audiol. 2007; 46(4):162–171. [PubMed: 17454228]
11. Borg E, Risberg A, McAllister B, et al. Language development in hearing-impaired children. Establishment of a reference material for a 'Language test for hearing-impaired children', LATHIC. Int J Pediatr Otorhinolaryngol. 2002; 65(1):15–26. [PubMed: 12127218]
12. Kiese-Himmel C. Unilateral sensorineural hearing impairment in childhood: analysis of 31 consecutive cases. Int J Audiol. 2002; 41(1):57–63. [PubMed: 12467371]
13. Sedey, AL.; Carpenter, K.; Stredler-Brown, A. Unilateral hearing loss: what do we know, what should we do?. National Symposium on Hearing in Infants; August 1, 2002; Breckenridge, Colorado.
14. Cozad RL. Speechreading skill and communication difficulty of children and young adults with unilateral hearing loss. J Aud Res. 1977; 17(1):25–29. [PubMed: 614336]

15. Klee TM, Davis-Dansky E. A comparison of unilaterally hearing-impaired children and normal-hearing children on a battery of standardized language tests. Ear Hear. 1986; 7(1):27–37. [PubMed: 3949098]
16. Lieu JE, Tye-Murray N, Karzon RK, Piccirillo JF. Unilateral hearing loss is associated with worse speech-language scores in children. Pediatrics. 2010; 125(6):e1348–e1355. [PubMed: 20457680]
17. Lieu JE, Tye-Murray N, Fu Q. Longitudinal study of children with unilateral hearing loss. Laryngoscope. 2012; 122(9):2088–2095. [PubMed: 22865630]
18. Bess FH, Sinclair JS, Riggs DE. Group amplification in schools for the hearing impaired. Ear Hear. 1984; 5(3):138–144. [PubMed: 6734964]
19. Oyler RF, Oyler AL, Matkin ND. Unilateral hearing loss: demographics and educational impact. Lang Speech Hear Serv Sch. 1988; 19:201–210.
20. Dancer J, Burl NT, Waters S. Effects of unilateral hearing loss on teacher responses to the SIFTER. Screening Instrument for Targeting Educational Risk. Am Ann Deaf. 1995; 140(3):291–294. [PubMed: 8651071]
21. Most T. The effects of degree and type of hearing loss on children's performance in class. Deaf Educ Int. 2004; 6(3):154–166.
22. Most T. Assessment of school functioning among Israeli Arab children with hearing loss in the primary grades. Am Ann Deaf. 2006; 151(3):327–335. [PubMed: 17087443]
23. Niedzielski A, Humeniuk E, Blaziak P, Gwizda G. Intellectual efficiency of children with unilateral hearing loss. Int J Pediatr Otorhinolaryngol. 2006; 70(9):1529–1532. [PubMed: 16820219]
24. Kimura D. Speech lateralization in young children as determined by an auditory test. J Comp Physiol Psychol. 1963; 56(5):899–902. [PubMed: 14050184]
25. Lieu JE. Speech-language and educational consequences of unilateral hearing loss in children. Arch Otolaryngol Head Neck Surg. 2004; 130(5):524–530. [PubMed: 15148171]
26. Fiscella K, Kitzman H. Disparities in Academic Achievement and Health: The Intersection of Child Education and Health Policy. Pediatrics. 2009; 123(3):1073–1080. [PubMed: 19255042]
27. Geers AE. Predictors of reading skill development in children with early cochlear implantation. Ear Hear. 2003; 24(1 Suppl):59S–68S. [PubMed: 12612481]
28. Moeller MP. Early intervention and language development in children who are deaf and hard of hearing. Pediatrics. 2000; 106(3):E43. [PubMed: 10969127]
29. Wechsler, D. [Accessed July 3, 2012] Wechsler Abbreviated Scale of Intelligence™ (WASI™). Available at: URL: http://www.pearsonassessments.com/HAIWEB/Cultures/en-us/Productdetail.htm?Pid=015-8981-502.
30. Wechsler, D. [Accessed June 23, 2011] Wechsler Individual Achievement Test - Second Edition (WIAT-II). Available at: URL: http://www.pearsonassessments.com/HAIWEB/Cultures/en-us/Productdetail.htm?Pid=015-8983-505.
31. Carrow-Woolfolk, E. Oral and written language scales (OWLS). Bloomington, Minnesota: Pearson Assessments; 1995.
32. Moore DR. Listening difficulties in children: bottom-up and top-down contributions. J Commun Disord. 2012; 45(6):411–418. [PubMed: 22766459]
33. Werner LA. Issues in human auditory development. J Commun Disord. 2007; 40(4):275–283. [PubMed: 17420028]
34. Bess FH, Tharpe AM, Gibler AM. Auditory performance of children with unilateral sensorineural hearing loss. Ear Hear. 1986; 7(1):20–26. [PubMed: 3949097]
35. Hartvig JJ, Johansen PA, Borre S. Unilateral sensorineural hearing loss in children and auditory performance with respect to right/left ear differences. Br J Audiol. 1989; 23(3):207–213. [PubMed: 2790305]
36. Carney AE, Moeller MP. Treatment efficacy: hearing loss in children. J Speech Lang Hear Res. 1998; 41(1):S61–S84. [PubMed: 9493747]

