Children with Unilateral Hearing Loss

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The present study examined the medical and educational status as well as the auditory skills of children with unilateral hearing loss. Medical and educational information was obtained via parental interview and/or school records. Auditory skills were assessed by a test battery designed to examine sound localization and syllable recognition abilities in a sound field setting. The results revealed that approximately one-third of the children with unilateral hearing loss had failed at least one grade. Almost 50 percent of the unilaterally hearing-impaired group had either failed a grade and/or needed resource assistance in the schools. The children with unilateral hearing loss performed much poorer than a matched group of normally hearing children on both the localization and syllable recognition tasks. There is an urgent need to re-examine current thinking on this population.

Many physicians, audiologists and special educators hold the widespread view that children with unilateral hearing loss experience few, if any, communicative or educational difficulties. The typical management strategy for this population is to identify the loss, counsel the parents to assure them that no significant problem exists, recommend classroom seating preference, and occasionally recommend the use of a CROS-type hearing aid on a trial basis. Perhaps the state-of-the-art for this population can best be demonstrated with a recent statement by Northern and Downs (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" (p. 143). As a result of this long-standing clinical premise, children with unilateral hearing loss are not considered educationally handicapped and seldom receive special attention in the classroom setting.

Despite the general impression that unilateral hearing loss is not a serious educational problem, there is a dearth of experimental evidence to support

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such an assumption. In fact, the findings of available research conducted primarily with adults, suggest that persons with only one good ear experience a variety of listening difficulties. Predictably, the greatest problem in hearing and understanding speech occurs when speech originates on the impaired side while a competing message or noise originates on the good side. Other problems commonly noted by unilateral hearing-impaired subjects include difficulty understanding speech originating from the impaired side when the normal ear is not receiving competing signals and difficulty attempting to locate a signal source. Furthermore, individuals with unilateral hearing loss have reported experiencing feelings of embarrassment, annoyance, confusion, and helplessness (Giolas & Wark, 1967).

Some of the problems that are experienced by subjects with unilateral hearing loss can be explained, in part, by the binaural phenomenon; that is, two ears providing a listening advantage over one ear alone. Binaural factors that contribute to a listening advantage include binaural summation (Keys, 1947; Shaw, Newman & Hirsh, 1947; Pollack, 1948), head shadow effects (Tillman, Kasten & Horner, 1963; Olsen, 1965; Olsen & Carhart, 1967), squelch effects (Norlund & Fritzell, 1963; Harris, 1965), and localization (Markides, 1977; Konkle & Schwartz, 1981).

Based on the findings with adults, it is not unreasonable to suspect that children with unilateral hearing loss may also encounter similar listening difficulties, particularly in the school setting. Such listening problems could possibly preclude the development of language and other communicative skills that are critical to the child's learning potential.

There is also some indirect evidence, albeit limited, that would suggest unilaterally hearing-impaired children experience some difficulties in the schools. Quiqley and Thomure (1968) reported that children with slight hearing losses demonstrated some language delay and also noted that "a number of the students had unilateral impairment." In another study, Boyd (1974) examined the educational effects of hearing loss on achievement and found that the small group of children with unilateral hearing loss demonstrated lags in academic achievement. Specifically, 38 percent exhibited reading problems, 31 percent had spelling problems, and 23 percent were found to have problems in arithmetic. Finally, at the Bill Wilkerson Hearing and Speech Center we have noticed that some children with unilateral hearing loss have experienced difficulties in the educational setting (Bess & McConnell, 1981).

Thus, there appears to be sufficient evidence to indicate that children with unilateral hearing loss could experience difficulties under various listening conditions that might compromise the normal development of language and auditory perceptual skills. This study was designed to examine in a more comprehensive fashion the auditory and linguistic performance of children with unilateral hearing loss. Data in this report represents only a portion of the findings from a larger study concerned with the auditory and psycholinguistic skills of unilaterally hearing-impaired children.

