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Unilateral and Mild Bilateral Hearing Loss in Children: Past and Current Perspectives

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Since the early 1980s, audiologists have become increasingly aware of the potential effect of even mild degrees of hearing loss on the psychoeducational and psychosocial outcomes of children. This review describes some of the key research findings during the past several decades that have led us to our current thinking about unilateral and mild bilateral hearing loss in children. The first section addresses unilateral hearing loss. This is followed by a review of the literature on mild bilateral hearing loss. Specifically, the issues addressed include the significance of permanent mild degrees of hearing loss on children's psychoeducational and psychosocial development and the speech, language, and auditory characteristics of children with mild degrees of hearing loss. Finally, some recommendations regarding the direction of future research are offered.

This review is followed by 2 articles summarizing the proceedings of a 2005 workshop convened by the Centers for Disease Control and Prevention (CDC), Early Hearing Detection and Intervention (EHDI) program, and the Marion Downs Hearing Center to address concerns about the underidentification of—and professionals' apparent lack of awareness of—permanent unilateral and minimal to mild hearing loss in children.[56,57]

Keywords: minimal; mild; unilateral; hearing loss; children

The 1964–1965 rubella epidemic resulted in approximately 12.5 million cases of rubella, which led to almost 12,000 babies being born deaf in the United States. As such, the following decade was one in which audiologists found themselves focused on the management of children with severe to profound degrees of hearing loss. Today, rubella is largely prevented through vaccination, and in 2004, there were only 9 rubella cases reported in the United States.[1] Given that backdrop, it is not surprising that the leaders of our profession took the following position about unilateral hearing loss (UHL) in children in 1978:

> Audiologists and otolaryngologists are not usually concerned over such deafness, other than to identify its etiology and assure the parents that there will be no handicap.[2(p143)]

After all, when compared to children with severe to profound hearing loss in both ears, many of whom had additional handicapping conditions, the potential effect of UHL on children seemed of little consequence. However, despite the common thinking of that time, in the early 1980s, Fred Bess began to notice more and more families coming into the Bill Wilkerson Center with concerns about their children with UHL. These families reported concerns such as "my child's teacher says that he daydreams throughout class," "my child is considered the 'class clown' when he should be paying attention to the

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Table 1. Distribution of Ages at Which 60 Children Were Identified With Unilateral Hearing Loss

Age Category	Percentage
1–2 years	3
3–4 years	20
5–6 years	50
7–8 years	20
9–10 years	5
11–12 years	2

Source: Adapted with permission from Bess and Tharpe (1984).[4]

Table 2. Academic and Behavioral Standing of 60 Children With Unilateral Sensorineural Hearing Loss

Academic Standing	Percentage
Satisfactory	51.7
Resource help required	13.3
Grade repetition required	35.0
Behavior problem as determined by teacher	
Yes	20.0
No	80.0

Source: Adapted with permission from Bess and Tharpe (1986).[3]

teacher," and "her teacher reports that she 'hears when she wants to' but often ignores those around her." Such reports initiated a series of studies at Vanderbilt University and elsewhere on UHL in children. The results from these early UHL studies fed a more general interest in UHL and mild bilateral hearing loss (MBHL) in children.[a]

Table 3. Early Academic Findings on Children With Permanent Unilateral Hearing Loss

Investigation	Failed (One or More) Grades	Resource Help (One or More Years)	Combined
Bess and Tharpe[3]	35%	13%	48%
Oyler et al[5]	27%	41%	68%
Bovo et al[6]	22%	12%	34%
Jensen et al[7]	18%	60%	78%

Psychoeducational Effect of Unilateral Hearing Loss

The first step in investigating the effect of UHL on children was to characterize the population and determine just how widespread the problem might be, if there was indeed a problem. Some of the earliest investigations began with Bess and Tharpe at Vanderbilt University when they collected descriptive data via medical and educational case histories on a population of 60 children with sensorineural UHL living in middle Tennessee.[3] All 60 children had been diagnosed with UHL of 45 dB or greater (.5, 1.0, 2.0 kHz) in the poorer ear and thresholds no worse than 15 dB (.5, 1.0, 2.0 kHz) in the normally hearing ear. These children ranged in age from 6 to 18 years. Approximately 52% of these children had no known etiology for their hearing loss. The most frequently cited suspected etiologies were viral complications (24%), meningitis (15%), and head trauma (8%). Table 1 provides a distribution of the ages at which these unilateral losses were identified.

