Since that time, others have adopted these definitions in an effort to enable meaningful comparisons of data across studies (Centers for Disease Control and Prevention 2005). Our attempts to evaluate current data obtained across studies are compromised when we are not using uniform definitions. For example, prevalence rates of minimal or mild bilateral hearing loss and unilateral hearing loss are uncertain because of the differences in defining the audiometric thresholds of these groups. Furthermore, because we do not currently target minimal and mild degrees of hearing loss with our newborn hearing screening programs, we can only estimate prevalence of such losses in the newborn period. Johnson and colleagues (2005) offered a conservative estimate of 0.55/1000 newborns with mild permanent bilateral (25–40 dB at 1.0, 2.0, or 4.0 kHz) and unilateral hearing loss. The number of babies with unilateral hearing loss in the neonatal period has been estimated at 0.7–1/1000 (Prieve et al. 2000; Davis, DeVoe and Robertson 2005) as compared to 3/100 by school age (Bess et al. 1998). Bess and colleagues also estimated 2.4/100 school-age children had minimal bilateral hearing loss.

The difference between estimated prevalence rates in the newborn period and at school age can be the result of several different factors including:

- misses by the early hearing detection and intervention systems (EHDI);
- low follow-up rates by newborn screening programs resulting in low estimates in the newborn period;
- progressive or late-onset hearing loss; and/or
- differing definitions of “hearing loss”.

This chapter will review what we know about the impact of minimal degrees of hearing loss on children. Perhaps more importantly, what we do not know about the effects of these degrees of hearing loss will also be discussed.
What We Know

In the 1980s, Bess and colleagues published a series of papers on the impact of permanent unilateral hearing loss (UHL) on speech-language, auditory, and psychoeducational outcomes in children (Bess and Tharpe 1986; Bess, Tharpe and Gibler 1986; Culbertson and Gilbert 1986; Klee and Davis-Dansky 1986). Prior to that time, most hearing professionals assumed that children with UHL would experience little if any adverse effects as long as they received preferential classroom seating. However, the results of those studies changed our thinking about how children with UHL should be managed. Perhaps the most surprising finding from those studies was that children with UHL were at academic and psychosocial risk. In fact, approximately 35% of these children had to repeat at least one grade in school and an additional 13% required resource assistance for academic difficulty. The academic failure rate was ten times that of their normal-hearing peers, a finding that was upheld by others (Oyler, Oyler and Matkin 1988). More recent reviews of the literature have confirmed that the academic difficulties experienced by children with UHL in early studies have not, on average, improved over time (Watier-Launey, Soin, Manceau and Ployet 1998; English and Church 1999; Lieu 2004).

The revelation of these findings was followed by a number of studies that were initiated to examine more closely the potential causative factors (e.g., speech-language, auditory, cognitive abilities) for these academic difficulties. Children with right ear impairment were found to be at greater academic risk than those with left ear impairment (Bess et al. 1986; Oyler et al. 1988; Jensen, Børre and Johansen 1989) and those with more severe degrees of unilateral loss were often found to be at greater risk than those with lesser degrees of loss (Bess and Tharpe 1986; Brookhauser, Worthington, and Kelly 1991; Sedey, Stredler-Brown and Carpenter 2005) but not always (Dancer, Burl and Waters 1995). Although all children enrolled in the Bess et al. studies had intelligence quotients (IQs) that were within normal limits, those who required grade repetition in school had significantly lower verbal IQs than those who were academically successful. But, surprisingly, speech and language evaluations did not reveal differences between those school-age children with UHL and their normal hearing peers (Klee and Davis-Dansky 1986). Other studies have also failed to find speech-language deficits in children with UHL (Hallmo, Möller, Lind and Tonning 1986; Tieri, Masi, Ducci and Marsella 1988; Kiese-Himmel 2002), but at least one study of preschool-age children identified specific language deficits (Sedey et al. 2005).

Approximately a decade following the publication of the landmark Bess studies on children with UHL, Bess and colleagues broadened their investigation to include children with permanent, minimal bilateral hearing loss (MBHL; Bess et al. 1998). The psychoeducational findings from that study were remarkably similar to those from the study of children with UHL. That is, the expanded group of school-age children with MBHL and UHL, on average, had an academic failure rate of approximately 37% with an additional 8% requiring resource assistance. The Comprehensive Test of Basic Skills revealed that these children, at the third grade level, had significantly lower scores than their normal-hearing peers on sub-tests of reading, language mechanics, word analysis, spelling and science. Similarly, a report from the Third National Health and Nutrition Examination Survey (NHANES-III) revealed that children aged 6–16 years with UHL or MBHL were twice as likely to score two standard deviations below the norm on standardized math and reading tests than normal hearing children (Ross, Visser, Holstrum and Kenneson 2005).