METHOD

The study was divided into two basic experiments. First, 60 children with unilateral hearing loss were selected from the patient files of the Bill Wilkerson Hearing and Speech Center, the files of the Nashville Metropolitan School System, and other local educational agencies in the mid-Tennessee region. These children ranged in age from six to 18 years with a mean age of 13 years. Forty-five percent of the subjects were males whereas 55 percent of the subjects were females. Medical and educational case history data were then obtained via parental interview and/or school records.

The second portion of the study involved selecting 25 of the 60 unilaterally hearing-impaired children for a more comprehensive examination of their auditory and linguistic skills. A matched group of 25 normally hearing children was also selected for this part of the investigation. The following criteria were used in the selection of the group with monaural hearing loss:

1. Age range between 6 and 13 years.
2. Hearing thresholds in the good ear no poorer than 15 dB (re: ANSI, 1969) through the speech frequency range (500-2000 Hz) with a monaural word recognition score above 90 percent as determined by one of three age appropriate tests: Word Intelligibility by Picture Identification (WIPI); the Phonetically Balanced Word List (PBK-50); or the Northwestern Auditory Test No. 6 (NU-6).
3. Hearing thresholds in the impaired ear no better than 45 dB (re: ANSI, 1969) through the speech frequency range (500-2000 Hz) and/or a monaural word recognition score no better than 50 percent.
4. Presence of the hearing impairment for at least three years as reported by the parent.
5. A negative case history of recurring episodes of middle ear effusion in the good ear.
6. Normal intelligence as determined by a licensed psychological examiner.
7. No evidence of central auditory dysfunction.
8. Normal growth and development and freedom from other significant medical problems.

Criteria for the normally hearing subjects included hearing thresholds no poorer than 15 dB (re: ANSI, 1969) bilaterally at octave intervals 250-8000 Hz, normal tympanometry in both ears, normal intelligence as determined by a licensed psychological examiner, normal auditory perceptual abilities, and a negative history of otitis media. These two groups of subjects were then matched for age, sex, intelligence, race, and socioeconomic status. Both groups received a test battery designed to assess auditory skills, cognitive and educational achievement, and language skills. The data to be reported herein represent some of the initial findings from tests on localization and syllable recognition — the test battery used to assess auditory skills.

Sound Localization

Localization skills were assessed in a large anechoic chamber (6m × 6m × 6m) at the Bill Wilkerson Hearing and Speech Center. The apparatus used for sound localization has been detailed in an earlier study (Humes, Allen, & Bess, 1980). Briefly, the stimuli consisted of pure tones (500 Hz, 3000 Hz) generated by an oscillator (General Radio Model 1310B), attenuated (Coulbourn Instruments Model S85-08), gated by an electronic switch (Grason-Stadler Model 1287B) in association with interval timers (Grason-Stadler Model 1216-A), amplified (Grason-Stadler Model 1288), and delivered to a series of 13 loudspeakers. The 13 speakers were separated by 15 degree intervals, mounted on a light framework, and placed on an arc of 180 degrees in a horizontal plane at ear level. The signals, which maintained an on-off time of 500 ms, were presented at a sound pressure level of 60 dB. Both the frequency and the intensity level of the signal were monitored on a continual basis.

Prior to each presentation a warning light flashed to ready the subject for the listening task. A single trial consisted of delivering four tone pulses to one of 13 speakers in a random fashion. The subject was instructed to maintain head fixation until the termination of the trial. The subject then reportedly verbally which of the various loudspeakers (clearly numbered) was activated. This procedure was repeated four times for each experimental condition (500 Hz and 3000 Hz). For the analysis, the initial trial was discarded and only the final three trials were considered in the computation of the error indices.

The localization data were scored using the procedure that was developed by Gardner and Gardner (1973) and employed recently by Humes et al. (1980). Briefly, the score is obtained for each subject by determining the number of speakers from the sound source the subject was in error. This error score is then divided by the error score due to guessing, thus yielding an error index value. An error index of 1.0 depicts random guessing whereas an index value of 0.0 would mean perfect localization performance.

