

Auditory Research

47. A cost-utility analysis of adult audiologic rehabilitation: is the benefit worth the cost?

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Objectives: The purpose of this study was to conduct a cost-utility analysis comparing two treatment approaches: 1) hearing aid use alone (HA); and 2) hearing aid use in conjunction with short-term group post-fitting audiologic rehabilitation (HA+AR). While post-hearing aid fitting audiologic rehabilitation programs have been shown to improve hearing aid use and satisfaction, they have not gained wide acceptance in the audiology community because these programs have been perceived as adding additional time and cost to the treatment process.

Methods: A total of 106 veterans, 68 males and 38 females, with at least a mild sensorineural hearing loss participated in this study. Approximately half of the participants were assigned to the hearing aids alone (HA) group and half to the hearing aids plus AR group (HA+AR). In total there were 16 cohorts tested - 8 HA cohorts and 8 HA+AR cohorts. The participants in the AR cohorts returned once a week, for four weeks, for two-hour group sessions which included a general overview of the hearing process, developing communication strategies, environmental management, telephone communication strategies, the use of assistive technology, and community resources for the hard-of-hearing. All participants were fit with binaural digitally programmable analog hearing aids from the same manufacturer. The MOS-SF36V was administered to each participant before and after treatment.

Results: The MOS-SF36V physical (PCS) and mental (MCS) component scores were subjected to a 3-way mixed model analysis of variance (ANOVA) with one between groups factor (i.e., treatment group) and two within groups factors (i.e., time and component). While the main effect of treatment group (i.e., HA-alone vs. HA+AR) did not reach statistical significance, both the main effects of time, pre- vs. post-treatment and component, PCS vs. MCS showed statistically reliable differences. Furthermore, the results of a cost-utility

analysis revealed that HA treatment cost \$30.91 per quality adjusted life years (QALY) gained, while HA+AR cost \$29.86 per QALY gained, making HA+AR the more cost-effective treatment.

Conclusions: It is concluded that both treatment options improved our patients' overall perception of their quality of life on a widely used generic quality of life instrument and did so in a cost-effective manner. The findings represent the first known evidence that hearing aid use, with or without adjunctive audiologic rehabilitation, yields significantly positive results on the MOS SF-36V – a widely used, generic quality of life measure without specific questions associated with hearing loss or communication. While the QALY difference between the groups was only a little more than one dollar per subject, the cumulative impact across the VA system could be substantial where in FY 2001, almost 155,000 hearing aid orders were placed at a cost of close to \$81,000,000.00. Potential direct and indirect benefits of a post-fitting AR program that were not examined as part of this investigation, such as reduced visits to the clinic for hearing aid modifications, should be considered for future study.

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48. The effect of stimulus parameters on vestibular evoked myogenic potentials.

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Objectives. The vestibular sensory organs include three semi-circular canals and two otolithic organs. Most routine clinical vestibular tests evaluate the horizontal semi-circular canal and fail to evaluate the remaining four vestibular organs. Recent research is focusing on developing clinical tests to assess otolith function. Vestibular evoked myogenic potentials (VEMP) are short latency electromyograms (EMG) evoked by high-level acoustic stimuli recorded from surface electrodes

over the tonically contracted sternocleidomastoid (SCM) muscle. These responses are presumed to originate in the saccule and have been proposed as a clinical test of saccular and/or inferior vestibular nerve function (1). However, the influence of various stimulus parameters on the VEMP is unknown. While most investigators have recorded VEMPs in response to click stimuli, animal studies suggest that the saccular nerve fibers are most sensitive to low frequency stimuli (2, 3). The purpose of this study was to investigate the effects of stimulus frequency and level on the VEMP recorded at the sternocleidomastoid muscle in humans.

Method. Nineteen subjects ranged in age from 18 to 45 years and had no history of audiovestibular and/or neurological disease. Audiovestibular function was confirmed with pure tone audiometric testing, acoustic immittance, and caloric testing. Input-output functions were obtained in response to tone burst and click stimuli delivered via insert earphones at a rate of 3.1/s. Tone burst frequencies ranged from 250 to 2000Hz. The stimulus intensity did not exceed 100 dB nHL. A two-channel recording of the myogenic response was obtained with noninverting electrodes at the midpoint of the sternocleidomastoid muscle on each side of the neck and the inverting electrodes at the sternoclavicular junctions. Subjects were seated upright and asked to turn their heads to one side (away from the stimulus ear) to unilaterally activate the sternocleidomastoid muscle. The magnitude of tonic neck muscle activity was controlled within each subject by monitoring the amplitude of the rectified electromyography (EMG) via an oscilloscope. Responses to 150 stimuli were averaged and three responses were obtained from each side at each stimulus level. Peak-to-peak amplitudes and peak latencies were measured from an average of the three responses.