The mean age of identification was approximately 5½ years; only 23% of children with UHL were being identified before the age of 5 years, quite late by today's standards. At that time, of course, routine newborn hearing screening had not yet made its entrance. These results suggested that the losses were identified on the children's entrance to school and their participation in school hearing-screening programs.

Perhaps the most noteworthy of the findings from these 60 children was the revelation that only half were performing satisfactorily in school. As summarized in Table 2, 35% of the children had repeated at least 1 grade in school, and an additional 13.3% required resource assistance such as academic tutoring. This was especially concerning given that the failure rate in that metropolitan area for the general elementary school population was only 3.5%.

Furthermore, 20% of the 60 children were identified by their teachers as exhibiting behavior problems. All of these children were receiving preferential classroom seating, the management option of choice at that time. A short time later, our colleagues at the University of Arizona[5] and our European colleagues[6,7] published strikingly similar educational results on school-aged children with UHL. A summary of the early academic trends found for children with UHL is presented in Table 3.

At about this same time, Julia Davis and her colleagues at the University of Iowa published the

a. The studies discussed herein use a variety of terms to describe the degree of bilateral hearing loss of interest in this review. These terms include *minimal*, *slight*, and *mild*. For the purposes of this review, the term *mild* is used throughout. However, it should be noted that the specific degree of loss associated with this term may vary across studies.

findings of a group of school-aged children with hearing loss including UHL.[8] They identified a slight decrement in verbal intelligence quotient (IQ) scores in the children with UHL relative to their performance IQs. Furthermore, achievement-test scores in reading, math, and spelling approximated the 50th percentile but were not related to the degree of the unilateral loss. That is, whether a child's UHL was mild, moderate, or profound, the average scores on achievement tests were relatively similar. In contrast, Culbertson and Gilbert[9] did not find significant differences between children with UHL and their normal-hearing peers on tests of IQ as measured by the Wechsler Intelligence Scale for Children—Revised (WISC-R)[10] and the Hiskey-Nebraska Test of Learning Aptitude.[11] However, when comparing the IQ scores of children with severe to profound UHL to those of children with mild to moderate UHL, those with more severe degrees of UHL had significantly lower full-scale IQs than those with lesser degrees of UHL. Furthermore, similar to the findings of Davis et al, Culbertson and Gilbert[9] found significantly lower scores on the subtests of word recognition and spelling of the Wide Range Achievement Test[12] in children with UHL as compared to their normal-hearing peers.

Early studies of children and adults with UHL suggested the potential for psychosocial problems.[13–15] In 1967, Giolas and Wark[13] reported that adolescents with UHL experienced feelings of embarrassment, annoyance, confusion, and helplessness. As noted previously, 20% of the children in the Bess and Tharpe[3] study were described by their teachers as having behavior problems, whereas Keller and Bundy[14] also reported that teachers observed uncooperative and inattentive behavior in school-aged children with UHL. Furthermore, using standardized scales, Stein[15] obtained behavior ratings from parents and teachers of a small group of school-aged children with UHL. Excessive behavior problems including social withdrawal and aggression were reported in 42% of these children. An assessment of verbal and nonverbal learning abilities revealed that 37% of these children scored significantly below an acceptable range relative to normal-hearing children in the areas of interpersonal and social adjustment. It should be noted that all of these children were performing adequately academically. This finding of teacher reports of behavioral and attentional difficulties in children with UHL was confirmed almost a decade later by another research group.[16] Self-perceived hearing handicap was examined in a group of adults with UHL.[17] Although considerable intrasubject variability was reported, a substantial number of these subjects expressed feelings of being frustrated, upset, and left out.

