Critical Review: Does every older adult with symmetric sensorineural hearing loss receive more performance benefit from binaural rather than monaural amplification in speech recognition with background noise?

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This Critical review investigated the objective benefit received from monaural versus binaural amplification in speech recognition with background noise among older adults with symmetric sensorineural hearing loss. The aim was to develop appropriate recommendations for the fitting practice in this hearing impaired sub-population. Three repeated measure within-subject design studies were reviewed. Overall, the studies support the view that binaural amplification is not always beneficial in recognizing speech in background noise among older adults with symmetric hearing loss.

Introduction

Previous studies have shown that most bilaterally hearing impaired adults with different types and degrees of hearing loss tend to prefer two hearing instruments over the fitting of just one hearing instrument (Erdman and Sedge, 1981; Briskey and Coles, 1983). This finding was also subjectively and objectively supported by a number of studies that measured and compared various performance differences between binaural and monaural amplifications in different listening situations. Some of the clear binaural advantages that have been described with literature are as follows: binaural summation, better intensity and frequency discrimination, better quality of sound and speech understanding, better sound localization, elimination of head shadow effect, no deprivation of the unaided ear; better speech recognition in noise for both symmetrical and asymmetrical hearing loss, binaural squelch and binaural redundancy (Erdman and Sedge, 1986; Balfour and Hawkins, 1992; Burkey and Arkis, 1993; Kochkin, 2000; Dillon, 2001). Because of these findings, most audiologists today believe that everyone who has an aidable symmetric hearing deficit in both ears should be fitted bilaterally. If anyone with symmetric hearing loss is fitted monaurally, it is due to a reason other than a benefit, such as a financial burden, physical limitation or cosmetic concerns (Walden & Walden, 2005). Consequently, most individuals with bilateral sensorineural hearing loss are typically fitted with binaural amplification.

The underlying basic assumption of binaural advantages is that all individuals with bilateral hearing impairment can benefit fully from the binaural integration (Walden & Walden, 2005). In other words, the assumption lies in the fact that both ears are working together to provide auditory benefits. However this assumption requires an optimal central auditory processing ability that might not be the case for all people. For example, it has been found that the central auditory system deteriorates as one ages (Stach, Spretnjak & Jerger, 1990; Grose, 1996). In fact, Gatehouse and Haggard (1986), cautioned against a fitting bilaterally for elderly people because of the possible central processing deficit. Moreover, in the absence of binaural integration, when two ears receive conflicting information, such as listening to speech with background noise, hearing can be adversely affected by binaural amplification. This phenomenon is known as the binaural interference effect (Henkin et al., 2007, original source; Jerger et al., 1993). Therefore, the present review was carried out under the premise that binaural amplification is not always beneficial among older adults with bilateral hearing loss in background noise when compared with monaural amplification.

Objectives

The purpose of this review is to critically evaluate recent studies that have examined the potential benefit of monaural over binaural amplification in elderly individuals with symmetric sensorineural hearing loss who might have difficulty with speech recognition in background noise with two hearing aids.

Methods

Search Strategy

Computerized databases, including PubMed and MEDLINES-Ovid were searched using the following search strategy:

> ((bilateral) OR (binaural)) AND ((unilateral) OR (monaural)) AND ((Benefit)) AND ((noise)) AND ((Symmetric)).

The search was limited to articles originally written in the English Language that were published after year the 2000 to reflect present research.

Some articles were retrieved by reviewing the references of relevant articles to gather general knowledge on the issue. No limits were set on the date of publication of these articles. These articles were not specifically reviewed.

Selection Criteria

Only the studies that specifically dealt with measuring speech recognition ability in background noise with binaural and monaural amplification by older adults with symmetric sensorineural hearing impairment were included in the investigation. However, there was no restriction on the demographics of the subjects and outcome measures.

Data Collection

The above selection strategy generated a total of three journal articles. There were three repeated measure within-subject design.

Due to the nature of audiological research, blinding and randomization were not accomplished for any of the three articles reviewed.