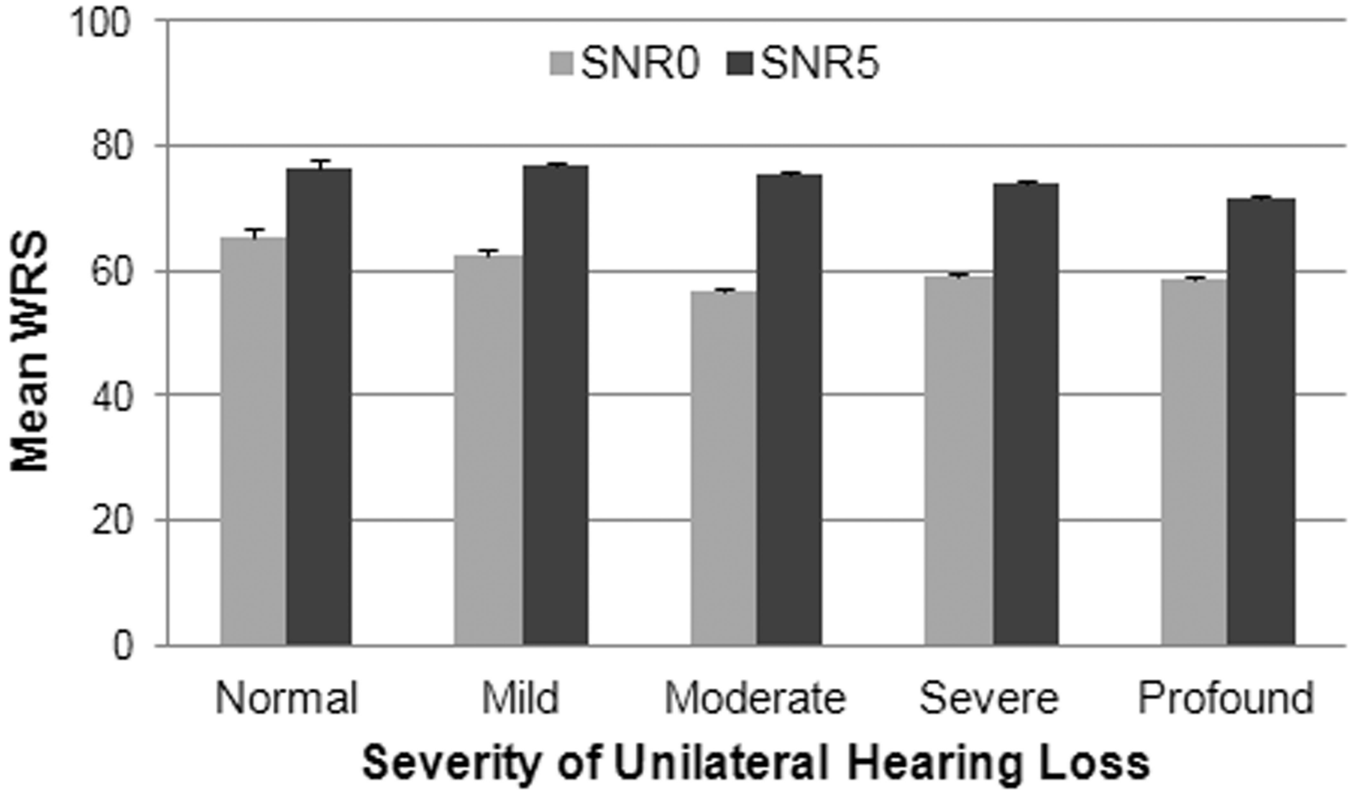

Figure 1.
Mean word recognition scores (WRS) in two noisy conditions, +5 and 0 dB signal-to-noise ratios (SNR5 and SNR0, respectively), are shown in relation to the severity of hearing loss in 108 children with unilateral hearing loss and 94 children with normal hearing. The error bars show the SD for the group.

