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Review article

# A review of unilateral hearing loss and academic performance: Is it time to reassess traditional dogmata?

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ABSTRACT

*Objective:* The aim of this paper was to review traditional approaches to habilitation of unilateral hearing losses as well as new research concerning management of unilateral hearing loss.
*Data sources:* Literature review/systematic review.
*Review methods:* A PubMed search was performed for articles pertaining to unilateral hearing loss and academic loss and academic performance. Articles ranged in date from 1986 to 2012. Five resources were reviewed for content to determine the pertinence of the materials to the understanding of the history of diagnosis of unilateral hearing loss, the traditional treatment methods and their advantages and disadvantages, and more recent publications concerning academic outcomes for patients with unilateral hearing loss with and without treatment.
*Results:* Unilateral hearing loss scan be detrimental to the academic success of children. Effects encompass not only auditory effects such as difficulty hearing in noise, but also self esteem and exhaustion. Although assistive devices were traditionally not offered as options, more recent literature suggests that devices such as BAHA, hearing aids, or FM systems may provide aids in the classroom and that early intervention may provide more favorable outcomes.
*Conclusion:* Since the 1980s, the approach to management of unilateral hearing losses has evolved. In order to maximize academic potential, treatment options should be discussed and implemented.


**Contents**



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## 1. Background

Hearing impairment is one of the most prevalent congenital abnormalities in this country with approximately 1–3 per 1000 infants in the United States clinically deaf at birth and an additional 1–6 born with some milder degree of impairment [1]. According to the CDC [2], unilateral, sensorineural hearing loss is the most prevalent form of hearing loss, affecting approximately 3% of school aged children. Despite the advent of newer and more affordable technologies permitting the early identification of congenital hearing loss, a percentage of these children do not receive a proper and timely diagnosis [2]. Beyond diagnosis, early intervention and treatment may improve the function of children with unilateral hearing loss. The objectives of this literature review were to determine the supporting evidence for current clinical practices in the counseling and treatment of children with unilateral hearing loss, to review the evolving data in performance outcomes for these hearing impaired children and to determine if treatment might be a "medical necessity."

## 2. Methods

Forty-five resources were reviewed for content to determine the pertinence of the materials to the understanding of the history of diagnosis of unilateral hearing loss, the traditional treatment methods and their advantages and disadvantages, and the content results of more recent publications concerning academic outcomes for patients with unilateral hearing loss with and without treatment.

## 3. Results and discussion

### 3.1. Pitfalls at diagnosis

Newborn screening is the most effective tool available to detect congenital hearing loss, but it is mandated in only 47 states [3]. It is a screening tool, and by definition is not a complete evaluation and risks failing to detect some mild hearing losses. Parental and primary care practitioner compliance is essential to completion of a thorough and timely evaluation for a failed screen, and as a result newborns remain at risk of delay of diagnosis throughout infancy and childhood.

Prior to screening, the average age of diagnosis of UHL was 8-years old [4]. Presenting symptoms of UHL can be subtle, such as decreased babbling during the 1st year of life [5] or apparent inattention, which may not be perceived as problematic until the child reaches school age [6]. Lack of toddler/kindergarten screening programs, improper screening techniques, or misinterpretation of the results puts these children with UHL at risk for delayed diagnosis and treatment.

> "Unilateral hearing loss (UHL) of any degree can be detrimental to the growth and development of a child." [7]

Once diagnosed, the traditional dogma in management of UHL is that single-sided hearing is the "minimum requirement" or "adequate" for speech and language development [6].

Children with UHL are capable of performing well in the preschool setting with respect to speech and language development [9].