Results

Articles:

Listeners Who Prefer Monaural to Binaural Hearing Aids

Carter et al. (2001) examined four different individuals with hearing impairment from Veterans Affairs Medical Center, Mountain Home, Tennessee. Participants' ages ranged from 52 to 79 years of age. All subjects had a mild to moderately severe symmetrical hearing loss with excellent word recognition scores (WRS) in a quiet environment bilaterally. WRS for right and left ears were not significantly different in quiet. Thus, subjects were similar in terms of audiometric configuration and word recognition performance in quiet. In addition, all subjects were initially fitted with in-the-ear (ITE) type hearing instruments binaurally. All four subjects were not satisfied with their aided hearing, particularly in a noise environment. The experience of the hearing aid usage ranged from 5 months to 9 months among the four subjects. They also reported on the use of monaural amplification: three of them wore in the right ear and one either in the right or the left ear, but not in both ears.

The subjects were examined for the free-recall condition and the directed-recall condition of the dichotic digit test. The free-recall condition requires a listener to reproduce all numbers that were heard through each ear, thereby testing cognitive processing such as memory. The directed-recall condition requires a listener to recall from only one ear, thereby testing central auditory processing ability. Therefore, there could be four patterns of response: both free-recall and directed-recall normal, free-recall worse than directed-recall, directed-recall worse than free-recall and both free and directed-recall abnormal. The latter two indicate a central processing deficit and either or both of these patterns were observed by all four subjects in addition to a poor left ear performance. The left ear deficit cannot be explained by the differences between right and left ears in the audiometry and word recognition score in quiet. These results indicated that all four participants had a central auditory processing deficit.

The second part of the study was done to investigate the relationship between the central auditory deficit and the performance in speech recognition in background noise with monaural amplification, both right and left and unaided as a control, and with binaural amplification.

In order to generate a simulated noisy environment, a test was carried out in a sound booth. The desired signal was presented at 70 dB SPL through a speaker located at 0 degrees azimuth and a noise through a second speaker located at 180 degrees azimuth from the subject's face. The subject's head was positioned 1.1 m from each speaker. The noise was a multi-talker babble that was presented at +6, 0 and -6 dB signal to babble ratio. Northwestern University's Auditory Test No. 6 (NU-6) monosyllabic words list was used as signals.

The result indicated that the binaural aided score (88%) in quiet was significantly higher than each monaural (26% right, 24% left) and binaural (14%) aided score in noise. One of the limitations of this study is that statistical analyses were not reported. Thus, it is unclear whether the monaural aided performance was significantly higher than the binaural aided condition in background noise.

Carter et al. (2001) compared four conditions: unaided, aided right, aided left and aided binaurally using four different amplification strategies: NAL-R, NAL-R & Directional Microphone, Noise Reduction Algorithm and FM system. The first three of these four amplification conditions resulted in higher word recognition scores with a right ear monaurally aided

than with a left ear monaurally aided, or binaurally aided. This finding further supports the idea of binaural interference, when signals presented in the right ear would interfere with the left ear processing (Carter et al., 2001; original source, Chmiel et al., 1997). There were some additional interesting findings. For example, subject three, who indicated that he would prefer to wear a hearing instrument either in the right or the left ear, but not both, achieved a higher a word recognition score for the binaural condition when NAL-R & Directional Microphone amplification strategy was used. Only with the FM system was the binaural condition higher than with both monaural conditions and the word recognition score was similar to that obtained in quiet. Moreover, aided left ear score was higher than aided right ear score with the FM system. This perhaps suggests that when two ears do not interfere, greater signal to noise ratio is achieved, thereby enhancing the left ear performance (Carter et al., 2001). Therefore, for participants of this study the FM system was the only appropriate binaural amplification strategy.

The major limitations of this study are the sample size and the fact that all subjects were male from the veteran population. This may restrict its application to other demographic groups. Furthermore, the study did not perform any formal statistical analyses of the data.

