Critical Review: Can the use of amplification prevent the effects of auditory deprivation in adults with sensorineural hearing loss?

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This critical review examines the use of amplification in preventing the effects of auditory deprivation in adults with sensorineural hearing loss. Studies evaluated consisted of two prospective clinical trials and two retrospective clinical trials. Overall, the research examined in this review did not provide substantial evidence for the use of amplification in preventing auditory deprivation. Results from these studies should be interpreted cautiously due to various limitations in their designs and methodologies.

Introduction

Arlinger et. al., (1996) defined auditory deprivation as a "systematic decrease over time in auditory performance associated with the reduced availability of acoustic information" (p. 87S). This phenomenon has been documented in several studies as a decrease in the word recognition performance for the unaided ear of bilaterally impaired adults who were monaural hearing instrument users (Arlinger et al., 1996). Auditory deprivation has been historically used as an argument for the provision of binaural amplification in adults with bilateral sensorineural hearing loss when contraindications to binaural amplification, such as manual dexterity and cost, are absent (Holmes, 2003). Unsurprisingly, the concept of a reduction in auditory performance for the unaided ear may be a deciding factor for both clinician and client in the selection of monaural or binaural amplification as a treatment approach to hearing loss. However, close examination of current evidence relating to auditory deprivation in adults exposes limitations with the existing research.

Although several studies have examined the effects of auditory deprivation in adults, much is still unknown regarding the onset and underlying mechanisms of this phenomenon. There are numerous reasons for the current lack of understanding regarding auditory deprivation. Firstly, a difficulty commonly encountered when conducting research on auditory deprivation in adult populations is in controlling extraneous variables that may potentially confound results (Neuman, 1996). The particular type, degree and cause of hearing impairment may affect the underlying mechanisms that determine the occurrence or progression of auditory deprivation. Therefore, results obtained from studies involving individuals with asymmetrical or conductive hearing losses may not be comparable with those obtained from research conducted on populations with bilateral, symmetrical sensorineural hearing loss (BSSNHL). Secondly, due to the nature of this phenomenon, it is difficult and potentially unethical to conduct prospective, randomized controlled trials and consequently withhold what may be the most appropriate form of treatment from individuals (Neuman, 1996). As a result, much of the current evidence and knowledge for the existence and progression of auditory deprivation is derived from retrospective studies and case series. Thirdly, the onset time of auditory deprivation may vary widely between individuals (Arlinger et. al., 1996). This is problematic as researchers wishing to conduct a prospective study may be required to design lengthy studies of sufficient duration.

Due to these research limitations, it is important for clinicians to carefully examine the current evidence before utilizing the argument of auditory deprivation as a basis for monaural or binaural amplification. This critical review will examine the use of amplification as a preventative measure to auditory deprivation in adults with BSSNHL, given that the majority of adult patients seen by the clinician commonly present with this type of hearing impairment.

Objective

The primary objective of this critical review is to determine from existing evidence whether or not the use of amplification can result in the prevention of auditory deprivation in adults with bilateral, symmetrical sensorineural hearing loss (BSSNHL).

Methods

Search Strategy
Computerized databases including PubMed, MEDLINE and Google Scholar were searched using the following strategy: [(auditory OR hearing) AND deprivation] AND [(hearing) OR (loss) OR (sensorineural) OR (bilateral) OR (adult) OR (aid) OR (monaural)]. The

search was limited to studies reported in English and including human subjects. Additional articles were obtained through the reference lists of acquired articles.

Selection Criteria

Retrospective and prospective studies that examined the effects of auditory deprivation on a variety of measures in adult subjects with BSSNHL were included. Case series and single-subject design studies were not selected. Studies including children or subjects who had other forms of hearing loss were also rejected.

Data Collection

A total of four studies were included in this review. The first two studies examined were retrospective non-randomized clinical trials. The third study examined was a prospective, single-blind, non-randomized clinical trial. The fourth study examined was a prospective, non-randomized clinical trial.

Results and Discussion

Retrospective Studies

Study #1. Silman, Gelfand and Silverman (1984) conducted a retrospective, non-randomized clinical trial examining the effects of auditory deprivation in monaural and binaural hearing instrument users through patient records obtained from the Veterans Administration Medical Center in New Jersey. Subjects consisted of 67 adult males who presented with BSSNHL. Of the 67 subjects, 44 were monaural hearing instrument users, and 23 wore binaural amplification. These individuals were initially assessed, fitted with amplification and re-assessed four to five years subsequent to initial fitting at the medical center. Age of the subjects varied widely, with a mean age of 59 years and standard deviation of 12.2 years in monaural group, and a mean age of 57.9 years and standard deviation of 10.1 years in the binaural group. All individuals reported having adult-onset hearing loss with a positive history for noise exposure. Subjects were required to have normal middle ear function, negative history for neurological or ear diseases and reported usage of hearing instruments for minimally eight hours daily. Threshold differences between ears of the subjects were required to be 15 dB or less across testing frequencies from 250-8000 Hz.

