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Adult-Onset Auditory Deprivation

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Abstract

Adult-onset auditory deprivation following prolonged lack of amplification in the unaided ears of persons with bilaterally symmetrical sensorineural hearing impairment was first reported in 1984. This article on the phenomenon includes a review of the literature on adult-onset auditory deprivation in relation to etiology, pathophysiology, hearing-loss manifestations, typical audiologic profile, amplification strategies, contraindications or challenges to conventional hearing-aid fitting, and future research. A case study illustrates the phenomenon of auditory deprivation from monaural amplification with recovery following binaural amplification. The results of a complete audiologic and acoustic-immittance evaluation are presented for a bilaterally sensorineural hearing-impaired male with adult-onset auditory deprivation who initially was fit monaurally and later was fit binaurally. A significant decrement in the suprathreshold word-recognition scores occurred only in the unaided ear following monaural amplification, illustrating the phenomenon of adult-onset auditory deprivation. Following binaural amplification, the suprathreshold word-recognition scores for the formerly unaided ear improved significantly, illustrating the phenomenon of recovery from the adult-onset auditory deprivation with binaural amplification.

Key Words: Auditory deprivation, binaural amplification, hearing aids, monaural amplification, sensorineural hearing impairment, suprathreshold word-recognition score

Prolonged lack of amplification in the unaided ears of persons with bilaterally symmetric sensorineural hearing impairment (BSSHI) appears to be the basis for the phenomenon of adult-onset auditory deprivation. The phenomenon was first reported in 1984 by Silman, Gelfand, and Silverman. Unlike the auditory deprivation phenomenon resulting from congenital or early onset hearing impairment in childhood, this adult-onset phenomenon occurs long after any critical period for auditory stimulation (Stein and Schuckman, 1973; McGinn and Henry, 1975; Webster and Webster, 1977).

NATURE OF ADULT-ONSET AUDITORY DEPRIVATION

Auditory deprivation, from lack of amplification in adults with BSSHI who are fitted monaurally, is manifest as a decrement in the suprathreshold speech-recognition score. It is usually unaccompanied by significant changes in the pure-tone hearing threshold levels or speech-recognition thresholds. Adverse effects on the speech-recognition threshold in noise, however, may be observed (Gatehouse, 1989a, b).

Auditory-deprivation effects have been observed in approximately 40 percent of persons with BSSHI fitted monaurally (Silman et al, 1984; Hurley, 1991). Two studies suggest that auditory-deprivation effects may also occur in the unaided ears of persons with mixed hearing impairment (Dieroff and Meibner, 1989; Dieroff, 1990). The auditory-deprivation effect associated with lack of binaural amplification in persons with asymmetrical, sensorineural hearing impairment has not yet been investigated. As the duration of lack of binaural amplification increases, the magnitude of the auditory-deprivation effect appears to increase (Stubblefield and Nye, 1989).

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The existence of auditory-deprivation effects in the bilaterally unaided ears of persons with BSSHI is unresolved (Gelfand et al, 1987; Stubblefield and Nye, 1989). Auditory-deprivation effects have not been observed in the aided ears of monaurally or binaurally fitted persons with BSSHI (Silman et al, 1984; Gelfand et al, 1987; Stubblefield and Nye, 1989; Hurley, 1991).

Etiology

The onset of the auditory-deprivation effect is variable, occurring approximately 1 to 12 years post monaural hearing-aid fitting with 4 years post fitting as the average time of onset. The findings of two recent reports, however, indicate that auditory-deprivation effects may be observed with speech-in-noise materials presented at suprathreshold levels in less than 3 months post monaural hearing-aid fitting (Gatehouse, 1991, in press).