Once formal schooling begins, these same children can show subtle weaknesses that stem from their impairment. Bess and Tharpe found that students with UHL were frequently labeled as cognitively slow, unintelligent, distracted, aggressive, or misbehaved [7]. Bess and Tharpe evaluated the case histories of 60 children with UHL with particular attention to the academic and social obstacles encountered. This study revealed that 35% had failed at least one grade – most commonly observed early in their academic careers. This percentage was 10-times higher than that of the normally hearing population, in which only 3.5% of the children had ever been retained in a grade. The groups were stratified in several ways to exclude the possibility of confounding, and ultimately it was concluded that single-sided hearing was inadequate for achieving the same success in the classroom as those with binaural hearing [7]. Follow-up revealed that reasoning described for grade-retention was most commonly student "immaturity" or "hyperactivity."

A subsequent study one year later by Oyler documented similar findings after distributing a set of surveys to teachers; children with hearing impairment were disproportionately described as "underachievers" [11]. The result of this management technique was that the hearing impaired child was removed from the class with which he or she had grown comfortable and joined new students that subsequently recognize and label him or her as "different" [12] and then ostracize the "underachiever" [13].

Reuben and Schwartz [14] showed hearing to be an integral component to proper language development. Students with UHL display difficulty with receptive communication due to background noise and sound localization difficulties. Such difficulties can lead to personal embarrassment and, ultimately, social exclusion.

In a more recent study by Most et al. [15] the examiners used the Hebrew version of the SIFTER (screening instrument for targeting educational risks) to probe the effect of degree of hearing loss on academic performance. Their hypothesis was that degree of hearing loss would correlate to classroom performance and that the more significant the hearing loss, the poorer the academic performance. However, the results showed that children with greater degrees of hearing loss actually scored better academically and in participation than children with milder degrees of loss. It is possible that part of the underlying reason for the disparity may be that children with more significant hearing losses had been provided with intervention in the way of hearing aids and support services at a younger age.

A longitudinal study by Lieu et al. [9] followed 49 children aged 6 to 12years with unilateral hearing loss for 3 years. The subject group included children with both sensorineural hearing loss as well as more permanent conductive hearing losses. Standardized tests for cognition, achievement, and language were evaluated each year. They found that while language and cognition scores improved over time, the average achievement scores did not change. The authors noted that approximately 25% of subjects continued to show academic difficulty after 3 years.

> "Single-Sided Hearing is Inadequate for Development."-Culberston & Gilbert, Bess & Tharpe

For decades, studies have demonstrated single-sided hearing to be inadequate for proper development [7,10], but the mechanism has been scientifically explored only recently and is unappreciated

by a large portion of the general public as well as physicians [14]. Carron et al. [17] demonstrated through a questionnaire-based study that family practitioners, who provide a large portion of primary pediatric care nationwide, were significantly less knowledgeable about diagnosing and managing congenital hearing loss compared to pediatricians. Holstrum et al. [8] proposed that the failure to teach others of the specific difficulties that accompany UHL is heavily responsible for the slow and substandard evolution of identifying and managing those with UHL. Even when UHL is properly identified at an early age and treatments are offered, they are often imperfect and do not provide sufficient aid to create an equal opportunity at success [18]. UHL results in more than just an audiometric loss, and many of the sequelae (described below) are not compensated for with traditional hearing aid devices, thus making management difficult.

### 3.2. Loss of sound source

The most obvious difficulty sustained in living with UHL is the loss of half of the auditory receivers available to detect sound when an individual goes from two functional ears to one. If one sustains any degree of hearing loss, he or she is going to be less able to perceive sound, especially soft sounds and those that are not directed toward the functional ear. This is an aspect that can effectively be addressed with the use of hearing aids, which amplify the perceived auditory signal [19].

### 3.3. Sound shadow effects

The "sound shadow" is an effect in which the impaired ear hinders the ability of the functional ear by casting a dulling effect upon the functional ear, rendering it less sensitive to auditory signals [19]. This essentially enhances the audiometric loss that is a result of impaired sensorineural or conductive components [20].

