

Critical Review: Do Elderly Hearing Aid Users Perform Better on Speech Recognition in Noise Tests when Fitted Monaurally or Binaurally?

Ashley Blay

M.Cl.Sc. (AUD.) Candidate

University of Western Ontario: School of Communication Sciences and Disorders

This critical review examines if elderly hearing aid users perform better on speech recognition in noise tasks when fitted with amplification monaurally or binaurally. Study designs included: two within group (repeated measures) studies and three single subject 'n-of-1' studies. Overall, the research suggests that a group of patients with hearing loss may understand speech in noise better when using one hearing aid as opposed to two. This may be a result of binaural interference and is clinically relevant in order to provide appropriate amplification strategies for such patients.

Introduction

Binaural input is important for early developing auditory systems and preservation of auditory function in adult systems. Binaural listening is known to improve speech understanding, sound localization, sound quality and ease of listening. Such improvements are a result of factors such as binaural summation, binaural redundancy, binaural squelch and head diffraction effects. Binaural summation and redundancy are when small amounts of summation occur when identical signals are presented to both ears. Binaural squelch is the central suppression of interfering noise based on binaural hearing. These factors can increase loudness of speech and improve speech understanding in noise. Therefore, input through binaural amplification is important for proper auditory function for patients with hearing loss. Thus, bilateral hearing aid fitting has been an accepted clinical practice within the field of audiology for children and adult patients with hearing loss.

However, there are individuals who do not always benefit from bilateral hearing aid fittings. These patients may experience a phenomenon called binaural interference, in which conflicting information presented to the two ears may cause aided binaural performance to be worse than aided monaural performance. Although patients may have a symmetrical pure-tone hearing loss, suprathreshold speech recognition may be different between ears. In such cases, different auditory signals presented to the central auditory system by the two ears may result in binaural interference. Age related changes to the central auditory system may also impact the ability to benefit from binaural amplification and may contribute to binaural interference.

Objectives

The primary objective of this review is to critically evaluate existing literature that examines if adults with

bilateral symmetrical sensorineural hearing loss have equivalent speech recognition in noise when fitted with hearing aids monaurally or binaurally. The secondary objective is to propose evidence-based practice recommendations of hearing aid use for individuals who experience binaural interference.

Methods

Search Strategy

Computerized databases PubMed and Scopus were searched using the following search strategy:

[(binaural interference) AND (hearing aids)
OR (amplification) OR (elderly) AND/OR
(noise)].

Reference lists of relevant articles were also used to retrieve research articles.

Selection Criteria

Studies selected for inclusion in this critical review were required to investigate monaurally and binaurally aided speech recognition in noise tasks in adults. No limits were set regarding the methodological design of the studies.

Data Collection

Results of the literature review yielded the following types of articles congruent with the aforementioned selection criteria: within group (repeated measures) (2), single subject 'n-of-1' (3).

Results

Within Group (Repeated Measures)

Walden and Walden (2005) compared unilateral and bilateral aided speech recognition in background noise in 28 patients that were fitted with amplification. All patients had bilateral, symmetrical sensorineural hearing impairments. Patients ranged from 50 to 90 years of age with a mean age of 75.1 years and had 0 to 17 years of

experience with bilateral hearing aid use. Following the hearing aid fitting, Quick Speech-in-Noise (QuickSIN) test was used to assess speech recognition in noise in four randomized conditions. The four conditions included unaided bilaterally, aided right ear, aided left ear and aided bilaterally. The test was presented at 70dB HL in sound field from a loudspeaker at 0° azimuth. Dichotic Digit Test (DDT) was also conducted to assess binaural interference/separation.

QuickSIN tests resulted in signal-to-noise ratio (SNR) loss, less SNR loss represents better performance. Repeated measures analysis of variance (ANOVA) revealed a significant main effect. Bonferroni t-test revealed that each of the three aided conditions were significantly different from the other two ($p < 0.05$). On average, performance was significantly better in the right ears compared to the left ears and aided bilaterally was significantly poorer than either monaural performance. Data was analyzed again based on better ear, poorer ear performance on the QuickSIN test and ANOVA once again revealed a significant main effect ($F = 33.5$, $p < 0.001$). Post hoc analysis revealed that the better performing ear's scores were significantly different from the poorer performing ear and aided bilateral scores ($p < 0.001$). However, poorer ear performance and aided bilateral performance were not significantly different ($p = 0.10$). Inspection of individual data revealed unilateral performance was better than aided bilateral performance for 82.1% of participants. When test conditions were correlated with age, results revealed that older patients have greater SNR loss and a weak correlation showed a greater tendency for unilateral performance to exceed bilateral performance for older patients. These results indicated that older patients have greater difficulty understanding speech in competing noise and may function better with one hearing aid as opposed to two.