Pathophysiology

According to Silman et al (1984), the underlying mechanism(s) of the auditory-deprivation effect are unclear. The effect may reflect structural changes and/or physiologic aberrations at the peripheral and/or central levels of the auditory system, and/or changes in perceptual functioning. Hurley (1991) hypothesized that the effect results from cochlear disuse leading to auditory brainstem dysfunction or central suppression leading to cochlear dysfunction. Gatehouse (1989a, b) initially interpreted the auditory-deprivation effect in terms of an acclimatization or habituation effect to the presentation level of speech to which the ear (unaided) is typically exposed. Later, however, Gatehouse (1991, in press) used the term auditory deprivation to describe the decrement in speech-recognition ability in the unaided ears of monaurally fitted subjects. Hood (1990) hypothesized that Silman et al's (1984) findings resulted from auditory deprivation or neglect. He further suggested that a contributing factor could be the lack of central binaural integration, which would accrue from binaural amplification. All of these hypotheses are speculative, however, as there are no direct anatomic and physiologic data on late-onset auditory deprivation at this time.

HEARING LOSS MANIFESTATIONS

Silman et al (1984), in a retrospective study of adult males with BSSHI consistent with a noise-induced origin, reported that at approximately 4 to 5 years post hearing-aid fitting, the W-22 Suprathreshold Word-Recognition Scores (SWRS), using 50-word, taped lists, decreased significantly (below the 95% critical-differences lower limit established by Thornton and Raffin, 1978) under earphones in 39 percent of the unaided ears as compared with only 4 percent of the aided ears of the monaurally fitted group. The average decrement in the SWRS in the unaided ears was 18.5 percent as compared with only 2.6 percent in the aided ears of the monaurally fitted group. These results were essentially unchanged after the effects of age and hearing sensitivity were parcelled out. An auditory-deprivation effect was absent in both ears of the binaurally fitted subjects.

Hood's (1984, 1990) data indirectly support the concept of auditory deprivation. He found that the SWRSs of the impaired ears (under phones) of persons with unilateral sensorineural hearing impairment due to Meniere's disease were lower than those of matched ears of persons with bilateral Meniere's disease. Also, the SWRSs of the poorer ears were markedly poorer than those of the better ears of persons with only slightly asymmetrical, sensorineural hearing impairment due to Meniere's disease. Hood concluded that these subjects made dominant use of the better ear to the neglect of the poorer ear. Hood (1990) suggested that his results for the poorer ears of patients with Meniere's disease were analagous to Silman et al's (1984) results for the unaided ear of monaurally fitted persons with BSSHI.

Silman et al's (1984) findings for the unaided ears of monaurally fitted subjects versus the aided ears of monaurally and binaurally fitted subjects were substantiated by the retrospective and prospective findings of several investigators in this country (Silman et al, 1984; Gelfand et al, 1987; Silverman, 1989; Stubblefield and Nye, 1989; Emmer, 1990; Silverman and Silman, 1990; Hurley, 1991) and abroad (Dieroff and Meibner, 1989; Gatehouse, 1989a, b, 1991, in press; Dieroff, 1990). Gelfand, Silman, and Ross (1987) reported that the change in W-22 SWRS (using taped, 50-word lists) in the unaided ear (under earphones) between the initial test and retest (the interval ranged from 4.0 to 17.3 years) was significantly and directly correlated with the initial SWRS in the unaided ear in the monaurally fitted group. The correlation between changes in SWRSs in the unaided ear from initial test to retest, on the one hand, and subject age, interval between initial test and retest, or initial pure-tone average, on the other hand, was nonsignificant in the monaurally fitted group.