Results. Short latency, large amplitude responses were evoked with click and tone burst stimuli during tonic neck flexor activation at stimulus levels from 90-100 dB nHL. Responses were obtained from both sides of the neck in all subjects. The salient features of the response waveform were a positive peak at 11-14 ms and a negative peak at 19-22 ms. The amplitude of the VEMP increased as a function of click stimulus level, however, the response latency remained constant. The response amplitudes also varied with stimulus frequency, and the largest amplitude VEMP was obtained with 500 Hz tone bursts. Tone burst evoked responses showed an inverse relationship between stimulus frequency and the response latency of the VEMP.

Conclusions. The VEMP is influenced by stimulus level and frequency. Additional study is needed to determine

the threshold of the VEMP at each tone burst frequency and to ascertain the ideal stimulus to evoke the response in a clinical setting. This potential may provide unique information about vestibular function and prove useful in the evaluation of veterans with vestibular disorders.

Funding Acknowledgment. RR&D Career Development Award

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49. Auditory evoked response methods for assessment of speech and language processing

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Objectives: The overall purpose of our investigation is to test the precision of auditory evoked responses (AERs) to provide a prognosis for improvement in aphasia subsequent to a left hemisphere thromboembolic infarct. This presentation reports our methodology and preliminary results from normal subjects.

Methods: Fifteen normal subjects were evaluated with language and AER test batteries. The language test battery consisted of the Western Aphasia Battery (WAB), the Porch Index of Communicative Ability (PICA), the Token Test (TT), the Auditory Comprehension Test for Sentences (ACTS), and the ASHA Functional Assessment of Communication Skills for Adults (ASHA FACS). AERs elicited with puretone, phonemic, semantic, and syntactic stimuli were included in the AER test battery. The AERs of interest were the MMN (puretone and phonemic), the T-complex (puretone and phonemic), the N400

(semantic), and the P600 (syntactic). All tests were repeated after 6 weeks. The Neuroscan Inc. data acquisition system allowed simultaneous stimulus presentation and recording of each response. Auditory stimuli were presented through earphones at a comfortable level of 80-90 dB SPL. During the phonologic, semantic, and syntactic tasks visual stimuli were presented on a computer monitor simultaneously with the auditory stimuli presented through earphones. AERs were recorded from Fz, Cz, C3, C4, T5, and T6 electrode sites, according to the 10/20 system. A Fpz reference was used.

Results: Results of the language test battery indicated normal responses from all subjects. Test-retest reliability was excellent for these tests. Preliminary results of the puretone and phonemic AER tests indicated presence of the responses in 90-100% of the subjects. Moderate to good test-retest reliability of these tests was shown as well.

Conclusions: The MMN and T-complex AERs, elicited by puretones and speech stimuli, were present and reliable in normal adult subjects. Data collection for subjects with moderate and severe aphasia is on going. Developing methods to predict improvement in veteran aphasic patients such as those reported here should have a significant influence on the quality of care and the allocation of limited resources.

Funding Acknowledgment: This study was funded by the VA Rehabilitation Research and Development Service.

50. Application of digital amplification to low cost, portable audiometry

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Objectives: A low-cost, pocket-sized audiometer capable of testing the full range of human hearing would contribute to the efficiency of hearing testing done outside the audiology clinic. Furthermore, if these devices were relatively inexpensive and extremely easy to operate, remote hearing testing, as well as patient in-home monitoring and testing would be practical. The long term goal of this research &

development is to develop inexpensive, handheld, audiometer-like instruments suitable for computer assisted, patient guided, full range hearing testing. Typical modern audiometers are composed of a user interface, programmable logic, data storage, and external interfaces and the stimulus signal path consisting of signal generation, mixing, attenuation, and transducer buffer amplification. Recent developments of the powerful pocket-sized computer and digital audio technology have made the implementation of all the key components except the final stages of the stimulus signal generation path possible in a pocket-sized package. Another recent technological breakthrough has been the application of digitally driven pulse-width-modulation techniques to power amplifier designs resulting in strong performance and efficiency improvements over traditional analog designs. The entire audiometer stimulus functionality less output filter and acoustic transducer should now be realizable as a pure digital instrument in a package size that would fit in a coat pocket if not shirt pocket. The objective of this work was to assemble a prototype pure digital audiometer-like instrument using standard components, evaluate basic performance, and demonstrate feasibility of building high performance, low-cost, pocket-sized audiometer-like instruments using similar techniques. This prototype project was called the Digital Programmable Audio Lab (DPAL).

