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Apparent Auditory Deprivation from Monaural Amplification and Recovery with Binaural Amplification: Two Case Studies

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Abstract

The suprathreshold word-recognition scores for 2 young, adult males with bilateral, symmetrical sensorineural hearing impairment were evaluated following monaural and then binaural hearing-aid fitting. Subjects were obtained by retrospective review of records. Subject 1 was followed over an approximately 11.5-year time period and Subject 2 was followed over an approximately 6-year period. Results revealed that a significant decrement occurred in the unaided ear following the monaural hearing-aid fitting. Then, significant improvement in the formerly unaided ear occurred following the binaural hearing-aid fitting. The implications with respect to recovery from apparent auditory deprivation after binaural amplification are discussed.

Key Words: Auditory deprivation, binaural amplification, monaural amplification, speech audiometry, speech perception, suprathreshold word-recognition ability.

Apparent late-onset auditory deprivation has been a topic of recent research interest. Silman et al (1984) initially reported that in veterans with bilaterally symmetrical sensorineural hearing impairment suprathreshold word-recognition scores of the unaided ears, in contrast to the aided ears, deteriorated significantly over a 4 to 5 year period following the initial hearing-aid fitting. This phenomenon was termed "late-onset auditory deprivation."

Subsequent investigators have confirmed or indirectly supported the observation of a reduction in suprathreshold word-recognition score in the unaided ears of adults with bilateral sensorineural hearing impairment (Gatehouse, 1989a,b: Gelfand et al, 1987; Hood, 1984, 1990; Silverman, 1989; Stubblefield and Nye, 1989). Hood (1984) observed that the suprathreshold word-recognition scores of the impaired ears of persons with unilateral hearing impairment were poorer than those of the better ears (matched in hearing sensitivity) of persons with bilateral sensorineural hearing impairment. Another finding was that despite the small interaural differences in pure-tone thresholds in the bilaterally hearing-impaired group, the suprathreshold word-recognition scores of the better ears were disproportionately better than those of the poorer ears. Hood (1984) hypothesized that when interaural pure-tone differences exist, persons make "dominant use of their better ear to the neglect of the poorer ear." Hood (1990) suggested that the unaided ear's deterioration in suprathreshold speech-recognition score results from auditory deprivation or neglect.

Gatehouse (1989a,b) confirmed Silman et al.'s (1984) finding of reduced suprathreshold word-recognition scores at high intensities in the unaided ears as compared with the aided ears

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of monaurally aided subjects. At intensities below 75 dB SPL, however, a reverse effect was observed. The findings were interpreted as reflecting perceptual learning by the process of acclimatization (i.e., a complex, long-term form of adaptation) to speech stimulation at certain intensities.

Silman et al (1984) proposed that research is needed to determine whether the effects of auditory deprivation are reversible through the introduction of binaural amplification. Research has not yet been done on this issue. Clearly the results of studies on this topic have implications regarding monaural vs. binaural fitting and would further contribute to a theory of apparent auditory deprivation as well as the binaural hearing-aid advantage. Therefore, the purpose of this retrospective case study was to investigate whether binaural amplification can reverse the effects of apparent auditory deprivation from monaural amplification.

METHOD

Subjects

Subjects consisted of two adult males with bilateral, symmetrical sensorineural hearing impairment with a reported onset of hearing impairment in adulthood consistent with a noise-induced origin. Subject 1 was 30 years old at the initial test and Subject 2 was 34 years old at the initial test.