Stubblefield and Nye (1989), in their investigation of adult females and males with presbyacusis, found a mean decrement in the W-22 SWRS (under earphones) in the unaided ears of monaurally fitted subjects of 10.66 percent after 3 years, 11.46 percent after 4 years, 12.66 percent after 5 years, and 15.46 percent after 6 years post fitting. These results indicated that the longer the subject was monaurally aided, the greater was the decrement in SWRS in the unaided ear. They also found that the auditory-deprivation effect in the 32 subjects monaurally fitted in the right ear did not differ significantly from that in the 28 subjects monaurally fitted in the left ear. Silverman's (1989) findings from two case studies indicated that the onset of auditory deprivation for W-22 materials presented under earphones (50-word, taped lists) can occur as late as 11.5 years after the initial monaural fitting. Gatehouse (1989a, b) evaluated the signal-to-noise ratio for 50 percent performance using single words in a background noise (taped, under earphones) in a group of 24 monaurally fitted subjects. The signal-to-noise (S/N) ratios for 50 percent performance at 65, 70, 75, 80, 85, and 90 dB SPL were examined at the mean time of 4.8 years from hearing-aid fitting to test. The results revealed significantly higher S/N ratios in the unaided as compared with aided ears at the two highest presentation levels, consistent with the results of other investigations on auditory deprivation; reverse findings were obtained at the lowest presentation level. In more recent studies, Gatehouse (1991, in press) examined speech-recognition-in-noise ability in four subjects with BSSHI at the time of monaural hearing-aid fitting, and at weekly intervals up to 12 weeks post fitting, using the speech materials employed in his earlier studies. Specifically, he investigated the signal-to-noise ratio yielding 70.7 percent correct identification. Significant decrements in speech-recognition-in-noise ability were observed when speech was presented under earphones to the unaided ears of monaurally fitted subjects at a level equivalent to 65 dB SPL plus aid gain with a flat frequency response and at a level equivalent to 65 dB SPL with an aid-processed frequency response. Gatehouse (1991, in press) reported that these findings could be interpreted as demonstrating the existence of auditory-deprivation effects occurring within 3 months post fitting, at least for speech-in-noise materials. Gatehouse's (1991, in press) finding of an auditory-deprivation effect at 65 dB SPL supports the concept of auditory deprivation being manifested for speech presented at low as well as high intensity levels. Gatehouse (1991, in press) also reported that speech-recognition-in-noise ability improved in the fitted ears of monaurally fitted subjects when speech was presented at 65 dB SPL through an aid-processed frequency response and at 65 dB SPL plus aid gain with an aid-processed frequency response. He interpreted this result in the fitted ear as manifesting the effects of acclimatization to the hearing aid and its frequency response. Replication studies are needed to substantiate this finding in the fitted ear.

Hurley (1991) recently conducted a prospective study of 178 adult males and females between 34 and 72 years of age with BSSHI, 80 of whom were binaurally fitted and 98 of whom were monaurally fitted. Significant decrements in the NU-6 SWRSs and suprathreshold SSI-ICM scores at 0 message-to-competition ratio (MCR) (under earphones) were observed in the unaided but not aided ears of monaurally and binaurally fitted subjects at the retest performed 5 to 6 years post fitting. The mean change in NU-6 score from initial test to retest was –11.8 percent and + 5.8 percent, respectively for the unaided and aided ears of the monaurally fitted group. The mean change in SSI-ICM score from initial test to retest was –13.3 percent and –0.7%, respectively for the unaided and aided ears of the monaurally fitted group. The percentages of unaided versus aided ears in the monaurally fitted group and left versus right aided ears in the binaurally fitted group that decreased significantly (Thornton and Raffin, 1978) when the last retest NU-6 score was compared with the initial NU-6 score, were similar to those found by Silman et al (1984). Hurley reported that it took at least 2 years post monaural fitting for the auditory-deprivation effect to develop.

Unpublished data of Silman and Gelfand indicate that the magnitude of the auditory-deprivation effect is larger in adults with BSSHI having pure-tone averages (PTAs) greater than 50 dB HL than in those with PTAs less than 50 dB HL. In addition, their data indicate that recovery from auditory deprivation with binaural amplification is faster and greater in persons with PTAs less than 50 dB HL than in those with PTAs greater than 50 dB HL.