Unilateral versus Bilateral Amplification for Adults with Impaired Hearing

Walden and Walden (2005) tried to replicate the findings of the Carter et al. study reviewed above. Two major advantages of this study are that Walden and Walden reported the results of statistical analyses to indicate the significance of the findings. In addition, there was a much greater sample (N=28) included. However, some limitation in generalization lies in the fact that all subjects came from the Army Audiology and Speech Center and only two were females. There were 23 subjects whose experience with amplification ranged from 1 to 17 years and 5 were new users. Subjects' age ranged from 50 to 90 years and averaged 75.1 years. Another advantage of this study is that Walden and Walden controlled important confounding variables. For example, none of the subjects had dementia or other neurological conditions or had experienced a stroke. Moreover, all subjects had a symmetric sensorineural hearing loss and scored "good" to "excellent" for word recognition bilaterally in quiet, using the NU-6 monosyllabic words list.

All subjects were tested for word recognition ability in noise and dichotic digit performance. Recognizing speech in noise was examined using a Quick Speech in Noise (SIN) test in a sound field at 70 dB HL in four different conditions: unaided, monaural aided right, monaural aided left and binaurally aided. A speaker was located at 0 degree azimuth from the face of the subject. Six sentences containing five key words were presented with four people speaking in the background. The Signal to Noise Ratio (SNR) was decreased 5 dB per sentence starting at 25 dB SNR to 0 dB SNR for the last sentence.

The final product of the QuickSIN test is the SNR loss, in which case the lower score indicates a better performance. The dichotic digit test was performed to assess the existence of binaural interference and similar to the Carter et al. study, free-recall and directed-recall conditions were used in the test.

When performance of the three aided conditions were compared, a Bonferroni t-test indicated a significant difference from one another ($p<0.05$). Specifically, the aided right performance was found to be better than aided left and the left was better than the binaural condition. An analysis of variance showed that the main effect is significant ($F=15.5$, $p<0.001$). The observation of individual data indicated that the results for 22 subjects were in agreement with this trend. Specifically performance in the right aided condition was better than left aided condition and for 23 subjects the monaural performance was better than the binaural. There was also a significant, but weak correlation between better unilateral performance than bilateral amplification and increasing age ($r=0.38$, $p<0.05$). Unlike the study done by Carter et al., the directed-recall for right and left ears was not significantly different ($t=0.53$, $p=0.60$) even though when matched with QuickSIN, scores indicated that subjects who scored well for QuickSIN tended to have a better directed-recall score in the same side.

The benefits of bilateral versus unilateral amplification for the elderly: are two always better than one?

This study conducted by Henkin et al. (2007) also looked at speech recognition performance in noise, the dichotic listening test and the relationship between better unilateral aided performance in noise in people over 60 years of age. The study assessed the subjects' speech recognition in noise and dichotic listening ability in three different conditions: aided monaural right, aided monaural left, and binaurally aided.

Twenty eight participants whose ages ranged from 62 to 87 with a mean age of 72.8 were examined. There were 21 male and 7 female subjects. Thus, a limitation of generalization exists because of a gender

disproportion. Each had a mild to severe symmetrical sensorineural hearing loss bilaterally. Twenty one subjects had less than one year of experience with binaural amplification and the remaining subjects' experience ranged from 14 to 32 months. Speech recognition ability in quiet was tested using AB open-set monosyllabic words list in the Hebrew language. The scores of the subjects ranged from 60% to 100% bilaterally. Mean scores for the right and left ears were 89.2% and 87.8%, respectively. Subjects wore various styles of hearing instruments. There were 15 subjects with in-the-canal (ITC), 5 subjects with in-the-ear (ITE) and 8 subjects with behind-the-ear (BTE) hearing instruments. However, all hearing instruments came from one manufacturer. This can act as a confounding variable since hearing instruments' performance is not necessarily identical across hearing aid manufacturers. In addition, a limitation lies in the fact that all subjects were Hebrew speakers. This may restrict the study's application to a native English speaking population with a similar type and degree of hearing loss. Furthermore, the study did not reveal the backgrounds of the subjects other than the fact that they all spoke Hebrew.