Syllable Recognition

Syllable recognition ability was assessed using the original male-talker recording of the Nonsense Syllable Test (NST) (Levitt & Resnick, 1978). A preliminary study with these materials revealed that children between the ages of six and 13 years performed similarly to an adult population (Bess & Gibler, 1981). The NST is comprised of consonant-vowel and vowel-consonant syllables categorized into seven subtests of seven to nine syllables each. These subtests differ in several ways: (a) the class of consonants represented (voiced and voiceless); (b) the position of the consonants (initial and final); and (c) the vowel context. The format is a closed set, forced choice test, and the subject's response to a syllable presentation is limited to syllables within the same subtest. The test is comprised of 62 items which include one repeat item within each subtest (actual items = 55). The carrier phrase "you will mark _____ please" is used with each stimulus syllable. By scrambling the syllables within subtests as well as the order of the subtests, eight different forms or "modules" of the test have been produced.

The instrumentation used to present the speech material included a tape recorder (Revox-A-77) that was fed to one of several calibrated diagnostic audiometers (Amplaid 300, Grason-Stadler 1701, Grason-Stadler 1704) whose output was then routed to two loudspeakers. Calibration of the speech testing apparatus was checked periodically throughout the experiment. All testing was conducted in two-room sound treated test suites specifically designed for threshold measurements.

Each subject was placed in the center of the acoustically treated room. The two speakers were located at 45 degrees from midline at a distance of 72 inches from the head. The primary speaker signal was presented at a level of 65 dB sound pressure level (SPL). A cafeteria noise was used to achieve the desired primary to secondary (P:S) ratios (+20, +10, 0, -20). A quiet condition was also employed.

The unilaterally hearing -impaired children were evaluated in a monaural direct (MD) condition (speech to the good ear and noise to the impaired ear) and a monaural indirect (MI) condition (noise to good ear and speech to the impaired ear). The normal hearing children were assessed in the MD condition (speech to the right ear and noise to the left ear) only.

The order of presentation for the P:S conditions was determined by random selection. Subjects were instructed to look straight ahead, listen carefully to the primary speaker, and circle the appropriate syllable response on the answer sheets. Subjects verbally demonstrated their ability to read and/or produce orally all stimulus items and were provided a brief practice period prior to beginning the task. The children were encouraged to guess when necessary. Frequent breaks were permitted throughout the testing sequence. The performance data for each subject represent an average percent score on each subtest, weighted by the number of items per subtest, and corrected for random guessing.

RESULTS AND DISCUSSION

Experiment I

The suspect etiologies for the 60 children with audiologically confirmed unilateral hearing loss, shown in Table 1 indicate that etiology was unknown in 51.7 percent of the subjects. This finding is consistent with previously reported studies on unilateral hearing loss (Kinney, 1953; Everberg, 1960; Tarkkanen & Aho, 1966). The most highly suspect etiologies were viral complications in 26.7 percent of the group followed by meningitis and head trauma.

Table 1

Suspected Etiologies for 60 Children With Unilateral Hearing Loss
(Some Children Presented More than One Possible Etiology)

Etiology	Percent
Unknown	51.7
Viral Complications	26.7
Meningitis	13.3
Head Trauma	8.3
Anoxia	1.7
Low Birth Weight	1.7
Hyperbilirubinemia	1.7
Hypoglycemia/Hypocalcimia	1.7
Pneumonia	1.7