Gelfand et al (1987) reported the absence of an auditory-deprivation effect in a bilaterally unaided group of 19 adult males with BSSHI. Hypotheses proposed to account for the lack of an auditory-deprivation effect in this group included the following: (a) unknown subject differences between the unaided and monaurally fitted groups; (b) central nervous system suppression of input from the unaided ears of the monaurally fitted subjects; (c) slight audiometric differences between the monaurally fitted and unaided groups; (d) the unaided but not the monaurally fitted person manipulates the environment to increase the intensity of speech (e.g., by turning up the radio or television and asking others to speak loudly). Stubblefield and Nye's (1989) findings contradict those of Gelfand et al (1987). Stubblefield and Nye (1989) reported that the mean change in SWRS from initial test to retest was –7.80 percent in the bilaterally unaided group as compared with –12.52 percent for the unaided ears of the monaurally fitted group and + 0.15 percent for the aided ears of the monaurally fitted group. These results remained essentially unchanged after chronologic age was partialed out.

TYPICAL AUDIOLOGIC PROFILE

At approximately 4 years post monaural hearing-aid fitting of an adult with BSSHI, the unaided ear, under earphones, shows an average decrement of 18.5 percent for W-22 monosyllabic PB words (50-word, taped lists) presented at 40 dB SL re: Speech-Recognition Threshold (SRT) (Silman et al, 1984) and approximately 12 percent decrement for NU-6 monosyllabic PB words (taped, 50-word lists) (Hurley, 1991). The pure-tone and speech-recognition thresholds, under earphones, generally are unaffected in the unaided ear or are increased essentially equally in the two ears, consistent with aging effects (Silman et al, 1984; Gelfand et al, 1987; Dieroff and Meibner, 1989; Silverman, 1989; Stubblefield and Nye, 1989; Dieroff, 1990; Silverman and Silman, 1990; Hurley, 1991). The decrement in the SSI-ICM is approximately 13 percent at 0 MCR in the unaided ear (Hurley, 1991). At approximately 5 years post monaural hearing-aid fitting, the signal-to-noise ratio for 50 percent performance under earphones is approximately 4 dB higher in the unaided than aided ear when monosyllabic words are presented at 90 dB SPL (Gatehouse, 1989a, b).

AMPLIFICATION STRATEGIES

Silverman and Silman (1990) presented two cases (young, adult males with BSSHI) of apparent auditory deprivation from monaural amplification and recovery with binaural amplification. In the first case, apparent auditory deprivation in the unaided ear was first observed approximately 6.5 years following the monaural hearing-aid fitting. Binaural amplification was introduced 8 years post monaural fitting. At approximately 2.5 years following the binaural fitting, the initially unaided ear showed significant improvement in the W-22 SWRS under earphones; this improvement was maintained at nearly 4 years post binaural fitting. In this case, the recovery was partial. In the second case, apparent auditory deprivation in the unaided ear was first observed approximately 22 months following the monaural hearing-aid fitting. Binaural amplification was introduced 2.5 years post monaural fitting. Significant recovery in the formerly unaided ear was present at the retest performed approximately 2 years post binaural fitting; this improvement was maintained at the retest performed approximately 4 years post binaural fitting. In this case, the recovery was essentially complete. These findings suggest that partial or complete recovery from auditory deprivation associated with monaural amplification may be obtained with binaural amplification when binaural amplification is introduced within 1 year of the time that the auditory-deprivation effect is first observed with SWRSs. The finding that the recovery process may take year(s), rather than hours or days, of binaural amplification underscores the need for binaural rather than monaural amplification in persons with BSSHI.

Hurley's (1991) prospective findings substantiated the retrospective findings of Silverman and Silman (1990). He reported that binaural amplification reversed the effects of auditory deprivation associated with monaural amplification in six of nine initially monaurally fitted subjects with BSSHI. These subjects were the youngest of the sample ranging from 34 to 72 years. Hurley did not report the extent of the recovery and did not indicate the time span between onset of significant auditory deprivation and binaural fitting.