The following measures obtained from the initial and follow-up assessments for each ear of the subjects and were compared: pure tone air and bone conduction audiometric thresholds (from 250-8000 Hz), speech recognition thresholds (SRT), word recognition scores (WRS, obtained using W-22 PB word list at 40 dB SL re: SRT), tympanograms and acoustic reflex thresholds. The results taken from the initial assessment were categorized as initial test data, with the results from the follow-up assessment represented as the re-test data by the researchers. T-tests for repeated measures revealed a statistically significant difference ($t(44) = 8.17$, $p<0.0001$) between the initial WRS and the re-test WRS for the unaided ears of individuals in the monaurally aided group. The researchers did not find a statistically significant difference between the test and re-test WRS for the left and the right ears of the binaurally aided group. The researchers also conducted an ANOVA to determine if there were any potential effects of age and hearing thresholds on the word recognition scores. The results indicated that there were no statistically significant differences between test and re-test hearing thresholds and SRTs for the ears of both groups. Additionally, the difference between the test and re-test WRS for the unaided ears of the monaurally aided group remained statistically significant after age and hearing threshold effects were removed.

The authors of the study concluded that the auditory deprivation effect was observed as a decline in the speech-recognition performance of the unaided ear.

Study #2. Following the 1984 study by Silman et al., Gelfand, Silman and Ross (1987) conducted a retrospective, non-randomized clinical trial to further explore the effect of auditory deprivation. The researchers decided to include several changes to the design of their follow-up study. Subjects consisted of 86 adult males with BSSNHL, chosen from patient records obtained from the Veterans Administration Medical Center in New Jersey. The subjects were divided into three groups. The first group consisted of 19 individuals who were non-users of amplification. The second group consisted of 19 binaural amplification users and the third group consisted of 48 monaural amplification users. The age of individuals in the study ranged from 21 to 86 years. Subjects were required to have a negative history of neurological or otologic disease, normal middle ear function and adult-onset hearing loss with a positive history for noise exposure. Data was obtained from one randomly selected ear for each individual in the unaided and binaurally aided groups,. The monaurally aided group had both ears tested. The time between the initial test and re-test at the medical center ranged from four to 17.3 years.

The researchers conducted an ANOVA and found that the groups were no significant differences ($p>0.05$) between groups on age and the time between initial testing and re-testing. The researchers discovered that there were some significant increases in threshold and corresponding SRT in several individuals across each of the groups, but concluded from the ANOVA that these changes were not significantly different between groups. Like the previous study, the researchers found a significant difference between the initial and re-test WRS in the unaided ears of the monaural group. However, they failed to find a significant difference between the initial and final word recognition scores in the aided ears of the monaural group, binaural group and unaided ears of the non-amplification group. The authors also did not find any significant correlation between the change in WRS and time interval between the initial and final test. They hypothesized that there may be a plateau effect for auditory deprivation.

The authors concluded that the results of their study confirmed those that they reported from their 1984 study. However, they were not able to find any evidence that supported their initial hypothesis regarding the decrease in WRS for subjects who wore no amplification. They hypothesized that this may have been the result of audiometric differences or a potential suppression effect of the unaided ear. They also noted that the individuals who did not use amplification may have increased the volume of the television and radio to a comfortable level of listening, contrary to monaurally aided individuals who would adjust the volume to the desired level of listening through their aided ear.

Discussion. A grade three level of evidence is provided by both studies (Dolloghan, 2007). The statistical analysis conducted in both studies were appropriate based upon their design. The tasks in both studies were largely described in sufficient detail for replication. The authors in both studies examined individuals over a sufficiently wide time frame. However, several limitations exist with the designs and methodologies of these two studies. These studies were retrospective in nature and thus difficult to control for confounding factors. The researchers relied upon the personal reports of hearing aid usage, which may not have been entirely accurate. These studies included only males who varied widely in age and likely had a history of noise-induced hearing loss. This limits the applicability of these studies to older populations of adults who may have hearing loss that is primarily presbycusic in nature. Additionally, it is difficult to account for neurologic changes and other confounding effects within the subject population.