Henkin, Waldman and Kishon-Rabin (2007) conducted a similar study, which assessed aided unilateral and bilateral speech recognition in noise in elderly hearing-impaired patients. Twenty-eight patients between 62 and 87 years of age with a mean age of 72.8 years participated in the study. All patients had bilateral symmetrical mild-to-severe sensorineural hearing loss and had 1 to 32 months of hearing aid use experience. Patients were fitted binaurally with in-the-canal (ITC), in-the-ear (ITE) or behind-the-ear (BTE) digital hearing aids. Speech recognition in noise test consisted of consonant-vowel-consonant phonemically balanced words presented in sound field at 0° azimuth and competing noise presented at 180° azimuth in sound field. Speech recognition in noise was assessed in three randomized conditions, which included aided right ear,

aided left ear and aided bilaterally. Threshold-of-interference tests evaluated dichotic function.

Repeated measures ANOVA evaluated the effects of listening condition on aided speech recognition. Results revealed no significant differences between test conditions. 'Bilateral-unilateral difference' scores, defined as the difference between speech recognition in noise with bilateral versus better unilateral aided ear showed that 19 patients performed better with unilateral amplification for correct words and 20 patients for phonemes. Pearson's correlation coefficient revealed a moderate negative correlation between 'bilateral-unilateral difference' phoneme scores and age, which indicated better unilateral performance with increasing age ($r = -0.41$, $p = 0.03$).

Single Subject Studies

Carter, Noe and Wilson (2001) evaluated speech recognition in noise of four patients who preferred monaural amplification over binaural amplification. Patients ranged from 52 to 79 years old, had bilateral, symmetrical sensorineural hearing loss and were experienced hearing aids users. All patients were fitted with binaural BTEs that included four different programs (amplification strategies). Programs included National Acoustics Laboratories-Revised (NAL-R), NAL-R with directional microphones (NAL-R + DM), manufacturer's "party noise" program and FM system program. The speech recognition in noise test consisted of Northwestern University Auditory Test No. 6 (NU-6) words presented in sound field at 70 dB SPL by a loudspeaker at 0° azimuth and multitalker babble noise presented at -6, 0 and 6 dB relative to the speech signal at 180° azimuth. Aided right ear, aided left ear and aided binaural conditions were all assessed for each amplification strategy stated above and all three signal-to-babble (S/B) ratios. The strategies were counterbalanced and the order of the conditions and S/B ratios were randomized within each amplification strategy. DDT was also administered to each patient to determine central auditory function.

Subjects one and two showed poorer aided left ear performance than aided right ear for NAL-R, NAL-R + DM, and party noise strategies. The only successful binaural amplification strategy was the FM strategy. For the other three strategies binaural performance was either slightly better (2-4%) or worse than monaural right ear aided performance. Results indicated that subject one and two performed better using one hearing aid in the right ear than binaurally. Subject three showed better performance binaurally for the NAL-R + DM strategy. However, left ear aided and right ear aided performance was better than binaural performance for the party noise strategy and both monaural party noise

performance was equal to or better than performance with the FM strategy. Results from the party noise strategy supported the fact that subject three reported he could wear his hearing aids in his left or right ear but not binaurally. Subject four performed better on the right ear aided condition than the left and binaurally aided conditions for NAL-R, NAL-R + DM and party noise strategies. As with the other three cases, subject four performed best in the binaural condition with the FM strategy. Consistent with subject preference, results indicated that subject four recognizes speech in noise better using one hearing aid in the right ear rather than binaural amplification.