Table 1

Demographic and clinical characteristics of 109 children with unilateral hearing loss (UHL) compared to 95 siblings with normal hearing (controls).

	UHL	**Controls**	***P* value**
Age, mean years (SD)	8.62 (1.87)	9.25 (2.40)	0.04
Males, n (%)	53 (48.6%)	48 (50.5%)	0.89
Adopted, n (%)	10 (9.17%)	7 (7.37%)	0.60
First-born, n (%)	44 (40.4%)	35 (36.8%)	0.78
Mean birth weight, grams (SD)	3226 (646)	3331 (687)	0.27
Premature, n (%)	13 (11.9%)	11 (11.6%)	0.89
Birth complication, n (%)	24 (22.0%)	17 (17.9%)	0.49
Age at 1st word, mean months (SD)	11.1 (4.18)	9.99 (4.27)	0.07
Age at 1st 2-word sentence, mean months (SD)	18.5 (8.90)	15.4 (7.94)	0.02
Head trauma, n (%)	17 (15.6%)	3 (3.16%)	0.008
Chronic medical problems			
Asthma, n (%)	23 (21.1%)	13 (13.7%)	0.20
Recurrent otitis media, n (%)	31 (28.4%)	20 (21.1%)	0.26
ADHD, n (%)	14 (12.8%)	6 (6.3%)	0.16
Takes regular meds, n (%)	49 (45.0%)	36 (37.9%)	0.32
Right handed, n (%)	90 (82.6%)	82 (86.3%)	0.70
Wears glasses, n (%)	27 (24.8%)	26 (27.4%)	0.75

SD, standard deviation; ADHD, attention deficit hyperactivity disorder

Table 2

Parent-reported characteristics of 109 children with unilateral hearing loss.

	Total (n = 109)
Age at identification, mean (SD) years	4.6 (2.6)
How was UHL identified?	
Newborn screening, n (%)	9 (8.3%)
School screening, n (%)	39 (35.8%)
PCP screening, n (%)	10 (9.2%)
Parental suspicion, n (%)	18 (16.5%)
Audiogram for ear infections, n (%)	11 (10.1%)
Other, n (%)	25 (22.9%)
Parent or teacher suspected hearing loss, n (%)	53 (48.6%)
Hearing loss has progressed, n (%)	17 (15.6%)
Preferential seating in class, n (%)	78 (71.6%)
Trial of amplification, ever	
FM system, n (%)	30 (27.5%)
Hearing aid, n (%)	18 (16.5%)
CROS aid, n (%)	4 (3.67%)
Bone anchored hearing aid, n (%)	4 (3.67%)
Amplification used currently	
FM system, n (%)	21 (19.3%)
Hearing aid, n (%)	14 (12.8%)
CROS aid, n (%)	3 (2.8%)
Bone anchored hearing aid, n (%)	3 (2.8%)
Overall impact of UHL on child	
None, n (%)	3 (2.8%)
Very little, n (%)	31 (28.4%)
Little, n (%)	24 (22.0%)
Some, n (%)	31 (28.4%)
A lot, n (%)	16 (14.7%)
Huge , n (%)	3 (2.8%)
Side of hearing loss	
Right	59 (54.6%)
Left	49 (45.4%)
Severity of hearing loss	
Mild	5 (4.6%)
Moderate	22 (20.4%)
Severe	19 (17.6%)
Profound	62 (57.4%)
Etiology of hearing loss	

	Total (n = 109)
Congenital, n (%)	36 (33.0%)
Trauma, n (%)	7 (6.4%)
Meningitis, n (%)	3 (2.8%)
Unknown, n (%)	51 (46.8%)

Table 3

Audiologic characteristics of 108 children with unilateral hearing loss (UHL) compared with 94 siblings with normal hearing (controls). Children with right-sided unilateral hearing loss (right UHL, n=59) are also compared with children with left-sided unilateral hearing loss (left UHL, n=49).