Of interest today is whether the studies of the 1980s triggered any educational or management changes that have resulted in improved outcomes for children with UHL. Recent reports suggest that indeed, there has been increased interest among professionals to provide audiological management to children with UHL.[18,19] However, several studies since the 1980s have documented the unrelenting below-average academic performance of children with UHL.[16,20,21] A survey of 26 educational audiologists, who served a total of 423 children with UHL, revealed that 26% of these children used hearing aids, frequency-modulation systems, or a combination thereof.[21] In addition, 54% of these children were receiving special education services (ie, amplification monitoring, resource assistance, speech-language services). The authors concluded that despite an increased awareness of the high-risk status of children with UHL and increased intervention with these children relative to that of the 1980s, the proportion of children with UHL performing at below-average academic level had not changed. Results such as these certainly beg the question of whether factors other than auditory accessibility are contributing to the less than optimal academic performance.

Speech, Language, and Auditory Characteristics of Children With Unilateral Hearing Loss

The educational findings from Bess and Tharpe's study of 60 children with UHL prompted a closer look at the audiological characteristics of a subgroup of 25 of those children who were closely matched to 25 peers with normal hearing.[22] Bess and colleagues examined the localization and speech-recognition abilities of these matched pairs of children, and predictably, they found that the localization scores were significantly poorer for the children with UHL than for the children with normal hearing. These localization difficulties increased as the degree of UHL increased. As seen in Figure 1, the children with UHL also had significantly poorer speech-recognition scores than their normal-hearing counterparts. This was true whether the test was conducted in quiet or noise and whether the speech stimuli were directed toward the poorer ear (monaural indirect condition with noise directed toward the normal-hearing ear) or toward the normal-hearing ear (monaural direct

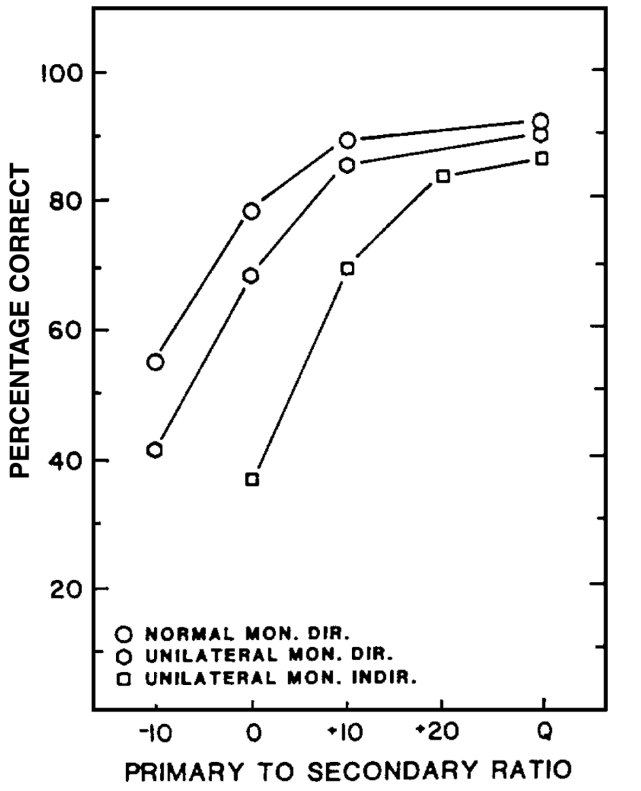

Figure 1. Mean sound-field composite scores in percentage correct on the Nonsense Syllable Test (Levitt and Resnick[23]) across several primary-to-secondary ratios (ie, signal-to-noise ratio) for children with UHL (n = 25) and children with normal hearing (n = 25). Reprinted with permission from Bess and colleagues (1986).[22]

condition with noise directed toward the poorer hearing ear).

Similarly, numerous studies have demonstrated poor localization ability in children with UHL relative to children or adults with normal hearing in both ears.[6,24,25] Other research groups have documented poor speech-recognition performance of children with UHL when measured in the presence of background noise.[6,26] For example, Bovo et al[6] found significantly poorer speech-recognition performance for a group of children with UHL as compared to their normal-hearing peers, even in a monaural direct condition. This was the case whether the child had left or right ear impairment. Ruscetta and colleagues[26] also examined performance of school-aged children with severe to profound UHL on speech-recognition tasks as compared to children with normal hearing. When evaluated in noise in a variety of speaker azimuth conditions, the children with UHL required greater signal-to-noise ratios than children with normal hearing. This difficulty with speech perception in noise was observed for nonsense syllable and sentential speech materials.