### 3.4. Loss of sound localization

Another auditory challenge stems from the lack of a "stereo" auditory system, when one goes from two functional ears to one. Those with UHL have been demonstrated in performance studies to have significant impairment in the ability to localize sound [12,15–23]. At the minimum, this presents a safety hazard [18]. The additional effect is a failure to orient within the sound-field to optimally discriminate a signal from extraneous noise [24].

One method those with UHL employ to overcome this loss of sound localization is a phenomenon called "learned localization," which refers to an increased ability to identify from where a sound is originating as one adapts over time to UHL [25]. Although the exact process by which this compensatory mechanism occurs is unclear, it serves as a plausible explanation for the predominance of grade failures early in the academic career and a narrowing gap in success as children age. However, learned localization has not been shown to fully compensate for UHL and equal the hearing abilities of the binaural population, thus it should not be mistaken for being alone adequate for proper development [18].

### 3.5. Loss of signal from noise discrimination

The decreased ability to discriminate signal from noise is a multi-factorial problem that is due to a combination of the audiometric loss, sound shadow effects, and loss of sound localization [18]. Signal-from-noise discrimination is a practical measure of hearing function and has emerged as a key determinant for the efficacy of hearing impairment interventions [26]. Those who remain unaided or inadequately aided must rely on the ability to visualize the sound source and focus on a specific tone or quality of the sound source in order to discriminate signal-from-noise. This technique is also not as effective as binaural discrimination, and it demands a significant amount of additional effort and concentration, particularly if the source of the tone and quality of voice are similar. This increased energy requirement can affect the global functioning and well-being of these individuals [21].

### 3.6. Stress, exhaustion and self-esteem

Results of Bess' survey-study in 1998 demonstrated that some children with UHL have significantly decreased self-esteem and increased level of exhaustion and stress due to effort requirements to hear [27]. Bess' study suggests that they could potentially perform at a higher level and/or they could do so while expending much less energy. A quick search of the internet reveals multiple citations regarding "star performers." In any study population, approximately 15% may be what are considered "star performers," or those who will succeed no matter the resources or circumstances. The remaining population is 83% "moderate" performers and only 2% "poor performers;" this reflects the previously mentioned studies that the standard for grade retention is approximately 3.5%. While a subset of UHL patients who are academically successful will exist, a disproportionately large student group will risk suffering from the impairment unless modifying steps are taken, as reflected by the 10-fold increased level of "poor performers," such as the 35% grade-retention rate.

### 3.7. Incomplete bilateral cortical pathway development

According to very recently published works, the developing brain requires exposure to language models in order to promote development of higher-order cognitive and psychological pathways [28]. Cortical growth and synaptic development, requires sensory input to stimulate the pathways of development. Those with a sensory deprivation such as UHL, consequently, experience cortical reorganization [29].

One example of the impact of this differential development is the anecdotal phenomenon known as "Right Side Bias." This refers to the enhanced negative effects on development that are observed when UHL occurs on the right side as opposed to the left. To explain this phenomenon, it has been hypothesized that if someone is not receiving stimuli through the right ear, the result is a lack of development in the left-hemisphere, which is usually the site of the language center [28]. Although behavioral differences have yet to be proven in studies to be associated with an affected side, there is an undeniable structural modification that exists in UHL [29].

A similar cortical reorganization process occurs in the setting of strabismus. In the case of visual sensation deprivation, improper cortical development can be irrevocable, thus rendering the patient forever unable to detect visual stimuli that would otherwise be received by the impaired eye [30]. With early intervention, this problem is very manageable with a good prognosis [31]. While Rouger et al. showed that cochlear implantation can actually allow for cortical reorganization, the results of delay of treatment remain undefined and concerns for irreversibility persist. Studies do exist that have shown long-term use and early intervention to be beneficial [32], and these results could be explained by such a process of cortical reorganization.

### 3.8. History of treatment of unilateral hearing loss

Bess and Tharpe's work in 1986 demonstrated the academic shortcomings of those with UHL, yet English and Church [33] showed thirteen years later that still little had been done to effectively address management of this problem. Their study determined that over half of those with UHL still required special

education assistance, and nearly a quarter of those with UHL continued to perform at a significantly lower academic level than their peers [33].