Most studies that examined speech and language abilities of children with MBHL included them as part of a larger group of children with greater degrees of loss. For example, Blair and colleagues (Blair, Peterson and Viehweg 1985) compared a group of children with mild bilateral hearing loss (25–45 dB in the better ear) with their normal hearing peers. They found that the vocabulary, reading, comprehension and language use of the children with mild hearing loss was lagging behind that of their normal hearing peers. Likewise, Davis, Elfenbein, Schum and Bentler (1986) found that children with mild bilateral hearing loss (< 45 dB PTA) had receptive vocabulary, verbal ability and reasoning scores that were more than one standard deviation below the mean. In addition, numerous investigators have reported behavior problems in children with UHL relative to children with normal hearing (Keller and Bundy 1980; Stein 1983; Bess et al. 1986; Oyler et al. 1988; Brookhauser et al. 1991; Dancer et al. 1995; English and Church 1999), although this has not been a universal finding (Colleti, Fiorino, Carner and Rizzi 1988).

In addition to traditional psychoeducational and speech-language evaluations, Bess and colleagues utilized functional health status assessments, the Cooperative Information Project Adolescent Chart Method (COOP; Nelson et al. 1987; Nelson, Wasson, Johnson
and Hays 1996). These charts were designed to assess the domains of physical, emotional, and social functionality. The COOP scores revealed that school-age children with MBHL and UHL had self-perceived deficits in the areas of energy, stress, social support, self-esteem and behavior (Bess et al. 1998).

The findings from the COOP evaluations led to an interest in examining listening effort and fatigue in children with minimal to moderate degrees of bilateral hearing loss. Listening effort refers to the attentional requirements necessary to understand speech (Downs 1982; Feuerstein 1988) and fatigue refers to the weariness that results from exertion, either physical or mental. When considering children with hearing loss, we are interested in the potential for mental fatigue that relates to one’s ability to attend or concentrate and contributes to a general feeling of being tired (Grandjean 1979; Kennedy 1988). Bourland-Hicks and Tharpe (2002) utilized salivary-cortisol measures to examine fatigue and a dual-task paradigm (visual attention and listening-in-noise tasks) to examine listening effort. Neither cortisol measurements nor self-rated measures of fatigue revealed significant differences between children with minimal to moderate degrees of hearing loss and their normal-hearing peers. However, the dual-task paradigm utilized to study listening effort indicated that children with hearing loss in this study expended more effort in listening than children with normal hearing. In dual-task paradigms, a decrease in performance on the secondary task has been related to the amount of effort expended in performing the primary task (Broadbent 1958). The primary task in this paradigm was a speech recognition measure in quiet and noise conditions (+10, +15, +20 dB), while the secondary task was a visual attention measure requiring the children to push a button whenever a small light-emitting diode (LED) was activated. Reaction times in pushing the button for the activated LED were significantly slower in all conditions for the children with hearing loss relative to the children with normal hearing. Therefore, the children with hearing loss were presumed to be expending more effort in performing the word repetition task than their normal hearing peers. The authors concluded that it is reasonable to expect students with minimal to moderate degrees of hearing loss will have similar expenditures of listening effort in the “real world” as those children under experimental conditions. That is, children are asked to perform multiple tasks in the classroom while listening to their teacher – tasks that can include note taking, answering questions, and/or following directions. Therefore, it is likely that secondary task performance (e.g., following directions, taking notes, etc.) might be compromised.

What We Don’t Know

Despite the fact that audiologists and educators are better informed about the potential impact of MBHL and UHL on children today than they were in the 1980s (Reeve, Davis and Hind 2001; McKay 2002), it does not appear that the psychoeducational outcomes for these children are, on average, any brighter (Dancer et al. 1995; English and Church 1999). That is, even though more children with MBHL and UHL appear to be receiving audiological and related services than ever before, academic difficulties persist in this group. Therefore, it has been speculated that other factors in addition to hearing loss alone may be at play. Keeping in mind that the majority of children with MBHL and UHL demonstrate no academic, speech, language or behavior problems, there must exist some contributing or predictive factors not yet identified that affect those children who do not fare as well. For example, the etiology of the hearing loss, rather than the hearing loss itself, might be an indicator of potential deficits. Consider that approximately 10,000 to 80,000 infants are born in the United States each year with congenital cytomegalovirus (CMV) infection (Stagno et al. 1986; Noyola, Demmler and Nelson 2001) making CMV the most common congenital viral infection and the leading cause of prelinguistic hearing loss in children (Nance 2007). Nance posited that the neurologic deficits associated with CMV might be to blame for the poor academic performance of children with UHL secondary to infection, rather than the hearing loss per se. At this time, we have not been able to make a convincing link between the academic difficulties of children with MBHL or UHL and CMV, or any other causative factor. However, should this speculation hold true, there is the implication that intervention strategies would need to encompass more than improvement of classroom acoustics or speech perception and that specific educational and speech/language interventions would also need to be explored.