CONTRAINDICATIONS OR CHALLENGES TO CONVENTIONAL HEARING-AID FITTING

According to Hood (1990), a minority of persons with BSSHI accept monaural but not binaural amplification. He suggested that in these cases, "cortical information derived from each ear is so disparate that any binaural amplification is limited by attentional factors" (p. 11).

In our clinical experience, we have observed that some persons with BSSHI who have worn monaural amplification for many years reject binaural amplification after this time, even when the W-22 SWRSs have remained essentially symmetrical throughout this period. Perhaps, in these cases, long-standing auditory deprivation, which is not apparent from the W-22 scores, associated with monaural amplification cannot be reversed with amplification. This hypothesis is being tested (Silman, Rubinstein, and Cherry, in preparation).

CLINICAL CASE STUDY

The following case study illustrates the adult-onset, auditory-deprivation effect. It also illustrates recovery from this effect following binaural amplification.

Subject Characteristics

The subject was an adult male with a reported onset of hearing impairment (BSSHI) in adulthood consistent with a noise-induced origin. He was 64 years old at the initial test. The pure-tone averages (based on 500, 1000, and 2000 Hz) were 75 and 78 dB HL for the right and left ears, respectively.

Both ears met the following criteria: (a) bone-conduction thresholds within 5 dB of the air-conduction thresholds; (b) tympanometric peak pressure within ± 50 daPa (Porter, 1974); (c) static-acoustic middle-ear impedance not exceeding 3000 ohms for the 220-Hz probe tone (Margolis and Fox, 1977); (d) contralateral acoustic-reflex thresholds for the 500-Hz, 1000-Hz, and 2000-Hz tonal activators not exceeding the 90th percentile levels associated with hearing impairment of cochlear etiology (Silman and Gelfand, 1981); (e) negative tone-decay results at 500, 1000, and 2000 Hz (Olsen and Noffsinger, 1974); (f) negative history of ear disease and central nervous system disorder. The subject also exhibited the following characteristics: (a) initial interaural pure-tone threshold differences not exceeding 15 dB at all audiometric test frequencies; (b) initial suprathreshold speech-recognition interaural difference not exceeding 10 percent; (c) monaural hearing-aid fitting within 2 weeks post initial audiologic evaluation; (d) significant decrement (below the 95% critical-differences lower limits established by Thornton and Raffin, 1978) in the retest SWRS as compared with the SWRS obtained at the initial, monaural hearing-aid fitting; (e) negative radiologic and otoneurologic studies following the significant decrement in the unaided ear to rule out retrocochlear pathology as a cause of the unilateral decrement; (f) binaural fitting following a significant decrement in the SWRS in the unaided ear; (g) reported hearing-aid usage at least 8 hours per day.

Procedure

Pure-tone air-conduction thresholds between 250 and 8000 Hz, pure-tone bone-conduction thresholds between 250 and 4000 Hz, speech-recognition thresholds, CID W-22 PB words (50-word, taped lists) presented at 40 dB SL re: SRT, acoustic-immittance, and tone-decay results were obtained just prior to the monaural fitting in 1986, just prior to the binaural fitting in 1988, and again in 1991.

Table 1 Initial and Retest Evaluations for the Subject Initially Fit Monaurally in the Right Ear and Later Fit Binaurally

	Pure-Tone Air-Conduction Threshold (dB HL)									
Date	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*	*8000 Hz*	*SRT (dB HL)*	*SWRS (%)*	*95% CDLL*	*95% CDUL*
Right ear (aided)										
1986	70	75	70	70	85	100	65	92	78	
1988	60	70	60	70	85	95	65	80		
1991	65	70	65	70	85	90	70	84		
Left ear										
1986*	75	75	75	85	95	100+	70	84	68	
1988*	65	80	80	85	90	100+	70	52		70
1991†	65	75	70	85	85	100	70	78		

95% CDLL = 95% critical-differences lower limit (Thornton and Raffin, 1978).
95% CDUL = 95% critical-differences upper limit (Thornton and Raffin, 1978).
*During the period of monaural amplification; †during the period of binaural amplification.