Methods: The DPAL prototype was composed of three pieces: 1) digital stimulus generator consisting of a small personal computer with soundcard and serial data output, 2) digital amplifier module with serial data input, and 3) headphone transducer. System digital resolution of 16 bits or 96dB was used. The amplifier module and transducer were characterized acoustically with a CDRom player and audio test CD serving as the digital stimulus generator. Various techniques for signal attenuation were investigated. A demonstration system was built with a simple audiometer-like user interface generating the digital stimulus signals for the power amplifier. All software for the prototype system was developed using standard Microsoft Windows development tools.

Results: The operation of the DPAL pure digital audiometer-like system will be demonstrated. Performance results indicate the instrument is capable of testing the full range of human hearing. DPAL demonstrates the feasibility of developing a pocket-sized instrument by replacing the small generic digital

amplifier module with an even smaller customized digital amplifier module and utilizing an inexpensive shirt pocket-sized personal computer as the human interface and digital stimulus generator.

Conclusions: The DPAL system is usable for many types of hearing testing including bedside hearing testing. Efficient development of powerful hearing test applications is supported, including multimedia and networking. Overall project work remaining to be done includes redeployment on a smaller, less expensive, pocket-sized device with inexpensive transducers, and implementation of a centralized control, data collection and repository system for interfacing with remote site testing locations and gathering patient data.

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51. Rapid identification of a limited, sensitive frequency test range for early detection of ototoxicity

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Objectives: A leading cause of sensorineural hearing loss arises from therapeutic treatment with drugs having ototoxic potential (3), especially the aminoglycoside antibiotics (AMG) and the chemotherapeutic agent cisplatin (CDDP). It has been shown that a sensitive range of ototoxicity (SRO) can be identified for individuals receiving ototoxic drug treatments. A reliable and time-efficient protocol for early identification of ototoxicity would allow routine clinical monitoring to be expanded to a greater number of patients. The development of such clinically efficient monitoring techniques could significantly reduce the number of patients who suffer from disabling hearing losses requiring expensive, avoidable rehabilitation and allow patients to retain a better quality of life. This project investigated an efficient protocol for rapid identification of the SRO.

Method: Twenty-one hospitalized male patients not receiving any medications with known ototoxic

potential were tested for this study. For the full baseline protocol, pure tone thresholds were obtained initially at all frequencies from 2 kHz through 20 kHz. Using 1/6 octave steps above 8 kHz. Then threshold testing was repeated with a second protocol named the rapid identification protocol. The rapid identification protocol used an algorithm developed to identify the highest frequency where a threshold could be obtained at or below 100 dB SPL This was the uppermost target frequency of the SRO. Testing began at 20 kHz and proceeded to the next lowest frequency until the criterion was met. The target frequencies identified with the rapid identification protocol were compared to those identified using the full baseline protocol to determine the accuracy of the rapid method for identifying the SRO.

Results: The rapid identification protocol identified the same uppermost target frequency as the full baseline protocol in 36 of the 42 ears tested. Differences in target frequencies between the two methods were small (half-octave or less). Although the number of threshold responses decreased as frequency increased beyond 10 kHz, uppermost target frequencies fell within the routine clinical test range (≤ 8 kHz) for only eight of the 42 ears.

Conclusions: This study emphasizes the need for high frequency (≥ 8 kHz) threshold testing for early detection of ototoxicity. These frequencies can provide early warning information that may permit intervention before the frequencies that affect speech understanding are affected. The rapid identification protocol makes it possible to extend hospital ototoxicity monitoring programs to a greater number of patients by affording significant time savings and diminished test fatigue for ill patients .

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52. Time-expanded speech and speech recognition in older adults

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Objectives: Several studies have shown that older listeners have difficulty understanding faster rates of speech and may better understand slower rates of speech. The purpose of this study was to investigate the effect of a new non-uniform time expansion algorithm, which expands and amplifies unvoiced consonants, on speech intelligibility. This study examined the effects of speech rate, consonant gain, background noise, age, and/or hearing loss on speech intelligibility.