### 3.9. Early intervention evaluations and programs

Despite the goals of the 2000 universal newborn hearing screening, by 2003, only 64% of children who were diagnosed with hearing loss at the newborn screening received intervention by 6 months of age [34]. While some states make services available to all children under the age of 3 years, state and regional funding for, and hence availability of, programs with audiologists, speech/language pathologists and teachers of early intervention varies and is influenced as well by periods of economic prosperity or failure.

### 3.10. Classroom design and seating

The simplest method employed to help those with hearing impairment succeed academically has been to provide them with preferential seating in the classroom. A position close to the teacher not only allows for better hearing, but it also allows the child to see the teacher and fellow classmates better so that he or she can pick up on visual cues that are often supplemental and very beneficial. While it is important to ensure that steps are taken to provide optimal settings to hear the target signal, limiting extraneous noise is just as important. This includes directing the good ear of the child away from noisy halls, and using classrooms that have permanent walls instead of temporary partitions that are easily traversed by sound waves [35]. In the Bess and Tharpe study [7], a subset of children who met criteria thought to best represent the global population of those with UHL, all those who failed a grade did so despite receiving preferential seating.

Student population size is a modifiable factor in the classroom setting that affects academic success in those with UHL [36]. In classes with fewer students, there is more individual instruction, less distraction, and an increased likelihood of proximity to the instructor. All of these components effectively increase the signal-to-noise ratio—which has been shown to benefit all students and not just those with UHL [37]. These aspects were elucidated in the Student Teacher Achievement Ratio (2001) study, which compared the academic achievements over a 4-year period by those in a "regular" sized class with a mean of 22 students per teacher and those in a "small" sized class with a mean of 15 students per teacher. The study was replicated in multiple states and consistently demonstrated an increased level of achievement by those in the small class, especially in areas where learning impairments or language barriers were prevalent [38]. Small classes are often not considered "cost-effective," and as fallout from the recent economic decline, student-to-teacher ratios have plateaued [39] and may soon rise at the expense of education.

Another variable is basic acoustic properties of the classroom. This can be influenced by construction materials, room decoration and the physical size of the classroom. The acoustics of 80% of classrooms are not in compliance with American National Standards Institute noise and reverberation standards [40]. Moreover, the prevalence of childhood obesity has doubled in America [41]. A downstream effect of this growth is that the actual size of the classroom must increase as well, and with students relegated to sitting a further away from the teacher, the signal-to-noise ratio will inevitably diminish.

### 3.11. Frequency modulated systems

Many students with UHL are managed with sound amplification devices that employ a frequency modulator (FM) system. The FM system utilizes a microphone worn by the instructor to relay sound to a speaker near a student, thus providing him or her with a more favorable signal-to-noise ratio [37]. There are multiple types of FM systems including ear level receivers as well as speaker systems. Often children with UHL utilize speakers as the use of an ear-level receiver obstructs the better hearing ear.

The benefits of speaker systems are limited by several factors, the first of which is classroom acoustics [42]. The second is system use; portable speakers require that the child bring it with him or her to each class. One obvious drawback is the physical burden; more subtle is an emotional burden as it is easily identifiable and can become a target of teasing. Many of the interventions for UHL in the past share this feature of being either inconvenient or embarrassing, which often leads to non-compliance among children who would rather struggle with their hearing impairment as an alternative to being ridiculed [43].

An alternative to the portable speaker system is to construct speakers into each classroom. This setup was subsequently found to benefit not only those with hearing impairment, but all those sitting around him or her that also enjoyed an enhanced signal-to-noise ratio [44]. However, the cost to install speaker systems into each classroom is greater than providing a single portable speaker to each impaired student. Given that each individual with UHL suffers to a different degree, this arrangement is not able to conform to the specific needs of each child for maximum benefit [44].