Both ears of each subject met the following criteria for inclusion in this study: (a) three-frequency pure-tone average greater than 25 dB HL; (b) bone-conduction thresholds (ANSI, 1972) within 5 dB of the air-conduction thresholds (Studebaker, 1962); (c) tympanometric peak pressure within ±50 daPa (Porter, 1972); (d) static-acoustic middle-ear impedance not exceeding 3000 ohms for the 220-Hz probe tone (Margolis and Fox, 1977), (e) 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); (f) negative tone-decay results at 500, 1000, and 2000 Hz (Olsen and Noffsinger, 1974); (g) negative history of ear disease or central nervous system disorder; (h) initial interaural pure-tone threshold differences not exceeding 15 dB at all audiometric test frequencies; (i) initial suprathreshold speech-recognition interaural difference not exceeding 10 percent; (j) monaural hearing-aid fitting 1 to 2 weeks after the initial audiologic evaluation; (k) decrement in the suprathreshold word-recognition score in the unaided ear from the initial, monaural hearing-aid fitting to a retest below the 95 percent critical-differences lower limit (Thornton and Raffin, 1978), (l) 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; (m) binaural fitting following a significant decrement in the suprathreshold speech-recognition score in the unaided ear below the 95 percent critical-differences lower limit; (n) reported hearing-aid usage at least 8 hours per day.

Subjects were obtained by retrospective review of records from four speech and hearing centers affiliated with the authors and were selected only after the aforementioned criteria were established. The two cases presented here were the only cases meeting these stringent criteria. Review of the records for Subjects 1 and 2 revealed that binaural hearing-aid fitting was done because of complaints of localization difficulties or imbalance in auditory perception. Review of the records for Subjects 1 and 2 also revealed that the ear selected for the initial monaural hearing-aid fitting was the ear used for the telephone.

Procedure

Pure-tone air-conduction thresholds between 250 and 8000 Hz, pure-tone bone-conduction thresholds between 250 and 4000 Hz, speech-recognition thresholds (SRTs), suprathreshold word-recognition scores for taped, 50-word lists of the CID W-22 PB words at 40 dB SL re: SRT, static-acoustic immittance, and tone-decay results were obtained for each subject prior to the monaural hearing-aid fitting and at varying intervals following the monaural hearing-aid fitting and following the binaural hearing-aid fitting. All testing was done in a two-room audiometric suite meeting ANSI S3.1 (1977) standards for audiometric environments. All pure-tone, acoustic-reflex activating, and taped signals were routinely calibrated with a sound-level meter (B & K 4150) and coupler (NBS-9A).

Table 2 The Pure-Tone Air-Conduction Thresholds and Suprathreshold Word-Recognition Scores (SWRSs) at the Initial and Retest Evaluations for the Right and Left Ears of Subject 2

	Pure-Tone Air-Conduction Threshold (dB HL)						95%	
Date	250	500	1000	2000	4000	8000 Hz	SWRS (%)	CDLL CDUL
Right ear (aided)								
10/77	5	5	35	50	65	60	84	68
11/78	15	15	35	55	60	50	80	
03/80	15	15	50	60	70	55	84	
08/81	5	5	45	60	60	60	86	
04/84	5	20	45	65	70	65	84	
05/85	10	20	50	60	70	65	84	
01/86	10	15	50	60	65	60	88	
11/87	15	20	45	65	70	65	88	
02/89	10	15	50	60	65	65	86	
Left ear (a) unaided								
10/77	0	0	45	55	70	60	88	74
11/78	15	15	45	70	65	65	76	
03/80	10	10	50	70	75	60	80	
08/81	5	0	50	50	60	65	76	
04/84	10	15	60	70	70	65	56	
05/85	10	15	55	65	70	65	40	58
(b) aided								
01/86	10	10	65	65	65	65	50	
11/87	10	15	65	65	70	65	72	
02/89	10	10	65	65	65	60	70	

Subject 1 was initially fitted monaurally in the right ear and later on was fitted binaurally. The 95% critical-differences lower limits (CDLLs) are shown for the SWRSs for both ears at the initial test and the 95% critical-differences upper limit (CDUL) is shown for the left-ear SWRS at the binaural fitting.

Subject 1 had the monaural fitting of the right ear on 10/77, binaural fitting on 5/85, and was followed over an approximately 11.5 year time period. Subject 2 had the monaural fitting of the left ear on 3/80, binaural fitting on 9/82, and was followed over an approximately 6-year period.

RESULTS

The pure-tone thresholds, SRTs, and suprathreshold word-recognition scores for Subject 1 are shown in Table 1. Inspection of this table reveals that the pure-tone thresholds, SRTs, and suprathreshold word-recognition scores were high and essentially symmetrical at the initial test.