Methods: A total of 36 subjects were involved in this study. There were three groups of 12 subjects each; Young listeners with normal hearing, Older listeners with normal hearing, and Older listeners with mild to moderate sensorineural hearing loss. The speech material, Connected Speech Test (CST), was processed through a non-uniform time expansion algorithm. The word recognition scores of the CST in twelve different conditions were compared. The twelve different conditions consisted of three rates (normal, 1.2 times slower than normal, and 1.4 times slower than normal), two different consonant gain conditions (with or without), and two different background conditions (with or without multi-talker babble).

Results: The results revealed that speech processed by the current algorithm decreased speech intelligibility compared with unprocessed speech regardless of conditions. Young listeners showed better speech intelligibility than older listeners in all conditions. However, there was no effect of hearing loss in the older groups in the any of the conditions. When the two different rates of processed speech were compared, the slower rate improved speech intelligibility in noise. Consonant gain also showed a positive effect on speech intelligibility under some conditions.

Conclusion: The speech processed by the current algorithm unexpectedly decreased speech

intelligibility. This may be due to the distortion caused during the speech signal processing. The current algorithm needs to be developed further in order to improve speech understanding among elderly and people with hearing loss. However, this study showed some positive evidence that a slower rate of speech and emphasized unvoiced consonants may improve speech understanding in certain conditions. The method of identifying unvoiced speech segments needs to be modified. Then, this technology could be integrated into assistive listening devices.

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53. The evaluation of the use of insert earphones for bedside ototoxicity monitoring

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Objectives: The VA RR&D National Center for Rehabilitative Auditory Research (NCRAR) has been involved in developing an effective and efficient protocol to monitor patients for ototoxicity. Fausti, et al., (1994) established that ototoxicity is predominantly detected earliest in the high frequency range in individuals with high-frequency hearing sensitivity. This investigative work led to the publication of national guidelines for the effective monitoring of ototoxicity (ASHA, 1994).

As part of our efforts to improve the methodology for ototoxicity monitoring, we are evaluating the use of insert earphones which would offer several advantages, primarily the attenuation of background noise, thus allowing the testing of patients at bedside. The purpose of the present study is to evaluate the use of insert earphones for bedside testing. Utilization of insert earphones for audiometric evaluation at bedside may improve threshold reliability, versus using circumaural earphones, by reducing ambient noise at the eardrum. The Etymotic ER-4B insert earphone was chosen due to the fact that they are presently the only insert earphones that can reproduce the entire range of puretone frequencies employed in ototoxicity

monitoring (0.5-20 kHz). The present study will evaluate the insert earphones for reliability of responses at bedside. Good test-retest reliability is necessary for serial monitoring application, which must be fully documented using the ER-4B's.

Methods: Testing will be done using 20 hospitalized patients not receiving ototoxic drugs (at bedside and in the laboratory). Test-retest reliability of thresholds will be compared between the ER-4's and the circumaural earphones used for audiometry. During each session, subjects will be tested at the baseline audiometric frequencies with each transducer, and test order will be counterbalanced between the transducers. Repeat testing will be done over two sessions for each subject, and the intersession variability of thresholds will be compared between transducers.

Results: Data collection has been initiated, however results are to be forthcoming.

Conclusions: Prior studies at the NCRAR have documented that the ER-4B insert earphones can be used to obtain reliable measures of high-frequency hearing sensitivity. The next step in evaluating the efficacy of using ER-4B insert earphones for ototoxicity monitoring is to evaluate their reliability in the hospital room. We anticipate a positive outcome in the ability of the ER-4B transducer to reduce ambient background noise, thus making it possible to achieve reliable auditory thresholds on hospital wards.

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54. Screening protocol for antibodies against cochlear antigens in clinical hearing loss

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Objectives: In patients with acute hearing loss there is often no clear etiology of disease. Steroids are often used clinically to treat these individuals, however, without knowledge of disease mechanisms affecting hearing loss, steroid treatment can be used indiscriminately and may not be effective. Since steroid therapy can cause potentially serious side effects, it would be advantageous to avoid unnecessary treatment. We speculate that circulating antibodies to specific inner ear antigens will be indicative of cochlear pathology and allow prediction of which patients will be responsive to steroid treatment. We propose to use identification of specific antibody responses to develop diagnostic criteria that will permit the early identification of steroid-responsive patients with various forms of acute hearing loss. Preliminary studies were done examining serum antibodies in the MRL/MpJ-*Fas*^{lpr} mouse with spontaneous autoimmune inner ear disease and demonstrated hearing loss. These studies identified potential relevant antigens and optimal screening protocols that will now be used to screen patient sera to predict which patients will be responsive to steroid treatment.