Another possible contributing factor to the academic difficulties experienced by these children could be their late age of identification and/or intervention. Although hearing loss of moderate or greater degree can be identified in the newborn period, universal newborn screening protocols do not target hearing loss in the minimal to mild range (Joint Committee on Infant Hear-
who are at greatest risk for psychoeductional difficulty might be effective. Until such time that those children will be negatively affected or which interventions difficulty, at this point in time, we do not know which children with MBHL or UHL will experience academic diffic-

Conclusions

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One of the most common audiologic interventions for minimal bilateral and unilateral hearing loss, frequency-modulated (FM) system technology, enhances speech perception under adverse listening conditions (Kenworthy, Klee and Tharpe 1990; Updike 1994; Flexer 1995; Tharpe, Ricketts and Sladen 2003). Various types of hearing aids have also been recommended for those with MBHL and UHL (McKay et al. 2008). However, as noted previously, there is no direct evidence that improving listening via hearing aids or FM usage for children with MBHL and UHL improves academic outcomes for these children, although one would expect that to be the case.

Although we know that more than a third of children with MBHL or UHL will experience academic difficulty, at this point in time, we do not know which children will be negatively affected or which interventions might be effective. Until such time that those children who are at greatest risk for psychoeductional difficulty can be identified, it is reasonable to institute a proactive management approach with children who have MBHL or UHL. This approach includes:

• Counseling. Audiologists can counsel families about the importance of a good acoustic environment for communication and how to create a rich language atmosphere within the home. For those with UHL, a discussion regarding safety issues related to poor localization skills should also be included. When appropriate, these discussions can include daycare professionals and schoolteachers. Keeping in mind that the effects of these losses will likely be subtle, parents might not understand that their child with MBHL or UHL hears any differently than other children. Therefore, our counseling challenge is to explain or demonstrate to families, perhaps through the use of simulations or other tools, the impact these losses may have on listening, as they may not be readily apparent.

• Etiologic Evaluation. Medical evaluation of children found with any degree or configuration of permanent hearing loss should include a search for genetic and environmental causes. As previously noted, CMV is the most common causative factor of non-genetic, pre-lingual hearing loss and must be identified during the first two to three weeks of life. Other causative factors associated with MBHL and UHL include prematurity, genetics, enlarged vestibular aquaduct (EVA), noise exposure, viral and bacterial infections, and auditory neuropathy/dysynchrony (Tharpe and Sladen 2008).

• Acoustic Modifications. Preferential seating arrangements may help to provide children with MBHL and UHL with enhanced visual and auditory cues needed for improved communication. Modifications may be needed in the home, daycare setting, and/or school environment. These modifications can be inexpensive and low-tech, like strategic placement of carpet remnants within the room, or might be high-tech, like the placement of a sound field FM system.

• Speech and Language Monitoring. Although most studies of speech and language abilities of school-age children with UHL have not identified specific deficits (Hallmo et al. 1986; Klee and Davis-Dansky 1986; Tieri et al. 1988; Kiese-Himmel 2002), at least one study found that children with UHL who failed a grade in school had significantly lower verbal IQ scores than those children with UHL who were academically successful (Klee and Davis-Dansky 1986). However, both the academically successful and unsuccessful UHL groups had verbal IQs within the normal range. Examination of the speech and language abilities of chil-
dren with MBHL has been lacking. Despite the fact that no clear pattern of speech and/or language deficits has emerged in children with MBHL or UHL, obtaining a speech and language evaluation provides a good opportunity to document baseline functioning and allows a speech-language pathologist to talk with families about how to support a language-rich home environment.

- Functional Auditory Assessments. Another source of information important to the management of MBHL and UHL is functional auditory assessment. Because the behavioral effects of such losses are often more subtle than those of greater degrees of loss, parents, educators, and other professionals may tend to overlook them and think that no problems exist. Functional auditory assessments are designed to evaluate listening behavior in real-world settings, where parents, teachers, and other caregivers spend their time with children. Tools like the Children’s Home Inventory for Listening Difficulties (CHILD; Anderson and Smaldino 2000), for use by parents, or the Screening Inventory for Targeting Educational Risk (SIFTER). Retrieved February 11, 2008, from www.hear2learn.com., can provide valuable information for assisting professionals in developing management plans for children with MBHL and UHL. For example, such tools may reveal that although a child is progressing well academically, there may be difficulty hearing under specific listening conditions (e.g., soft speech or speech in noise). Therefore, the results of functional assessment tools, in addition to other evaluations, may support the need for FM system technology or hearing aids (McKay et al. 2008). Many of the functional auditory assessment tools do not have published psychometric data at this time. Therefore, they should be considered as only one part of an assessment battery contributing to management decision making.

Children with MBHL and UHL are clearly at risk for academic difficulty. But it is important to keep in mind that not all of these children have difficulty and, at this time, we cannot predict with certainty which children will fare better than others. Furthermore, we do not have strong evidence to support specific intervention strategies, including amplification, for all children with MBHL and UHL (CDC 2005; McKay et al. 2008). Therefore, it is reasonable to monitor the auditory, speech-language, and psychoeducational progress of all children with MBHL and UHL and determine intervention strategies on an individual basis, as needed.

References