The suprathreshold word-recognition score in the unaided, left ear fell below the 95 percent critical-differences lower limit approximately 6.5 years following the monaural hearing-aid fitting. This decrement in the unaided, left ear was reliable as evidenced by the significantly reduced suprathreshold word-recognition score at the following retest. The suprathreshold word-recognition score in the aided, right ear never fell below the 95 percent critical-differences lower limit over the entire, approximately

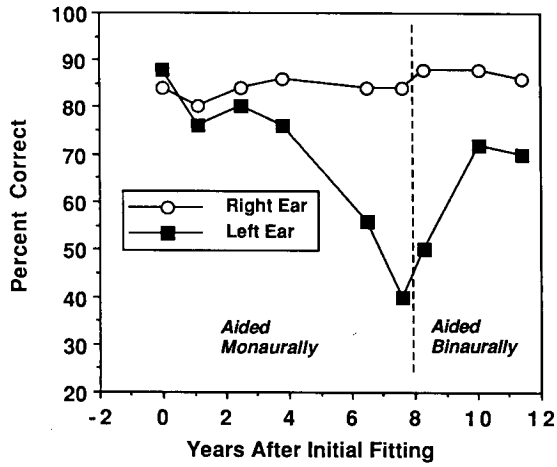

Figure 1 Time course of changes in suprathreshold word recognition for Subject 1. Dashed line indicates change from monaural to binaural fitting.

Table 2 The Pure-Tone Air-Conduction Thresholds and Suprathreshold Word-Recognition Scores (SWRSs) at the Initial and Retest Evaluations for the Right and Left Ears of Subject 2

	Pure-Tone Air-Conduction Threshold (dB HL)						95%	
Date	250	500	1000	2000	4000	8000 Hz	SWRS (%)	CDLL CDUL
Left ear (aided)								
03/80	10	20	30	35	70	60	88	74
01/82	5	10	20	35	70	65	92	
09/82	5	15	20	35	75	60	86	
06/84	5	20	25	35	75	55	96	
05/86	5	20	25	40	75	65	92	
Right ear (a) unaided								
03/80	15	20	30	40	85	65	90	76
01/82	10	15	20	40	80	75	64	
09/82	15	20	30	35	80	60	60	78
(b) aided								
06/84	5	10	25	45	85	70	84	
05/86	10	15	25	45	85	80	80	

Subject 2 was initially fitted monaurally in the left ear and later on was fitted binaurally. The 95% critical-differences lower limits (CDLLs) are shown for the SWRSs for both ears at the initial test and the 95% critical-differences upper limit (CDUL) is shown for the right-ear SWRS at the binaural fitting.

11.5-year period of investigation. That is, the suprathreshold word-recognition score in the aided, right ear remained stable in contrast with significant decrement in suprathreshold word-recognition score in the initially unaided, left ear.

Inspection of Table 1 further reveals that the suprathreshold word-recognition score in the initially unaided, left ear improved significantly at the retest performed approximately 2.5 years following the binaural fitting. This improvement was reliable as indicated by the significantly increased suprathreshold word-recognition score at the subsequent retest.

The time course of these suprathreshold changes in word-recognition scores for Subject 1 is illustrated in Figure 1.

The pure-tone thresholds, SRTs, and suprathreshold word-recognition scores for Subject 2 are shown in Table 2. Inspection of this table reveals that the pure-tone thresholds, SRTs, and speech-recognition scores were high and essentially symmetrical at the initial test.