Methods: Sera were collected from 5-10 month old MRL/MpJ-*Fas*^{lpr} autoimmune mice and normal C3H and CBA mice. Pooled sera from each group were tested by ELISA for reactivity against various cochlear antigens: heat shock protein 70 (bovine, human, bacterial), laminin, heparan sulfate proteoglycan, cardiolipin, and collagen types II and IV. To optimize ELISAs, sera dose response curves were

obtained for each antigen for both normal and immune sera, and various concentrations of antigen and secondary reagents were utilized.

Results: Autoimmune mouse sera showed significantly ($p < 0.001$) greater antibody reactivity against all of the antigens across all sera dilutions when compared to normal sera. Based on these results these antigens will be used in human studies. Optimal ELISA conditions were determined for each antigen.

Conclusions: A mouse model system was used to identify eight inner ear antigens against which sera from autoimmune mice showed significantly greater reactivity than sera from normal mice. It is predicted that steroid therapy will be effective in treating hearing loss with an autoimmune etiology. These studies have demonstrated the feasibility of detecting differences in antibody titers and developing a screening protocol for clinical treatment.

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55. 1/6th octave ototoxicity monitoring

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Objectives: The VA RR&D National Center for Rehabilitative Auditory Research (NCRAR) has been involved in developing an effective and efficient protocol to monitor patients for ototoxicity. The initial work involved patients with relatively good high frequency hearing (thresholds < 100 dB at 11.2k) and resulted in the use of an individualized 5 frequency ‘slope’ beginning with the highest frequency that had a threshold of 100dB or less and ending with a frequency five steps below the target frequency (Fausti, Henry, Helt, Phillips, Frey, Noffsinger, Larson, Fowler, 1999). This protocol tested at 1/6th octave steps above 9kHz but only tested 8, 6, 4, 3 and 2kHz below that since these are the frequencies tested in a standard clinical audiological evaluation.

We recently began testing patients in 1/6th octave steps over their individualized ‘slope’ regardless of where that range was. The primary question of interest is whether adding additional test frequencies when a patient has relatively poor hearing results in increased detection.

Methods: Data are currently being collected from four participating sites: VAMCs at Portland, OR; Nashville, TN; West Los Angeles, CA; and Vanderbilt University Medical Center, Nashville, TN. Patients receiving cisplatin or specified aminoglycoside antibiotics were recruited as meeting inclusion criteria. During each session, hearing thresholds were evaluated at 0.5 and 1k, and in 1/6th octave intervals at 2-20kHz. Baseline thresholds provided the reference against which all further tests were compared. The criteria for identifying ototoxic threshold changes were consistent with the national standards, developed at the NCRAR and published by the American Speech-Language-Hearing Association (ASHA) in 1994.

Results: To date we have collected data from 369 patients, 29 of which whose top slope frequency was 8kHz or less in one or both ears and who showed ototoxic change. If these patients had been evaluated using the standard clinical procedure, 20 of 35 ears of these patients (57%) would have been detected and 15 missed (43%).

Conclusions: Based upon these preliminary results, it appears that for individuals with poor hearing, the time required to evaluate additional frequencies results in increased detection of ototoxicity. Treatment with therapeutic drugs such as the aminoglycoside antibiotics and the chemotherapeutic agent cisplatin can cause hearing loss with potentially severe vocational and social consequences. Because of this threat to quality of life, early identification of hearing loss from ototoxicity is important to health care providers. According to our preliminary data, using a testing protocol of 1/6th octave steps provides an increased identification rate of potential ototoxic effects. The development of a rapid and sensitive protocol would ultimately result in improved post-treatment quality of life for these patients.