	UHL			Controls mean (SD)	*P* values	
	All mean (SD)	Right mean (SD)	Left mean (SD)		UHL vs. NH	Right vs. Left
Pure tone averages. dB nHL						
Better ear	8.1 (4.4)	7.9 (4.7)	8.4 (3.9)	7.1 (3.1)	0.052	0.54
Poorer ear	73.6 (28.2)	75.6 (26.6)	71.3 (30.2)	7.1 (3.1)	<.0001	0.43
Left ear	36.6 (37.7)	7.9 (4.7)	71.3 (30.2)	6.7 (3.8)	<.0001	<.0001
Right ear	45.1 (39.0)	75.6 (26.6)	8.4 (3.9)	7.5 (3.4)	<.0001	<.0001
WRS in quiet (%)						
Better ear	90.9 (11.0)	91.5 (6.7)	90.1 (14.6)	91.8 (4.9)	0.46	0.54†
Poorer ear	29.5 (38.9)	29.0 (38.7)	30.2 (39.6)	91.8 (4.9)	<.0001	0.87†
Left ear	63.7 (40.8)	91.5 (6.7)	30.2 (39.6)	91.4 (6.1)	<.0001	<.0001
Right ear	56.7 (42.9)	29.0 (38.7)	90.1 (14.6)	92.1 (5.5)	<.000	<.0001
WRS in noise (%)						
+5 dB SNR	72.9 (9.4)	72.9 (9.7)	72.8 (9.0)	76.5 (14.5)	0.041	0.98
0 dB SNR	58.6 (11.7)	60.6 (12.0)	56.2 (11.0)	65.5 (15.1)	0.0005	0.050

WRS, Word recognition scores; SNR, signal-to-noise ratio

Table 4

Scores on the Wechsler Abbreviated Scale of Intelligence (WASI) in 107 children with unilateral hearing loss (UHL) compared to 94 siblings with normal hearing (NH). Children with right-sided unilateral hearing loss (right UHL, n=59) are also compared with children with left-sided unilateral hearing loss (left UHL, n=48). Standard scores for the four subscales (Vocabulary, Block design, Similarities, and Matrix) are normed to a mean = 50 and SD = 10. Standard scores for the three summed scores (Verbal, Performance, and Full) range from 40 to 160 by age and grade, with mean = 100 and SD = 15.

	UHL			NH	*P* values	
	All	Right	Left		UHL vs. NH	Right vs. Left
Standardized scores	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**		
Vocabulary T-score	47.9 (11.2)	48.7 (11.6)	46.8 (10.8)	51.6 (10.2)	0.015	0.363
Block design T-score	48.0 (9.6)	48.5 (10.3)	47.4 (8.8)	50.3 (10.1)	0.111	0.576
Similarities T-score	52.5 (10.7)	52.3 (10.9)	52.8 (10.6)	55.0 (10.4)	0.094	0.804
Matrix T-score	51.4 (10.3)	51.5 (10.9)	51.4 (9.8)	52.6 (10.5)	0.438	0.967
Verbal sum IQ	100.9 (16.3)	101.6 (16.9)	100.1 (15.6)	105.5 (14.6)	0.040	0.657
Performance sum IQ	99.8 (14.4)	100.3 (15.5)	99.1 (13.0)	102.6 (14.5)	0.168	0.674
Full scale IQ	100.5 (15.2)	101.2 (16.0)	99.6 (14.2)	104.5 (14.3)	0.052	0.602
Scores >1 SD below mean	**n (%)**	**n (%)**	**n (%)**	**n (%)**		
Vocabulary T-score	29 (27)	15 (25)	14 (29)	11 (12)	0.008	0.670
Block T-score	23 (22)	13 (22)	10 (21)	15 (16)	0.369	0.880
Similarities T-score	12 (11)	6 (10)	6 (12)	9 (10)	0.819	0.764
Matrix T-score	17 (16)	10 (17)	7 (15)	12 (13)	0.553	0.796
Verbal IQ	19 (18)	8 (14)	11 (23)	9 (10)	0.106	0.309
Performance IQ	16 (15)	9 (15)	7 (15)	11 (12)	0.540	0.923
Full scale IQ	19 (18)	9 (15)	10 (21)	8 (8)	0.064	0.460
Any WASI result ≥ 1 SD below mean	46 (43)	28 (48)	18 (38)	30 (32)	0.112	0.331

Table 5

Achievement test scores in 107 children with unilateral hearing loss (cases) compared to 94 siblings with normal hearing (controls). Children with right-sided unilateral hearing loss (right UHL, n=59) are also compared with children with left-sided unilateral hearing loss (left UHL, n=48). Standard scores range from 40 to 160 by age and grade, with mean = 100 and SD = 15.