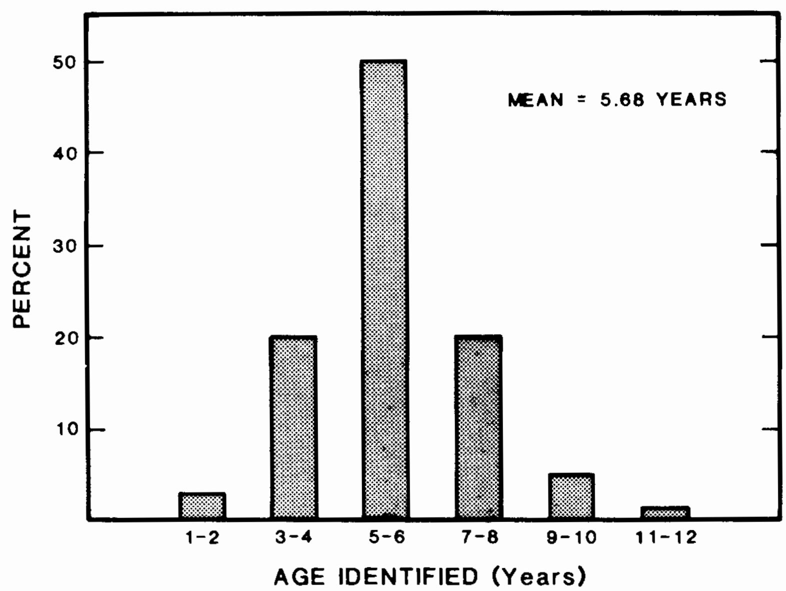

Figure 1. Percentage distribution showing the ages at which 60 children with unilateral hearing loss were identified.

The age at which the unilaterally hearing-impaired children were identified is shown in Figure 1. As noted from this figure, the vast majority of the children were identified between the ages of five and six years. Only 23 percent of the children had their hearing loss identified prior to five years of age whereas 26 percent were not identified until seven years or older. The mean age of identification was 5.7 years. These results suggest that most unilateral hearing impairments are detected at the initial screening program in the schools. Those children who were not identified until later may have acquired their hearing loss after the completion of the first grade. These findings on age of identification are similar to those reported by other investigators (Everberg, 1960; Tarkkanen & Aho, 1966).

It is of considerable interest to examine the educational progress of these children. The case history information revealed that 35 percent of the 60 unilaterally hearing-impaired children failed one or more grades. This percentage value is in contrast to only 3.5 percent of the Nashville public school population in grades kindergarten through six that fail a grade. It is also significant to note that many children, although not required to repeat a grade, were in need of resource help in the public schools. Hence, if one considers the number of students who had sufficient difficulty in the classroom to warrant either resource assistance or a grade repetition, it would encompass 48.3 percent of the hearing-impaired children in the subject population. This finding was indeed surprising since it has long been assumed that children with unilateral hearing loss would have few, if any, problems in school. It thus appears that the listening difficulties imposed by a unilateral hearing impairment often have an effect on the individual's classroom performance. Since all of the hearing-impaired children in this study were receiving preferential classroom seating, it can be concluded that greater efforts are needed to help them overcome the apparent listening difficulties they encounter in the educational setting. Finally, a distribution of the grades failed by the unilaterally hearing-impaired children is shown in Figure 2. Most of the subjects failed at the first grade level, although approximately one-half of the subjects failed grades above the first year.

Experiment II

This portion of the study compared the sound localization and syllable recognition performance of 25 unilaterally hearing-impaired children to that of a matched group of normal hearing listeners.[1] Interestingly, much of the pertinent case history information (causation, age of identification, educational progress) for this subgroup of hearing-impaired children was similar to that obtained on the total group of 60 subjects. For instance, 32 percent of

[1]Sound localization skills were assessed on 20 of the experimental subjects and 20 matched control subjects. Syllable recognition scores were available on only 17 of the subjects and their matches at the time of this writing.