The suprathreshold word-recognition score in the unaided, right ear fell below the 95 percent critical-differences lower limit at the retest performed approximately 22 months following the monaural hearing-aid fitting. This decrement in suprathreshold word-recognition score in the unaided, right ear was reliable as indicated by the significantly reduced suprathreshold word-recognition score at the following retest. The suprathreshold word-recognition score in the aided, left ear never fell below the 95 percent critical-differences lower limit over the entire, approximately 6-year period of investigation. That is, the suprathreshold word-recognition score in the aided, left ear remained stable in contrast with the significant decrement in

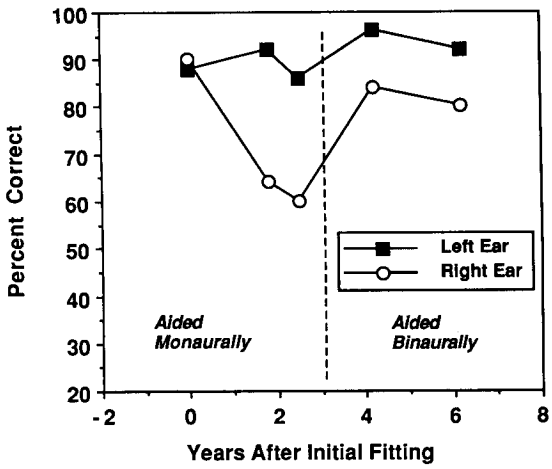

Figure 2 Time course of changes in suprathreshold word recognition for Subject 2. Dashed line indicates change from monaural to binaural fitting.

suprathreshold word-recognition score in the unaided, right ear.

Inspection of Table 2 further reveals that the suprathreshold word-recognition score in the initially unaided, right ear improved significantly at the retest performed approximately 2 years following the binaural fitting. This improvement was reliable as indicated by the significantly increased suprathreshold word-recognition score at the subsequent retest.

The time course of changes in word-recognition scores for Subject 2 is illustrated in Figure 2.

DISCUSSION

The unaided ears of Subjects 1 and 2 clearly show the decrement in suprathreshold word-recognition score associated with lack of amplification, substantiating the finding reported initially by Silman et al (1984) and subsequently confirmed by other investigators (Gatehouse, 1989a,b; Gelfand et al, 1987; Hood, 1984, 1990; Silverman, 1989; Stubblefield and Nye, 1989). These findings, together with those of Silman et al (1984) and subsequent investigators, suggest that the deterioration in the unaided ear of bilaterally sensorineural hearing-impaired adults is at least partially a suprathreshold phenomenon that is manifested in relation to a complex signal such as speech.

For Subject 1, a significant decrement in the unaided ear was absent at the retests performed 13 months, 29 months, and 46 months following the initial test. A significant decrement was first observed at the retest performed approximately 6.5 years following the initial test. Because no retest data were obtained between 8/81 and 4/84, it is possible that a significant decrement could have occurred between approximately 4 years and 6.5 years following the initial test. These data do indicate, however, that a decrement in the unaided ear of Subject 1 was not apparent until approximately 4 to 6.5 years following the initial test. Significant recovery was absent at the test performed at 8 months following the binaural hearing-aid fitting but was present at the retest performed at 2.5 years following the binaural fitting. Because no retest data were obtained between 1/86 and 11/87, it is possible that significant recovery could have occurred between approximately 0.67 and 2.5 years following the binaural hearing-aid fitting.

In contrast with Subject 1, the onset of the significant reduction in suprathreshold word-recognition score was unclear for Subject 2. Although a significant reduction was present at the first retest, performed approximately 2 years following the initial test, any significant deterioration in the unaided ear occurring in less than 2 years could not have been detected. Similarly, although significant recovery was present at the retest performed approximately 2 years following the binaural hearing-aid fitting, any significant recovery occurring in less than 2 years for Subject 2 also could not have been detected. Subject 2 had a smaller decrement following the monaural hearing-aid fitting and less recovery with binaural hearing-aid fitting than Subject 1.

The unique finding in both of these subjects in this study is that the decrement observed following monaural hearing-aid fitting was reversed following binaural hearing aid fitting. In Subject 1, the recovery was partial (i.e., the suprathreshold word-recognition score never improved to within the 95 percent critical-differences limits associated with the initial test) and a significant improvement did not occur until 0.67 to 2.5 years following the binaural hearing-aid fitting. In Subject 2, nearly complete recovery (i.e., to within the 95 percent critical-differences limits associated with the initial test) occurred.