	UHL			NH	*P* values	
	All	**Right**	**Left**		**UHL vs. NH**	**Right vs. Left**
Standardized Scores	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**		
Reading	101.1 (15.3)	103.1 (16.2)	98.7 (13.7)	102.7 (15.4)	0.470	0.135
Math	96.6 (15.9)	95.8 (15.9)	97.6 (16.2)	99.2 (16.6)	0.251	0.558
Writing	101.5 (14.8)	102.4 (15.6)	100.4 (13.8)	103.5 (16.2)	0.368	0.482
Scores >1 SD below mean	**n (%)**	**n (%)**	**n (%)**	**n (%)**		
Reading	13 (12)	7 (12)	6 (12)	12 (13)	0.845	0.920
Math	22 (21)	14 (24)	8 (17)	18 (19)	0.860	0.472
Writing	14 (13)	8 (14)	6 (12)	11 (12)	0.832	0.872
Any WIAT results ≥ 1 SD below mean	27 (25)	16 (27)	11 (23)	25 (26)	0.961	0.660

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 6

Scores on the Oral and Written Language Scales (OWLS) in 104 children with unilateral hearing loss (cases) compared to 91 siblings with normal hearing (controls). Standard scores range from 40 to 160 by age and grade, with mean = 100 and SD = 15.

	UHL			Controls	*P* values	
	All	**Right**	**Left**		**UHL vs. NH**	**Right vs. Left**
Standardized Scores	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**		
Listening comprehension	91.7 (10.9)	91.4 (11.8)	92.1 (9.7)	96.7 (14.2)	0.007	0.812
Oral expression	92.7 (15.8)	92.4 (15.0)	93.0 (16.9)	100.1 (18.5)	0.003	0.841
Oral composite	90.6 (13.0)	90.0 (13.2)	91.5 (12.8)	98.0 (15.7)	0.0004	0.562
Scores >1 SD below mean	**n (%)**	**n (%)**	**n (%)**	**n (%)**		
Listening comprehension	29 (28)	18 (30)	11 (24)	20 (22)	0.409	0.518
Oral expression	32 (31)	19 (32)	13 (29)	14 (15)	0.017	0.831
Oral composite	36 (35)	22 (37)	14 (31)	15 (16)	0.005	0.540

Table 7

Multivariable regression model of verbal, performance and full IQ scores.

Variables	Parameter estimate	SE	t value	P value
Verbal IQ				
Intercept	85.33	3.87	22.05	<.0001
UHL	−4.51	2.04	−2.21	.028
Maternal education level	6.33	1.12	5.64	<.0001
Performance IQ				
Intercept	89.10	3.75	23.77	<.0001
UHL	−2.82	1.98	−1.42	.1561
Maternal education level	4.45	1.09	3.90	.0001
Full IQ				
Intercept	85.79	3.70	23.22	<.0001
UHL	−4.06	1.95	−2.08	.0384
Maternal education level	5.89	1.07	5.50	<.0001

Table 8

Multivariable regression models of oral language scores.

Variables	Parameter estimate	SE	t value	P value
Listening comprehension				
Intercept	45.53	6.79	6.70	<.0001
UHL	−2.97	1.59	−1.87	.0632
Full IQ	0.43	0.057	7.57	<.0001
Age	0.62	0.37	1.68	.0948
Maternal education level	0.036	0.92	0.04	.9685
Oral expression				
Intercept	−3.07	7.33	−0.42	.6758
UHL	−3.60	1.71	−2.10	.0370
Full IQ	0.75	0.062	12.11	<.0001
Age	1.63	0.40	4.08	<.0001
Maternal education level	3.16	0.99	3.19	.0017
Oral composite				
Intercept	19.67	6.73	2.92	.0039
UHL	−4.39	1.57	−2.79	.0059
Full IQ	0.59	0.056	10.38	<.0001
Age	1.24	0.36	3.40	.0008
Maternal education level	1.72	0.91	1.89	.0605