There are three interesting differences between this study and the studies above. Firstly, both phonemes and words were used to assess speech recognition ability in noise. Secondly, phonemes and words were presented at 70 dB SPL with a signal-to-noise ratio of +10 dB for the speech in noise test. The positioning of the two speakers with respect to the subject was similar to the study conducted by Carter et al., (2001). Lastly, sentences rather than digits were used for the dichotic listening test. The sentence list was modified from the Willeford competing sentence list.

Eight study participants, or 30 percent of the total subjects, scored higher with unilateral rather than bilateral amplification in noise. Scores tended to be reduced with increasing age. However, it was also found that dichotic listening test results were not significantly correlated with the speech recognition score in noise. Unlike the studies above, monaurally aided right ear word recognition performance in noise was not significantly higher than monaurally aided left ear performance. However, the dichotic listening test indicated a significant difference between the two ears in that the right ear was found to be less likely to experience interference ($t=2.1$, $p=0.04$). Furthermore, the Pearson correlation coefficient analysis indicated no significant correlations in right, left and both ears between word recognition in noise and the dichotic listening test. When the difference between binaurally and monaurally aided phoneme recognition scores in noise was compared with increasing age, there was a moderate degree of negative correlation ($r=-0.41$, $p=0.03$). A similar trend was seen with WRS in noise, even though the result was not significant. This shows that increasing age contributes to a deterioration of speech recognition ability in noise, but aging is not a sole factor in the declining performance.

Summary and Research Recommendations

This review has shown that despite the many benefits that bilateral amplification provides, this fitting approach may not be suitable for everyone with symmetric hearing loss. This is especially true when recognizing speech in background noise is required. In fact, the performance results for speech recognition in background noise indicated a tendency for greater ability with monaural rather than binaural amplification among the elderly. There was also a greater tendency to gain more benefit with the monaurally aided condition with increasing age. However, this should be interpreted cautiously since statistical analyses indicated significant, but weak association. This suggests that aging is not a sole predictor of the benefit from monaural amplification. In addition, subjects tended to score better with aided right ear than aided left ear, yet Henkin et al. (2007) found no significant difference.

Dichotic listening test results indicated a relationship between increased binaural interference and a poor binaurally aided score in noise. However, Walden and Walden (2005) and Henkin et al. (2007) did not find the association between dichotic test results and WRSs in background noise. Thus, the relation between a central processing deficit measured by dichotic tests and the benefit from monaural amplification is as yet unclear (Henkin et al., 2007; page 204). Therefore, there is a need to include other test batteries to assess central processing ability such as Test for Auditory Processing Disorders in Adult (SCAN-A) or The Staggered Spondaic Word (SSW) Test to further investigate the relationship between central processing deficit and the benefit from monaural amplification in noise.

Henkin et al. (2007) reported that despite the better monaural amplification performance in background noise, most of the subjects continued to use two hearing instruments. This may suggest that there are other listening situations that binaural amplification assists among those who perform better with one hearing instrument in noise (Henkin et al., 2007). Consequently, future research should investigate not only the benefit received from the monaural fitting in noise, but also the listening situations that might provide benefit from binaural amplification among the

elderly who prefer one hearing instrument in background noise.

Finally, aside from the limitations mentioned above, all studies reviewed simulated speech in a background noise situation to assess the performance. Simulation of the background noise may not be truly representative of the real environment. Therefore, there is a limitation on generalizations regarding real everyday listening environments. Accordingly, researchers need to attempt carrying out a test in a real listening environment.

Conclusion and Clinical Recommendations

The present literature review suggests that binaural amplification may not always provide benefit in recognizing speech in background noise among older adults with symmetric hearing loss. Thus, hearing health care professionals have to be cautious when prescribing two hearing aids to the elderly. Furthermore, there is a need to administer speech recognition in noise and central auditory processing tests to determine the potential benefit of the monaural amplification in noise. However, for the newly prescribed hearing aid user it is best to experience it in the actual field to determine the benefit of monaural amplification in a noise environment. The author agrees with Walden and Walden (2007) who stated "we believe these data do suggest that our patients wearing bilateral amplification should be counseled to try removing one hearing aid, generally the one fit to the left ear, when they experience difficulty in noisy listening situations." (pg. 583).

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