The personal ear-level hearing aid that includes FM capabilities has garnered much success in that it is less noticeable than the portable speaker, less expensive than installing speaker systems throughout each classroom, and is fine tuned to each individual who will utilize it [44]. Still, it is often met with the problem of non-compliance due to discomfort and embarrassment [42].

### 3.12. Amplification devices

The contralateral routing of signal (CROS) amplification device has proven to be of particular benefit in quiet settings. In noisy settings its efficacy is hindered due to amplification of extraneous noise that drowns out the intended signal. As with the traditional ear-level FM device, the appearance of the CROS amplification headset has suffered complaints of discomfort and unpleasant esthetics [45].

The most recent development to assist those with UHL is the bone-anchored hearing amplification (BAHA®) device. This device utilizes implantation of a titanium screw into the bone of the impaired ear that becomes osseointegrated over the course of several months. It is connected to an abutment that traverses the skin and connects to a microphone/sound transmitter. The transmitter receives sound vibrations and transduces it to the titanium implant, which then vibrates the temporal bone, conducting sound directly to the inner ear. Having bypassed the external and middle ear compartments, the signal can then be relayed to the functional cochlea to hear – providing binaural hearing to those patients with ipsilateral conductive hearing loss and providing a contralateral microphone to an only-hearing ear in patients with sensorineural hearing loss [46]. The internalized segment of the BAHA® is completely out of sight, bypasses the layer of skin that lies overtop the bone providing less interference and clearer amplification, and its users report decreased discomfort levels compared to the traditional conduction aid [47]. This device has proven superior to the traditional conductive hearing aid in audiologic measures as well as comfort and satisfaction when compared to traditional externally worn devices [48]. Primary drawbacks include the need for essentially irreversible surgical placement of the titanium implant and local skin irritation and scar formation.

### 3.13. Medical necessity of treatment of UHL

The journey to get insurance coverage for assistive technology for UHL has been long and arduous. "Medical necessity" is a term that appeared in the 1960s from the insurance industry [49]; definitions include: "Services or supplies that are needed for the diagnosis or treatment of your medical condition and meet accepted standards of medical practice (About.com)," "Services or items reasonable and necessary for the diagnosis or treatment of illness or injury or to improve the functioning of a malformed body member [50] (CMS)." While "potentially beneficial but not harmful" used to be sufficient to meet the standards of medical necessity, now a multitude of stringent criteria must be met before insurance agencies will cover interventions. Treatment of UHL is often denied because it does not meet the modern criteria; in summation, since it is not a cure, it is unworthy of financial risk [49].

### 3.14. Revising the modern approach

This review of the published works over the last three generations of researchers in audiology, otolaryngology and speech pathology is in no way meant to be definitive. In a review of this magnitude, thorough discussion of the scrutiny of each study is impossible to include. However, these researchers, who are pillars in their fields, have published these works often in isolation. Taken comprehensively, they are all pointing toward a need to redesign our practices as clinicians and to be sure to tailor rehabilitative programs for our individual patients.

## 4. Conclusions

If one accepts that the goals of the provision of medical care to children include the removal of barriers to cognitive, academic and psychosocial development, then logically the same principles should apply to UHL since evidence supports a dependency of complex cognitive development upon optimal hearing, including preferentially restoring adequate bilateral hearing if possible. Therefore, patients with UHL should be properly considered as medically impaired and to benefit from appropriate steps in evaluation and management at an early age.

As has been discussed in detail, the traditional dogma for the minimalist approach to management of the patient with UHL should be re-examined and modified by current evidence. The ideal treatment modality for each individual may vary depending upon the specific needs of the patient. With any treatment modality, early intervention may be the key to maximum benefit, and the student/patient will likely benefit tremendously by removal of obstacles to the acquisition of the necessary devices and services.

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This was an unfunded project and there are no conflicts of interest to be disclosed.

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