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56. Assessing effects of two methods for treating tinnitus: a randomized clinical trial

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Objectives. For the VA healthcare system, tinnitus (the perception of “phantom” sound) presents a significant problem. The Office of Policy and Planning at VACO reported that, as of September 2001, 162,409 veterans were service-connected for tinnitus, with disability compensation amounting to approximately \$172,721,000 per year. In spite of the magnitude of the problem, most VA medical centers do not provide clinical management for veterans with problematic tinnitus. A randomized clinical trial is in its third year to prospectively evaluate the clinical efficacy of two non-invasive, non-pharmaceutical methods that have potential for effectively treating veterans with tinnitus. This report will focus on methodology and results obtained from the trial to date.

Methods. Veterans with clinically significant tinnitus are recruited from Audiology and Otolaryngology clinics at the Portland VA Medical Center, and from the surrounding area. Qualifying individuals are randomly assigned to either the Tinnitus Masking or the Tinnitus Retraining Therapy (TRT) group. Tinnitus Masking is conducted in a manner consistent with published descriptions of this method and personal consultation with the individual who is credited for developing the clinical masking approach (Dr. Jack Vernon). TRT is conducted using the program described by its originator, Dr. Pawel Jastreboff. While TRT follows closely the published protocol, the Masking protocol includes counseling that is consistent with Vernon’s masking approach, but has not been formally described. Also, Masking patients attend follow-up visits using the follow-up schedule that is specified for TRT. Prior to treatment, patients receive a complete audiological and tinnitus evaluation, and are examined by an otolaryngologist. In addition, a series of questionnaires is completed by-Trait Anxiety Inventory. During the initial evaluation, participants

are interviewed using the TRT Initial Interview Form. Follow-up treatment visits are scheduled at 3, 6, 12 and 18 months. Outcomes instruments are repeated at the follow-up visits.

Results. This study was funded beginning 1 October 1999. To date, 128 veterans are in various phases of treatment in the Masking and TRT groups. Additionally, 30 subjects have completed all initial testing, and have opted for a counseling session only in lieu of the full treatment schedule. Counseling-only subjects complete follow-up questionnaires at one year following their counseling session.

Conclusions. This study was designed to determine the effectiveness of two clinical techniques for treating severe tinnitus. Thousands of patients have received treatment with TRT and Masking, and numerous claims have been made regarding treatment success. These claims, however, have been made based on analyses of clinical data. It is critical to evaluate the effectiveness of these methods using prospective research techniques. This study will provide an impartial comparison of the two methods, which will contribute to a greater understanding of the efficacy of these techniques for treating veterans with tinnitus.

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57. In-the-ear (ITE) active hearing protection

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Objectives: The veteran who wears ear plugs or earmuffs religiously on the shooting range often will wear no hearing protection while hunting or in other situations that involve random impact noise. The wearable hearing protectors described in this report were designed: 1) to offer little or no sound attenuation in a quiet environment; 2) to “shut down” in the presence of any sound over 85 dB sound-pressure level (SPL); and 3) to be custom-molded in

soft polymer ear plugs that fit comfortably in the ear canals of the wearer.

Methods: “Off-the shelf” hearing aid-amplifiers and transducers were configured to produce a maximum (saturation) sound-pressure level (SPL) of 88 dB in a standard 2-cm² acoustic coupler. These units then were incorporated into custom hearing protectors for both ears of 10 listeners with normal hearing. The subjects all were hunters or shooters. The “real-ear” attenuation provided by these hearing protectors was evaluated with standard (ANSI) 1/3-octave bands of noise presented from a loudspeaker in a sound-insulated chamber. First, auditory thresholds were measured for each subject with both ear canals open. Next, the hearing protectors were inserted and auditory thresholds were determined again for each subject with the hearing protectors set to “full-on” gain. Finally, auditory thresholds were obtained for each subject with the hearing protectors turned off. For one test subject, a miniature microphone was imbedded in the canal portion of her right hearing protector and spectral analyses of sounds in her ear canal were accomplished while her ear was one meter from the report of a hunting rifle.

Results: When the active hearing protectors were turned off, the mean hearing protection was similar to that provided by the best passive earplugs. When set to “full-on” gain they provided less than 10 dB of sound attenuation at the low frequencies and less than 10 dB of amplification at the higher test frequencies. For the subject who wore active protection in the presence of rifle fire, the SPL in her ear canal was no greater with the hearing protector set to “full-on” gain than it was with the device turned off. Subjectively, the experimental subjects reported: 1) that rifle and shotgun reports sounded like “misfires;” 2) that the hearing protectors were comfortable to wear; and 3) that they experienced no tinnitus aurium after using them for hunting or for trap shooting.