Chmiel, Jerger, Murphy, Pirozzolo and Tooley-Young (1997) evaluated a 90 year-old woman patient who preferred and performed better with monaural amplification instead of binaural amplification. Basic audiometric data, dichotic speech testing, neurological tests and hearing aid performance data were all collected. The patient had bilateral, symmetrical sensorineural hearing loss. Hearing aid performance evaluation involved speech recognition in noise testing. The task involved synthetic sentence identification (SSI) in the presence of competing continuous discourse under four amplification conditions. The four conditions included unaided binaural, aided right ear, aided left ear and aided binaural listening. SSI sentences were presented in sound field from a loudspeaker at 0° azimuth and continuous discourse presented at 180° at varying message-to-competition ratios (MCR). Results showed performance was best for the right ear aided condition, poorest for left ear aided and aided binaurally performance was in between both monaural conditions. Results were consistent with the patient's complaints of understanding speech in background noise when fitted with binaural amplification.

Jerger, Silan, Lew and Chmiel (1993) examined four elderly hearing-impaired patients. One of the cases evaluated speech recognition in noise in an 81 year-old man who had bilateral symmetrical high frequency sensorineural hearing loss. Performance was evaluated using the Cued-Listening Task. The task consisted of continuous discourse presented from right and left loudspeakers (90° and 270° azimuth) and output from one speaker was offset by 60 seconds from the other speaker. A correct response was recorded when the patient pressed a response button each time "I" pronoun was heard from the cued direction. Multitalker babble was presented by a loudspeaker above the patients head on the ceiling. Speech was presented at a comfortable listening level and MCR was -5 dB. Aided right ear, aided left ear and binaurally aided conditions were tested. For each condition 100 "I" targets were

presented, 50 from the right side and 50 from the left side in quasi-randomized blocks of 5.

Correct identification score for the aided right condition was 37 percent, for the aided left condition was 18 percent and for the aided binaural condition was 34 percent. Laterality errors occurred when response to the "I" target was from the noncued side. The aided right ear laterality error score was 17 percent, the aided left ear 15 percent and binaurally aided was 28 percent. Detectability index d' was calculated by combining correct identification and laterality errors. Results revealed d' for aided right ear was 0.62, for aided left ear was 0.11 and for binaurally aided condition was 0.17 which indicated that binaural performance was only slightly better than the aided left ear condition and much worse than aided right ear condition. Analysis of laterality errors showed the aided right condition was 21 percent, aided left ear was 29 percent and binaurally aided was 56 percent. Results indicated possible interference of the poorer ear with the better ear creating reduced performance binaurally.

Discussion

All of the reviewed studies compared monaural and binaural aided performance on speech recognition in noise tests for elderly patients with bilateral, symmetrical hearing loss. Within group studies by Walden and Walden (2005) and Henkin et al. (2007) provided a high level of evidence, which showed that the majority of patients in both studies performed better on speech recognition in background noise tests while using unilateral amplification to the better ear compared to bilateral amplification. This suggests binaural interference occurred. Interestingly, both studies also reported many patients had better performance with the poorer unilateral aided ear condition than binaurally aided condition. Single subject studies by Carter et al. (2001), Chmiel et al. (1997) and Jerger et al. (1993) also provided examples of similar results indicating better performance on speech in noise tasks when monaurally aided as opposed to binaurally suggesting binaural interference. However, all findings should be interpreted with caution as there are limitations in each study.

Sample recruitment was a concern in studies by Walden and Walden (2005) and Henkin et al. (2007). In the study by Walden and Walden (2005), patients were first seen by the author at the Army Audiology and Speech Centre (AASC) resulting in a majority of male participants. Thus, the sample included in this study is not necessarily representative of the population of elderly hearing aid users because sampling only occurred through the AASC. Henkin et al. (2007) did not discuss recruitment procedures of participants,

making sample representation of the population unknown. For this reason generalizability of results may be unknown.

Additional limitations in the study by Walden and Walden (2005) involved methodological protocols. The stimuli test level was presented in sound field at 70 dB HL. This level is considerably high when participants are listening with amplification. QuickSIN test recommends 70 dB HL level when administering the test in an unaided condition. However, conversational speech level is closer to 50 dB HL or 65 dB SPL which should be used when testing aided conditions. The test also consisted of speech and noise being presented in sound field by a single loudspeaker at 0° azimuth. Both speech and competing noise stimuli coming from the same loudspeaker directly in front of the patient may not reflect real world listening situations. All other studies discussed in this review involved speech presented at 0° azimuth and competing noise at 180° azimuth, which may simulate a real world environment when a talker is in front of a listener and background noise comes from behind. The conditions used are not representative of real world listening environments and therefore, this may limit generalizability to speech understanding in natural listening situations with background noise.