Perhaps the greatest limitation seen in these studies relate to the reliance on WRSs as a measure of degraded auditory performance resulting from auditory deprivation. No mention was made on how the WRSs were obtained in either study. It is important to note that the scores between the initial test and re-test may differ due to a number of factors aside from the possible effects of auditory deprivation. Monitored live voice conducted by a different clinician and/or of the opposite gender introduces inconsistencies in testing and may have significant effects on the word recognition scores. The authors in both studies failed to indicate the number of words presented in the WRS testing. This is an omission of a critical detail, as the sensitivity of speech testing is directly associated with the number of trials presented (Thornton and Raffin, 1978). A larger number of words presented during the word recognition test will affect the 95th percentile critical difference range for test/re-test scores and thus the sensitivity of the test (Thornton and Raffin, 1978). Therefore, if a small number of words were used during testing, then the the sensitivity of the word recognition test may be poor and may not be sufficiently reflective of potential decrements in auditory performance as a result of auditory deprivation. Additionally, research has shown that individuals with sensorineural hearing loss commonly present with large test-retest variability in their WRSs (Engelberg, 1967). Ultimately, the validity and reliability of word recognition testing in these two studies should be questioned. Therefore these two studies only provide suggestive evidence for the existence of an auditory deprivation effect in the unaided ear of a monaurally amplified individual.

<u>Prospective Studies:</u>

Study #3. Silman, Silverman, Emmer and Gelfand (1993) conducted a prospective, single-blind, non-randomized clinical trial to expand upon the results from the previous two studies. Participants consisted of 19 monaurally aided adults with BSSNHL (7 females, 12 males) aged 23 to 84 years (mean = 65.4 years, standard deviation = 13.5 years), 28 binaurally aided adults (7 females, 21 males) with BSSNHL aged 40 to 80 years (mean = 65.4 years, standard deviation = 13.4 years) and 19 control adults (16 females, 3 males) with normal hearing aged 28 to 70 years (mean = 62 years, standard deviation = 14 years). Similar to the previous retrospective studies, subjects were required to have a negative history of neurological disease, absence of conductive hearing loss or middle ear dysfunction, and no greater than 15 dB difference between ears at 250-8000 Hz audiometric thresholds. Controls were required to have normal hearing.

The participants with BSSNHL chose to be fit with either monaural or binaural amplification.. Subjects were initially tested six to 12 weeks following the hearing aid fitting and re-assessed approximately one year post hearing aid fitting. Subjects were required to report at least four hours of hearing instrument usage per day. A blind design was implemented, where a different clinician would conduct the re-assessment.

The testing regiment included the following: pure tone air conduction audiometry from 250-8000 Hz, pure tone bone conduction audiometry from 250-4000 Hz, tympanometry, acoustic reflex threshold testing and a number of speech tests. In addition to word recognition testing (conducted using a male recording with CID W-22 50 word list at 40 dB SL re: SRT) and taped SRT testing, a modified speech in noise (SPIN) with recording and a nonsense syllable test (NST) with recording were utilized. T-tests were conducted to analyze the scores across all tests.

The researchers found no significant changes from the initial test to re-test in the air conduction thresholds and SRTs between the ears of the three groups.. The researchers did not find a significant difference in test/re-test scores between the ears of the control and binaurally aided group across all speech tests. In the monaurally aided group, the authors found significant differences ($p<0.05$) between mean test and re-test WRS and NST scores of the aided and unaided ears, but not with the SPIN scores. They hypothesized that the SPIN test may had been a less sensitive measure of the auditory deprivation effects or that the signal-to-noise ratio of the test may have masked potential effects. The researchers concluded that the overall findings of the study supported their previous work and recommended that binaural amplification be used in individuals with BSSNHL.

Study #4. Hurley (1999) conducted a prospective, non-randomized clinical trial with several objectives. The purpose of the study was to determine if the amount of hearing loss is a factor in the deprivation effect, whether one ear is more susceptible to the deprivation effect, and to further explore the onset time frame of auditory deprivation.

Subjects consisted of 142 individuals (93 male, 49 female) with BSSNHL, with an age range of 26 to 76 years and a mean age of 58 years. 77 of the subjects chose to be fitted monaurally and 65 of the subjects chose to be fitted binaurally. After the initial hearing instrument fitting, subjects were re-assessed one, three and five years post fitting. Individuals were required to report greater than eight hours of hearing instrument use daily. Subjects also met the following criteria: normal middle ear function, normal acoustic reflex thresholds, no interaural difference greater than 10 dB across audiometric thresholds and no interaural difference greater than 10% on WRS. Evaluations consisted of the following: air and bone pure tone audiometry, admittance measures, and WRS testing (pre-recorded NU-6 50 word list presented at 40 dB SL re: SRT).