Clinical Relevance: Veterans, as a group, have more noise-induced hearing loss than the general population. Continued exposure to high-level acoustic signals typically adds to the total disability associated with speech intelligibility in a background of noise and with tinnitus. The hearing protectors described in this report provide a solution for the veteran who elects not to wear hearing protection while hunting or in other situations that involve random impact noise. The cost of parts for these active hearing protectors currently is less than \$40.00 per ear.

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58. Comparison among stimulus trains for the rapid acquisition of high frequency (8-14kHz) auditory brainstem responses.

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Objectives: To compare the brainstem responses elicited by three different configurations of stimuli to determine their reliability and robustness. Also, to infer which stimulus sequence is the most suitable for the early detection and monitoring of ototoxicity.

Methods: There were two groups of subjects, those with normal hearing (N=50) and those with sensorineural hearing loss (N=40). Auditory brainstem responses were recorded in a conventional manner. Rapid rise time (1 ms) tone bursts were used as stimuli. Three configurations of tone bursts were used: (1) single tone bursts, (2) a 5-stimulus train, of increasing intensities, at one frequency, (3) a 15-stimulus train of 5 intensities at three different frequencies. The ipsilateral Wave V response latency and amplitude were the primary measures. Duplicate responses were obtained in each of two sessions.

Results: The test-retest reliability and the probability of response detection were determined for different frequencies and levels. Reliabilities (both intra- and intersession) were similar among the three stimulus configurations. Significant differences (ANOVA, ≤ 0.01) in Wave V latencies were found between the single and the 15-stimulus train. This latency delay (approx. 0.2 ms) from the train indicates some response adaptation when the frequencies are closely spaced (1/3 octave), however the biological significance of these differences depends upon the intended use. For example, the trains which produce a small amount of adaptation, and where a subject serves as their own control, is suitable for the early detection and monitoring of ototoxicity.

Conclusions: Tone burst trains are demonstrated to be reliable and efficient for obtaining ABRs. Trains of tone bursts are considered to be suitable for the early detection and monitoring of ototoxicity. The early detection of ototoxicity using objective methods could be extremely useful for patients receiving these drugs and who are too ill to provide reliable behavioral audiograms, which may be 40% of hospitalized patients receiving ototoxic drugs.

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59. Click-evoked otoacoustic emissions in normal-hearing and hearing-impaired subjects: effects of stimulus level

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Objectives: Objective measures of hearing often contribute critical data from which diagnostic, rehabilitative, and adjudication decisions can be made. Evoked otoacoustic emissions (EOAEs) are one such objective measure of hearing. EOAEs are the stimulated acoustic energy generated in the cochlea that travel laterally through the middle ear into the ear canal where they can be measured with a miniature microphone. It is generally accepted that the cochlear outer hair cells are an integral component in EOAE generation. Although EOAEs *per se* are not a necessary component in the process of hearing, the presence of EOAEs is an indication of normal outer hair cell function, which is a prerequisite for normal hearing. Thus, EOAEs have potential as an objective test for hearing loss. The purpose of this study is to determine the accuracy with which EOAE measurements can be used to differentiate patients with normal hearing from patients with hearing loss. This objective will be accomplished by examining EOAE response variables in patients with normal hearing and patients with hearing loss whose hearing status has been documented according to the results of standard behavioral audiological tests.

Methods: Adult subjects with either normal hearing (N=180) or sensorineural hearing loss (N=245) were recruited from the audiology clinic patient flow. Click-evoked otoacoustic emission (CEOAE) input-output functions were obtained from one ear of each subject at stimulus levels from 60 to 85 dB pSPL in 5-dB steps. CEOAE amplitudes and signal to noise ratios, analyzed into ½-octave bands centered at 1, 2, 3, and 4 kHz, were compared with the behavioral pure tone threshold at the same frequencies. Data were analyzed using clinical decision theory, cumulative distributions, and multivariate analyses.

Results: Preliminary analyses indicate that CEOAE amplitudes and signal to noise ratios can be used to identify hearing loss in adults. CEOAE test performance (accuracy in the classification of normal-hearing versus hearing-impaired ears) improved at stimulus levels below 80 dB pSPL for subjects with mild hearing loss.

Conclusions: Click-evoked otoacoustic emissions should prove to be a valuable adjunct to standard behavioral audiological tests in patients who are unable (for a variety of medical conditions that effect their cognitive and/or motor processes) or are unwilling (e.g., feigning a hearing loss for financial gain) to provide reliable behavioral responses.