Results and Discussion

The pure-tone thresholds, SRTs, and SWRSs, obtained under earphones, are shown in Table 1. Inspection of this table reveals that, at the initial test, the pure-tone thresholds and SWRSs were essentially symmetrical and the SWRSs were high.

Figure 1 (data are from Table 1) graphically displays the progression of SWRSs. The SWRS in the unaided, left ear decreased significantly (Thornton and Raffin, 1978) at the retest performed approximately 3 years following the monaural hearing-aid fitting. The SWRS in the aided, right ear remained essentially unchanged (with respect to the Thornton and Raffin, 1978 criteria) over the entire, approximately 5-year period of investigation. That is, the SWRS in the aided, right ear remained stable in contrast with the significant decrement in SWRS in the initially unaided, left ear. Inspection of Figure 1 further reveals that the SWRS in the initially unaided, left ear was improved significantly (Thornton and Raffin, 1978) at the retest performed approximately 2 years post binaural fitting.

The unaided ear of this subject demonstrates auditory deprivation associated with 3 years of monaural amplification as evidenced by the significant decrement in SWRS associated with lack of amplification. Complete recovery was present at the retest performed approximately 2 years following the binaural fitting as shown by the significant improvement in the left-ear SWRS.

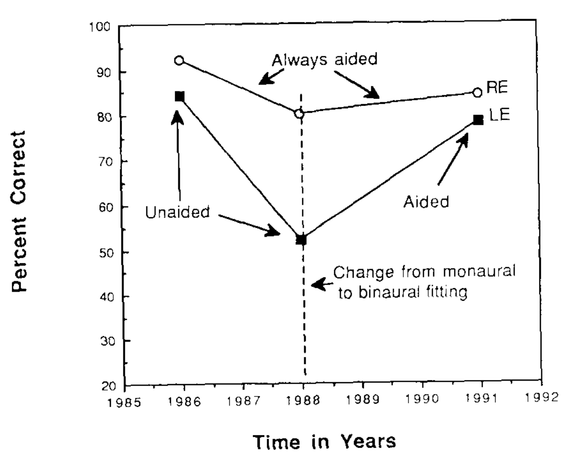

Figure 1 W-22 SWRS (% correct) as a function of time in years for the subject who initially was fit monaurally in the right ear and later was binaurally fit. The open circles represent the right-ear scores, and the filled squares represent the left-ear scores.

The question remains why this subject had high SWRSs bilaterally at the initial test after many years of longstanding BSSHI. Perhaps the subject manipulated the environment sufficiently to provide adequate bilateral stimulation. Another possible explanation is that auditory deprivation is associated with unequal stimulation of the two ears; prior to the monaural fitting, stimulation of the two ears was essentially equal and, after the monaural fitting, stimulation of the two ears was unequal.

FUTURE RESEARCH

Research is needed to describe the effects of auditory deprivation for a variety of speech materials. Prospective auditory-deprivation studies should also be conducted in persons with asymmetric and unilateral sensorineural hearing impairment and in persons with mixed or conductive hearing impairment. Auditory-deprivation studies using acoustic-immittance and auditory-evoked potentials measures need to be conducted in order to help establish the anatomic and physiologic mechanism of the phenomenon and to more fully describe the site (peripheral and/or central) of the phenomenon. Animal studies on auditory deprivation are also needed to establish any anatomic evidence of the phenomenon. Research is also needed to resolve the controversy regarding the possibility of auditory-deprivation effects in persons with BSSHI who are bilaterally unaided. Research is also needed to investigate soundfield performance under the unaided, monaurally aided, and binaurally aided condition following prolonged use of monaural amplification.

Large-sample, prospective research is needed to further substantiate the phenomenon of recovery from auditory deprivation with binaural amplification, to more fully describe the nature and time course of recovery, and to identify factors predicting recovery and lack of recovery.

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