Results revealed that 1% (1 of 77) of the monaurally unaided ears fell below the 95th percentile critical difference limit for test-retest WRS. However, by the 3rd year, 6% (5 of 77) of the monaural unaided ears fell below the critical difference limit, and at the 5th year, 20% (14 of 71) of the monaurally unaided ears fell below the critical difference limit. No significant difference in WRS was found at the one or three year re-assessment mark for the binaurally aided ears. However, at the fifth year, 6% (4 of 65) of the binaurally aided ears fell below the 95th percentile critical difference limit. There were no significant ear effects that were observed in the study, and no significant changes in test-retest audiometric thresholds were found. T-tests revealed a significant difference in pure tone averages between the individuals in the monaural and binaurally fitted groups who had a significant decrease in WRSs. The author noted that there was a smaller proportion of individuals who presented with the auditory deprivation effect, in comparison to the 1984 study Silman et al. He hypothesized that this may have been a result of greater levels of hearing loss in Silman's subject group.

Hurley concluded that the auditory deprivation effect can occur as early as one year post-fitting and is affected by the amount of hearing loss. However, he noted that the current definition for the auditory deprivation effect was based on the manifestation of a "significant reduction in the WRS for monosyllabic words, materials that are known to be relatively insensitive to subtle changes in auditory function" (p. 533).

Discussion. A grade two level of evidence is provided by the 1993 study from Silman et al. Hurley's study provided a grade three level of evidence (Dollaghan, 2007). The statistical analysis conducted in both studies were appropriate based upon their design. The tasks in both studies were described in sufficient detail for replication. The authors in both these studies reported finding an auditory deprivation effect at approximately one year post-fitting in the unaided ears of monaurally aided individuals. However, examination of these prospective studies reveal several caveats regarding their design and methodology. The age range of the subjects in both studies were widely varied and, as mentioned previously, this limitation may significantly confound the results of the study. The details regarding the word recognition testing conducted in these two studies were appropriately documented. However, the large test-retest variability associated with WRSs of individuals with sensorineural hearing loss continues to bring into debate the validity and reliability of word recognition testing as a measure of auditory deprivation effects (Engelberg, 1967). Neither of the prospective studies examined the effects of auditory deprivation on individuals who wore no amplification, although this may have been the result of ethical considerations. The study conducted by Hurley did not implement a blind design and did not include a control group of normal hearing subjects. Interestingly, Hurley's study also found a deprivation effect for several ears of the binaurally aided group. No explanation, however, was provided for this observation. Hurley's study examined individuals over a sufficiently wide time frame of five years. For the 1993 study conducted by Silman et al., the study followed individuals to only one year post-fitting and may not have been of sufficient length in order to reveal further auditory deprivation effects. Although the SPIN test did not reveal any potential deprivation effects, it may have been more representative of real-world performance for those subjects with hearing loss. Moreover, this result brings into debate the significance of the auditory deprivation effect on real-world auditory functioning in individuals who are monaurally aided. Altogether, these two prospective studies provide suggestive evidence for the existence of an auditory deprivation effect in the unaided ear of a monaurally amplified individual.

Conclusion and Clinical Implications

None of the studies examined in this critical review demonstrated a significant decrease in audiometric thresholds for the unaided ear over time. It is likely that the auditory deprivation effect may not be only due to changes in the peripheral auditory system, but also in the central auditory system (Neuman, 1996). Therefore, it is crucial to control for factors such as age or cause of hearing loss when conducting prospective research on auditory deprivation. Features such as data logging that are present in most digital hearing instruments today should be used in future studies as they provide an easier and more reliable method of monitoring hearing aid usage. As discussed earlier, conventional speech testing may not be the most appropriate method of measuring the effects of auditory deprivation. Researchers may wish to implement tests that measure the potential effects of auditory deprivation on other components of auditory functioning.

Although the studies examined in this review point to a possible auditory deprivation effect, the quality of evidence provided by these studies is open to discussion. Therefore, the results from these studies should be carefully interpreted by the clinician. It may be more appropriate for the clinician to err on the side of caution and provide other arguments for the provision of amplification when counseling individuals with BSSNHL.

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