Specific speech and language deficits have not been clearly identified in children with UHL. Klee and Davis-Dansky[27] performed a battery of standardized language tests with the Bess subgroup of 25 children with UHL and their normal-hearing peers. Although Klee and Davis-Dansky did not identify any specific language impairment in either group, they found that the children with UHL who had failed a grade in school had significantly lower verbal IQ scores than those children with UHL who were academically successful. However, both the academically successful and the unsuccessful UHL groups had verbal IQs within the normal range. Tieri and colleagues[28] were also unable to identify any speech or language problems from case-history reports obtained from parents of children with UHL. However, most parents surveyed reported that their children had learning problems. Likewise, other investigations of school-aged children with UHL have found no differences in language abilities when compared to children with normal hearing.[29,30] Taken together, the results of speech and language assessments in children with UHL have not revealed any specific deficits.

Psychoeducational Effect of Mild Degrees of Bilateral Hearing Loss

Early studies of children with mild degrees of hearing loss suggested that these children were not performing at expected academic levels.[31–34] For example, Quigley and Thomure,[33] in examining academic records of school-aged children, revealed a systematic progression in academic difficulty with increasing degrees of hearing loss. Even children with hearing thresholds between 15 and 26 dB were found to have a 1.11-grade delay between their expected grade performance and their actual grade performance. Blair et al[31] examined the educational performance of 24 school-aged children with mild bilateral sensorineural hearing loss compared to 24 children with normal hearing. On several of the subtests of the Iowa Test of Basic Skills, Blair found that third- and fourth-grade children with hearing loss scored poorer than their normal-hearing peers.

Those findings, along with the findings from the earlier Vanderbilt UHL studies, encouraged Bess and colleagues[35] to take a closer look at children with all

types of "minimal" hearing loss, including those with unilateral and bilateral impairment. They sampled 1228 children in the third, sixth, and ninth grades. For purposes of that study, minimal hearing loss included (1) unilateral sensorineural hearing loss, defined as average air-conduction thresholds (.5, 1.0, 2.0 kHz) ≥20 dB HL in the impaired ear, an average air-bone gap no greater than 10 dB at 1.0, 2.0, and 4.0 kHz, and average air-conduction thresholds in the normal-hearing ear ≤15 dB HL; (2) bilateral sensorineural hearing loss, defined as average pure-tone thresholds between 20 and 40 dB HL bilaterally with average air-bone gaps no greater than 10 dB at frequencies 1.0, 2.0, and 4.0 kHz; and (3) high-frequency sensorineural hearing loss defined as air-conduction thresholds greater than 25 dB HL at 2 or more frequencies above 2 kHz (ie, 3.0, 4.0, 6.0, or 8.0 kHz) in one or both ears with air-bone gaps at 3.0 and 4.0 kHz no greater than 10 dB.

A total of 66 children met 1 of those hearing-loss criteria. The Comprehensive Test of Basic Skills (CTBS), fourth edition,[36] was used to assess educational performance. Children with minimal hearing loss in the third grade demonstrated significantly lower skills than their normal-hearing counterparts for the subtests of reading vocabulary, language mechanics, basic battery, word analysis, spelling, and science. No differences were noted between groups for the sixth and ninth graders. The average grade-retention rate for all of the children with minimal loss was 37%. The retention rates for children in each grade are summarized in Figure 2. Note that these retention rates are significantly higher than the district norm rates at each grade level. Therefore, despite the fact that the older children in that study demonstrated a normal aptitude for educational performance (based on CTBS results), they still experienced difficulty in school.

Bess and colleagues also assessed the functional health status of the children with minimal losses in the sixth and ninth grades by using the Cooperative Information Project Adolescent Chart Method (COOP).[37,38] This chart is designed to extract data in the domains of physical, emotional, and social functionality. The COOP scores indicated significantly more dysfunction for the children with minimal hearing loss as compared to their normal-hearing peers in the energy domain. That is, the children with minimal hearing loss reported having less energy or were tired more frequently than their normal-hearing peers. Additionally, the ninth graders with minimal hearing loss demonstrated significantly more dysfunction in the domains of stress, social support, and self-esteem than the children with normal hearing.