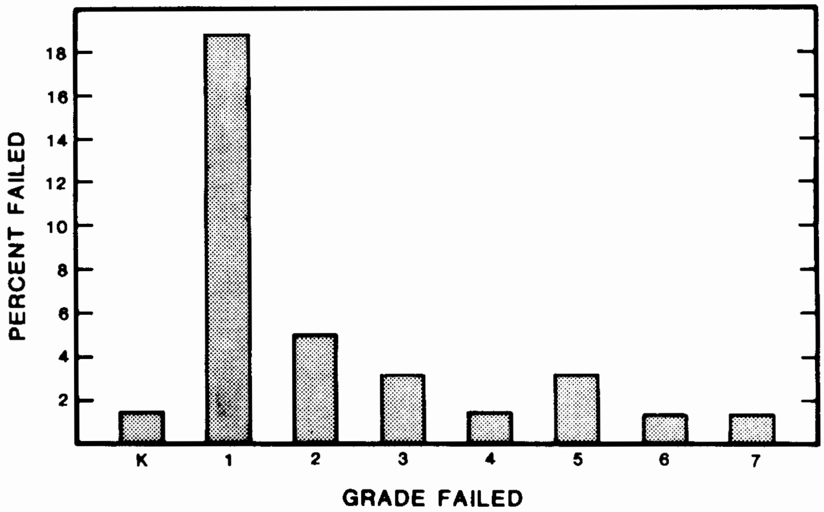

Figure 2. Percentage distribution showing the grades failed by 60 children with unilateral hearing loss. One child failed two grades.

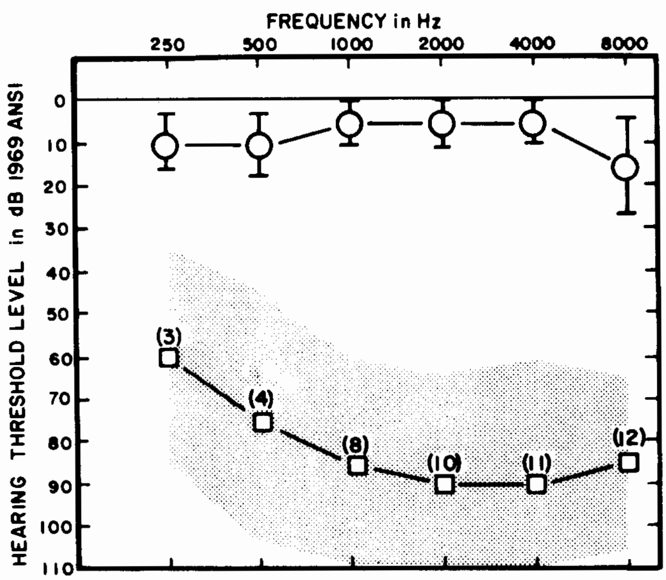

Figure 3. Audiogram depicting mean hearing threshold values for the normal ears (open circles) and the impaired ears (squares) on 25 children with unilateral hearing loss. Vertical bars represent standard deviations (±1 S.D.) for the normal ears and the shaded area represents the standard deviations (±1 S.D.) for the impaired ears. The numerical values at each test frequency depict the number of ears that failed to yield a response at the maximum output of the audiometer.

the 25 children failed at least one grade whereas none of their matched counterparts had to repeat a grade.

A composite audiogram for the normal and impaired ears of the 25 experimental subjects is shown in Figure 3. The data points represent mean hearing threshold levels, and the associated numbers in parentheses represent those ears that exhibited no responses at that particular frequency. The vertical bars depict the standard deviations (±1 S.D.) for the normal ears whereas the shaded area shows the standard deviations (±1 S.D.) obtained for the impaired ears.

The findings obtained for sound localization are shown in Figure 4. This figure illustrates the mean error indices and standard deviations at each experimental condition for 20 of the normal and 20 of the hearing-impaired children. Mean error index values taken from another study for normal hearing adults are also provided for comparison (Humes et al., 1980).