Similar to Silman et al (1984) and Silverman (1989), reduction in suprathreshold word-recognition score was observed in the unaided ear of adults who had high suprathreshold word-recognition scores, bilaterally, at the initial test. In both Subjects 1 and 2, amplification was introduced when the suprathreshold word-recognition score in the unaided ear approached chance level (40–60%). Research is needed to determine whether recovery from apparent auditory deprivation can occur when the suprathreshold word-recognition score in the unaided ear is poorer than 40 to 60 percent.

The mechanism underlying the decrement in surpathreshold word-recognition score in the unaided ears of monaurally fitted adults, which we have termed the apparent auditory-deprivation effect, remains unclear, Silman et al (1984) postulated that an apparent auditory-deprivation effect is manifested if lack of amplification results in behavioral deterioration as observed on audiologic measures. According to Silman et al (1984), this apparent auditory-deprivation effect has a physiologic, structural, and/or percep-

tual basis. Gelfand et al (1987) hypothesized that perceptual mechanisms for the observed auditory-deprivation effect might include central suppression of the inefficient (unaided) ear, adaptive learning, or selective attention. Gatehouse (1989 a,b), who proposed a perceptual learning mechanism, hypothesized an acclimatization or habituation effect to the level of presentation of speech. Hood (1990) suggested that the deterioration occurred through neglect.

Large-sample prospective investigations are needed to substantiate the findings of a decrement in suprathreshold word-recognition score following monaural amplification, and recovery with binaural amplification, in bilaterally hearing-impaired adults. If the finding reported here regarding recovery with binaural amplification is substantiated, then binaural amplification is an effective rehabilitative strategy in cases initially fit monaurally who subsequently demonstrate an apparent auditory-deprivation effect. Furthermore, substantiation of the finding of recovery would indicate that the effects of apparent auditory deprivation can be at least partially reversed through binaural amplification.

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REFERENCES

American National Standards Institute (1972). Artificial head-bone for the calibration of audiometer bone vibrators. *ANSI* S3.13-1972. American National Standards Institute. New York, NY.

American National Standards Institute (1977). Criteria for permissible ambient noise during audiometric testing. *ANSI* S3.1-1977. American National Standards Institute. New York, NY.

Gatehouse S. (1989a). Apparent auditory deprivation of late-onset: the effects of presentation level. *Br J Audiol* 23:167.

Gatehouse S. (1989b) Apparent auditory deprivation effects of late onset: the role of presentation level. *J Acoust Soc Am* 86:2103-2106.

Gelfand SA, Silman S, Ross L. (1987). Long-term effects of monaural, binaural and no amplification in subjects with bilateral hearing loss. *Scand Audiol* 16:201-207.

Hood JD. (1984). Speech discrimination in bilateral and unilateral hearing loss due to Meniere's disease. *Br J Audiol* 18:173-177.

Hood JD. (1990). Problems in central binaural integration in hearing loss cases. *Hear Instr* 41:6-11.

Margolis RH, Fox CM. (1977). A comparison of three methods for predicting hearing loss from acoustic reflex thresholds. *J Speech Hear Res* 20:241-243.

Olsen WO, Noffsinger C. (1974). Comparison of one new and three old tests of auditory adaptation. *Arch Otolaryngol* 99:94-99.

Porter T. (1972). Normative otoadmittance values for three populations. *J Aud Res* 12:53-58.

Silman S, Gelfand SA, Silverman CA.(1984). Effects of monaural versus binaural hearing aids. *J Acoust Soc Am* 76:1357-1362.

Silman S, Gelfand SA. (1981). The relationship between magnitude of hearing loss and acoustic reflex threshold levels. *J Speech Hear Disord* 46:312-316.

Silverman CA. (1989). Auditory deprivation. *Hear Instr* 40(9):26-32.

Stubblefield J, Nye C. (1989). Aided and unaided time-related differences in word discrimination. *Hear Instr* 40(9):38-43,78.

Studebaker GA. (1962). On masking in bone conduction testing. *J Speech Hear Res* 5:215-227.

Thornton AR, Raffin MJM. (1978). Speech discrimination scores modeled as a binomial variable. *J Speech Hear Res* 21:507-518.