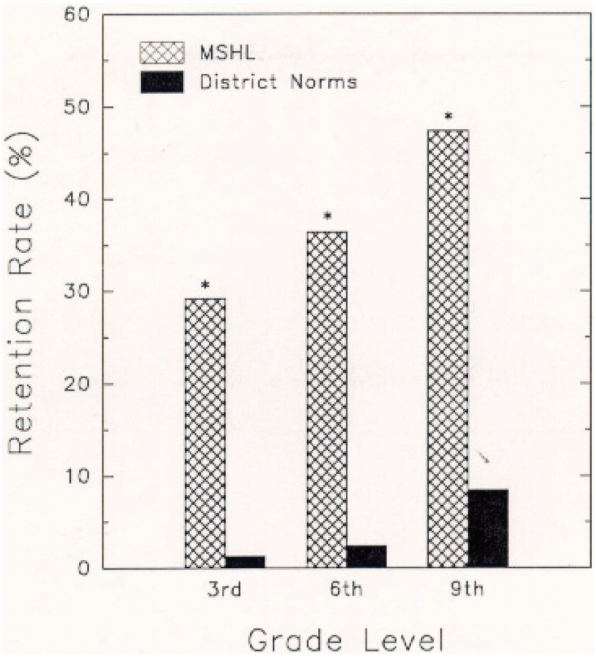

Figure 2. School retention rates for children with minimal sensorineural hearing loss (MSHL) at each grade level (3, 6, 9). School-district norm retention rates are included for comparison. Asterisks denote the grades in which significance ($P < .05$) was achieved between groups. Reprinted with permission from Bess and colleagues (1998).[35]

Speech, Language, and Auditory Characteristics of Children With Mild Degrees of Bilateral Hearing Loss

There were ample early data to suggest that children with MBHL may have difficulty listening in the presence of background noise relative to their normal-hearing peers.[39–43] However, most of those studies included subjects with greater degrees of hearing loss than those who are the focus of this review. For example, more favorable signal-to-noise ratios are required for equivalent performance on speech-perception tasks for individuals with mild to moderate hearing loss than for those who have normal hearing.[39] More recently, Crandell[44] examined the speech-recognition ability of school-aged children with minimal sensorineural hearing loss (thresholds between 15 and 30 dB bilaterally) and children with normal hearing. The speech-recognition scores of the children with hearing loss were significantly

poorer than those of the normal-hearing children under most of the listening conditions. Although there was little if any difference between groups in quiet, as the signal-to-noise ratio became more adverse (ie, from +6 S:N to –6 S:N), the difference between groups became greater.

Prompted by the finding of decreased energy and increased stress reported by the children with minimal hearing loss, Bourland-Hicks and Tharpe[45] examined listening effort and fatigue in children with minimal to moderate degrees of hearing loss when listening in a variety of signal-to-noise levels. Although no differences on measures of fatigue were found between the groups of normal-hearing children and children with hearing loss, between-group differences were noted on a dual-task paradigm designed to examine listening effort. Specifically, the children with hearing loss expended more effort in listening to speech in quiet and in the presence of background noise than did the children with normal hearing. Given that listening effort refers to the attention requirements necessary to understand speech,[46,47] the implication of these findings is that children with even a relatively mild degree of hearing loss may exert more energy than their normal-hearing peers to listen in a classroom setting, thus leaving them with less energy or attention capacity for processing what they hear, taking notes, and other activities required of school children.

Speech and language assessments of children with minimal degrees of bilateral hearing loss have been lacking. Most studies have examined children with minimal bilateral hearing loss as part of a larger group of children with greater degrees of loss. For example, in a comparison of school-aged children with mild, bilateral sensorineural hearing loss (25 to 45 dB in the better ear) to their normal-hearing peers, Blair and colleagues[31] revealed that the academic performance of children with mild hearing loss lagged behind that of their normal-hearing peers, especially in the areas of vocabulary, reading comprehension, and language use. Furthermore, Briscoe et al[48] compared a group of children with mild to moderate bilateral sensorineural hearing loss to children diagnosed with specific language impairment (SLI). They found that the children with hearing loss were as impaired as the children with SLI who had normal hearing on tests of phonological discrimination, phonological awareness, and nonword repetition. However, the children with mild to moderate hearing loss did not demonstrate deficits in language and literacy that characterize SLI. In another examination of children with mild degrees of hearing loss (<45 dB pure tone average [PTA] bilaterally), Davis and colleagues[32] found receptive vocabulary, verbal ability, and reasoning to be more than 1 standard deviation below the mean. It was of interest to note that the children with mild hearing loss in that study performed similarly to other study participants who had greater degrees of hearing loss (ie, PTA between 45 and 60 dB and PTA ≥ 61 dB).