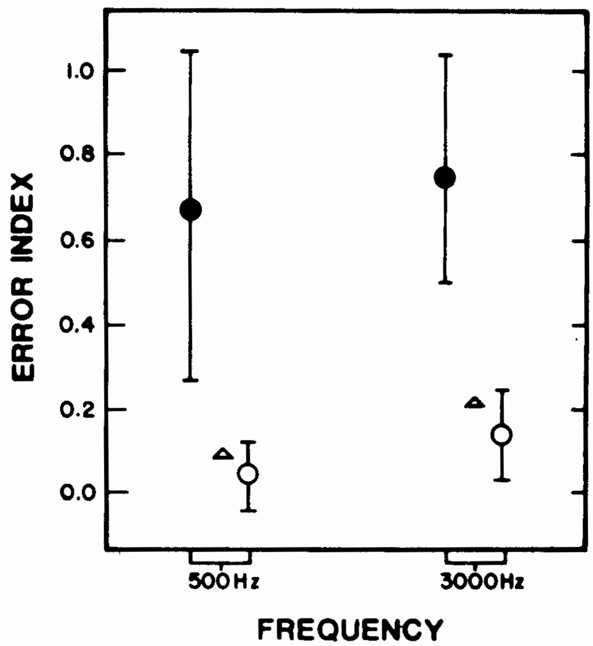

Figure 4. Mean error index values and standard deviations for the hearing-impaired (solid circles; N = 20) and normal hearing children (open circles; N = 20) at the two experimental conditions. Data for an adult population is also provided (triangles).

This figure illustrates several interesting points. First, the hearing-impaired subjects exhibited considerably higher error index scores than their normal hearing counterparts. Second, both the normal and hearing-impaired subjects showed greater difficulty localizing to a high frequency signal than a low frequency one. Third, there was considerable variability among the hearing-impaired subjects as exhibited by the large standard deviations. The wide variability in localization skills may have been due to differences in the hearing threshold levels of the impaired ears. Both Viehweg and Campbell (1960) and Humes et al. (1980) have suggested a relationship between the degree of hearing impairment and localization skills. That is, the more severe the hearing loss the poorer the localization performance. A preliminary analysis of the present data supports a relationship between the degree of hearing level in the impaired ear and the error index score. For the experimental condition 500 Hz, a significantly positive correlation of .78 ($<.001$) was obtained, whereas at 3000 Hz (average hearing loss at 2000 Hz and 4000 Hz), the correlation was .51 ($<.05$). Finally, also shown in Figure 4, the localization skills of the normal hearers were similar to those of an adult population.

Figure 5 depicts the mean syllable recognition scores in percent correct for both the normal (N = 17) and hearing-impaired children (N = 17) at several different P:S ratios and in quiet. These findings illustrate that the unilaterally hearing-impaired children exhibited considerably more difficulty than the normal hearers under all listening conditions. A somewhat unexpected finding was that the unilaterally hearing-impaired children performed poorer than the normal hearers under all MD conditions. That is, even when the primary signal was directed to the good ear with noise striking the poor ear at full impact, unilaterally hearing-impaired subjects did not perform as well as their normal peers. It is also apparent from this figure that the unilaterally hearing-impaired child exhibits considerable difficulty coping with an adverse listening condition. The more adverse the listening condition, the greater the discrepancy between the normal listeners and the unilaterally hearing-impaired children. In the MI condition, the children with unilateral hearing loss showed a rather marked breakdown in syllable identification even under the more favorable P:S ratios.

CONCLUSIONS

It is generally believed that a unilateral hearing impairment does not produce a handicapping condition for children. The preliminary findings from this study, however, would suggest that we have long been operating under a false assumption. That is, it seems clear that children with unilateral hearing impairment do experience a variety of difficult listening complications that may be compromising their educational progress. In a survey of 60 monaurally hearing-impaired children it was found that 35 percent had failed at least one grade in the schools. In addition, if one also considers those subjects who are in need of resource help the total number experiencing difficulty increases to almost 50 percent.