Carter et al. (2001) examined speech recognition in noise of four patients who preferred monaural amplification and found that, on average, performance was better when subjects used monaural amplification on the right ear compared to binaural fittings. The study design had a high level of evidence due to counterbalancing of the four amplification strategies, randomization of the conditions and S/B ratio and the use of four subjects. Percentage correct recognition was represented by visual analysis; however, statistical analysis was not performed. Thus, interpretation of results should be approached with caution.

Although Chmiel et al. (1997) performed an extensive case study; they failed to discuss a detailed protocol of the amplification evaluation where speech recognition in noise was tested. Randomization of amplification conditions or MCR was not stated. If these were not randomized the patient may have become fatigued towards the end of the tests. Level of speech stimuli was not stated which is problematic for interpreting results because one cannot determine whether the stimulus was presented at real world conversational levels. These factors resulted in a low level of evidence for this single subject study design, making it difficult to determine if results can generalize to a subgroup of patients.

All three single subject studies must be interpreted with caution because they represent individuals who experience better speech understanding in noise when monaurally aided but do not represent the entire population of elderly patients with hearing impairments. Research by Walden et al. (2005) and Henkin et al. (2007) provided larger sample size studies that showed similar significant results of binaural interference during speech recognition in noise. Further studies with larger samples sizes may be conducted to determine better generalizability of this phenomenon. Future research may aim to determine at what age binaural interference has a significant effect on speech understanding in noise in the hearing impaired population. Research may also be directed to determine what percentage of different age populations experience binaural interference and possible causes of binaural interference.

Conclusion

Overall, the research provides suggestive evidence that a subgroup of patients with hearing loss may understand speech in noise better when using one hearing aid as opposed to two. This may be a result of binaural interference and is clinically relevant in order to provide appropriate amplification strategies for such patients. Binaural interference must be occurring because we would expect binaural performance to be at least as good as performance of the better ear. However, binaural performance was poorer than better ear performance in the majority of patients in these studies; thus, stimulation of the poorer ear must be interfering with the response of the better ear. Results were correlated with age indicating older patients may have more difficulty understanding speech in noise with binaural amplification.

Similar results were found by Henkin et al. (2007) who used Hebrew word lists and non English speaking patients, as all other studies reviewed which used North American, English speaking patients. Similar results were also found across different speech recognition in noise tests that were reviewed indicating that this phenomenon can occur across different languages, places and different speech recognition in noise tests. Thus, results may generalize well to real world situations. The cause of such binaural interference is still unknown however. Therefore, there is no way of determining which patients will experience problems with binaural amplification when listening in noise before they are prescribed amplification.

Clinical Implications

Overall, the evidence provides support that a group of patients with bilateral symmetrical hearing loss may

understand speech in noise better when using only one hearing aid. These results suggest that patients with binaural amplification may find it helpful to only wear one hearing aid when they have difficulty listening in noisy environments with two hearing aids. Elderly patients may find an increased benefit using this strategy due to correlation of aided monaural speech recognition in noise and age.

Further evaluation of different amplification strategies by Carter et al. (2001) revealed that certain programs may be more helpful for an individual than others. In clinical practice this would require the clinician and patient to experiment with different strategies to determine which is most helpful for speech understanding in noise. Carter et al. (2001) also examined speech recognition in noise with FM systems and found this to be the only successful binaural amplification strategy. Improved SNR offered by the FM system may eliminate interference from the poorer ear. Thus, FM system may be a necessary strategy for patients who experience binaural interference when listening in noisy environments.

This evidence may also be beneficial for patients who reject their hearing aids in noisy environments. Speech recognition testing in noise for monaural and binaural amplification conditions may be beneficial to perform in clinical practice for patients who are having difficulty with amplification in noise. These tests may help the clinician determine whether the patient is experiencing binaural interference and if different amplification strategies should be employed such as monaural

amplification in noisy listening environments or the use of FM systems.

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