In another study, Elfenbein et al[49] examined the oral language skills of school-aged children with varying degrees of hearing loss. Children with mild hearing loss and those with normal hearing had similar semantic and syntactic skills. However, pragmatic errors and misarticulations were more prevalent in children with MBHL than those with normal hearing. Also of note in that study was that 66% of the children with MBHL self-reported that they had difficulty making themselves understood at times. They referred to speech errors, lack of vocabulary, and difficulty with correct word order as factors in their expression. This finding is similar to that from a more recent survey of parents of children with MBHL. Forty percent of respondents in that survey reported that their children had more difficulties than expected producing certain speech sounds.[50] Moreover, 15% reported that it was often or very often difficult to understand their child's speech.

In a recent population-based study by Wake et al,[51] no statistically significant differences on tests of language, reading, and behavior were found for a large cohort of children with slight or mild sensorineural hearing loss when compared to those with normal hearing. However, phonological short-term memory and phonological discrimination were poorer in the children with hearing loss than in those with normal hearing. These findings are consistent with the earlier Briscoe et al[48] findings. Difficulty with phonologic short-term memory has been associated with difficulties in reading in studies of children with and without hearing loss.[52]

Where Do We Go From Here?

During the past several decades, much has been learned about the effect of UHL and MBHL on children. Collectively, the data suggest that children with UHL and MBHL are at risk for psychoeducational and psychosocial deficits. But many questions still remain unanswered. Key questions include the following:

1. Are there any factors that would predict which children with UHL and MBHL are likely to be at highest risk for academic difficulty? Clearly, not all children with such losses experience significant learning or communication problems. The identification of potential trigger factors could allow us to focus our efforts on those children at highest risk. For example, etiology of the hearing loss, including prenatal or postnatal factors or genetic influences, may contribute to outcomes. Although early studies documented etiology of hearing loss when available, most causes of hearing loss were classified as unknown. With recent advances in genetic studies, we should now be able to determine etiology with a higher degree of accuracy. In cases of UHL, the affected ear (ie, right vs left) may be an indicator of learning outcomes. To date, there are conflicting reports regarding the significance of differences between the right and left ear.[5–7,53]
2. What are the best practice and management strategies for these children? Preferential classroom seating has proven to be an insufficient management strategy for a large number, if not for all, of these children. The use of frequency-modulated (FM) systems can aid in the ease of listening for children with UHL and MBHL by ameliorating the effects of distance and reverberation in classroom settings, and hearing aids can improve audibility. However, we do not know if improved listening ability alone is sufficient for countering the learning obstacles experienced by some of these children.
3. Can early intervention with these children reduce the negative effects of the hearing loss? The children included in most of the studies reported in this article were not identified as part of a hearing-screening program for newborns. It is of interest to consider whether early identification and parental awareness of the hearing loss would contribute to more favorable outcomes for these children.
4. How early do children with UHL and MBHL begin to exhibit learning difficulties? Because of the often late age of identification of UHL and MBHL, most studies thus far have included school-aged children in their cohorts. One retrospective study queried parents about the age of first words and first word combinations for their children with UHL.[30] The production of 2-word phrases, which typically occurs at about 18 months of age, was found to be delayed in these children. Inclusion of younger children in future studies of UHL and MBHL would aid in our understanding of the developmental trajectory of these children.
5. Will children with UHL and MBHL who have academic problems catch up with their normal-hearing peers as they get older? There are a few indications that this might be the case, at least for those with UHL.[54,55] For example, Colletti et al[54] compared a group of adults with UHL to adults with normal hearing. They found no between-group differences in the areas of scholastic achievement, types of employment, social problems, or sedative or alcohol use. However, results from tests of academic achievement on children with mild bilateral hearing loss suggested that academic difficulties might escalate as children get older.[31]

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