In view of previous assumptions regarding children with unilateral hearing

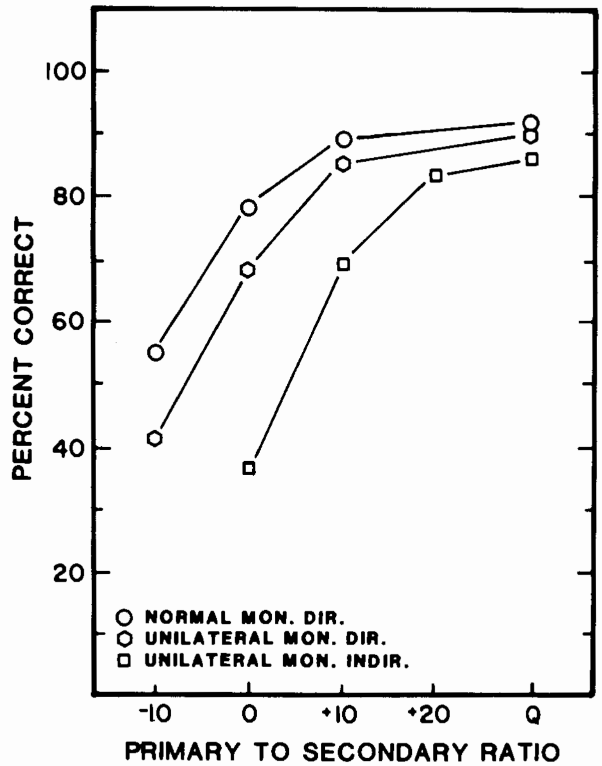

Figure 5. Mean sound field composite scores (in percent) on the NST across several P:S ratios for normal children (N = 17) and children with unilateral hearing loss (N = 17). The hearing-impaired children were assessed in the monaural direct and monaural indirect conditions whereas the normal hearing children were tested in the monaural direct condition only.

loss, it is only natural to pose the question, "Why do these children experience educational problems?" The data presented on auditory skills may help, in part, to answer that question. The localization of sound in space is recognized as a very basic and fundamental auditory skill, yet the unilaterally hearing-impaired children in this study performed significantly poorer on these tasks than did the normal listeners. These findings are consistent with some of the previous work on sound localization in unilaterally hearing-impaired individuals (Viehweg & Campbell, 1960; Nordlund, 1964; Humes et al., 1980).

This study also demonstrated clearly that children with unilateral hearing loss experience considerable difficulty understanding speech in the presence of a competing message. Perhaps the most significant finding was that the unilateral hearing-impaired children performed poorer than the normal listeners even when the primary signal was presented to the good ear. In considering these data, one cannot help but question the value of classroom seating preference. These findings also suggest that unilaterally hearing-impaired children will experience difficulty communicating efficiently in a classroom environment.

Certainly, there are other factors that may be contributing in some unknown and complicated way to the problems of these children. For instance, there are a number of animal studies that have reported subtle degenerative changes in the central nervous system following auditory deprivation (Greenough, 1975; Webster & Webster, 1977, 1979; Clopton & Silverman, 1977). Whether in fact such subtle changes could affect learning, however, and even more pertinent, whether such changes actually occur in humans have not been established. Indeed, the effects of auditory deprivation on humans is an area that is deserving of further inquiry. Other causative factors that may be operating are the complications that produced the hearing impairment. Certain prenatal and perinatal conditions are known to produce damage not only to the cochlear and eighth nerve but also to the central auditory pathways (Johnston, Angara, Baumal, Hawke, Johnson, Keet, & Wood, 1967; Overall, 1970; Carhart, 1967; Sells, Carpenter & Ray, 1975; Ferry, Cooper, Sitton, Sell, & Culbertson, 1981). Whatever the reason or reasons for the problems exhibited by these children with monaural deafness, there is no doubt that they do exist and that the prevalence is greater than originally suspected.

To summarize then, it has been shown that children with unilateral hearing loss experience considerably more difficulty in communication and in education than was previously supposed. Obviously, there is a significant need to re-examine the basic assumptions underlying the identification and educational management of this population.

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