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Clinical Relevance and Implications for the Veteran Population: Hearing loss is one of the three most common chronic diseases among the elderly population. When viewed as an individual major or lesser disability, hearing impairment is the most common service-related disability. EOAEs should prove to be valuable in the evaluation of veterans who are unable to perform the tasks associated with a standard audiological evaluation due to neurological insults that effect their cognitive and/or motor processes. As it is well established that EOAEs are altered by ototoxic agents, EOAE measures may be applicable for monitoring any changes in the peripheral auditory system of veterans who are being treated with potentially ototoxic drugs.

60. Prevalence of hearing loss among the veteran population in the Beaver Dam (WI) cohort

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Objectives: A recent population-based study of hearing loss, the Epidemiology of Hearing Loss Study (EHLS), in Beaver Dam, Wisconsin (Cruikshanks, Wiley, Tweed, et al, 1998) found that 46% of older adults were affected by hearing loss. Information about veteran status and service characteristics was collected. The purpose of this project was to determine the prevalence of hearing loss among the veterans enrolled in the EHLS. Specific objectives included: (1) Were veterans at a higher risk for hearing loss than non-veterans?; (2) Did veterans have a greater degree of hearing loss than non-veterans?; (3) Were veterans more likely to wear hearing aids than non-veterans?; and (4) Was hearing loss dependent on years of military service or other service characteristics?

Methods: In the EHLS, 3753 subjects participated in the baseline study (2164 female, 1589 male). Of the male subjects studied, 999 were veterans (mean = 64.6 years) and 588 were non-veterans (mean = 66.7 years). Hearing thresholds were obtained at 0.5-8 kHz and the pure tone average (PTA) was calculated using threshold data at 0.5, 1, 2, and 4 kHz. Hearing loss

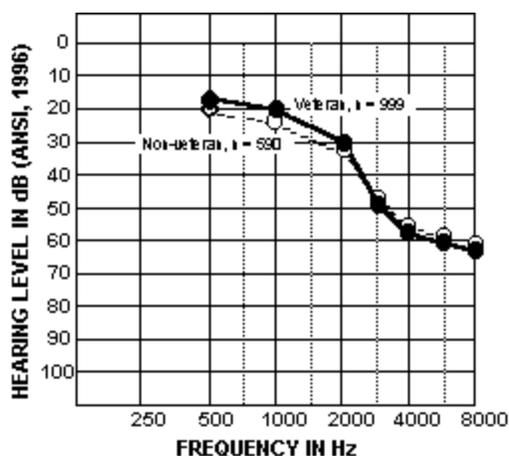


Figure 1. Audiogram of the two male groups from the Beaver Dam cohort.

was defined as PTA > 25 dB HL. Confounding variables included age, longest-held occupation, history of head injury, smoking and history of head injury.

Results: *Were veterans at a higher risk for hearing loss than non-veterans?* After adjusting for other confounders, veterans did not have increased odds of having a hearing loss compared to non-veterans (OR=0.97, 95% CI = 0.74, 1.27). No association was found between years of service and hearing loss. Veterans who served in the Navy were less likely to have hearing loss (OR=0.59, 95% CI = 0.41, 0.85). No other significant differences were found in PTA or hearing status by branch of service, war, type of service, function, or weapon use. *Do veterans have a greater degree of hearing loss than non-veterans?* After adjusting for age and other confounders, veterans had slightly better PTAs (better hearing) than non-veterans (30.6 dB vs. 33.6 dB; p = .0008). Figure 1 displays adjusted threshold data for veterans and non-veterans. *Were veterans more likely to wear hearing aids than non-veterans?* Non-veterans with hearing loss reported greater hearing aid experience than veterans with hearing loss (27.4% vs. 18%, p = .0014). This result remained significant after adjusting for age (p = .025). Current hearing aid use was significantly greater for non-veterans (17.3% vs. 11.7% p = .0014), however, once the data were adjusted for age, there was no significant difference. **Conclusions:** Veterans and non-veterans were equally likely to have a hearing loss. Surprisingly, there was a higher prevalence of hearing aid use with non-veterans than with veterans. Since hearing aids are typically not covered by 3rd party insurers, but are provided to eligible veterans through the Department of Veterans Affairs, these results suggest a significant under-utilization of hearing health care available to veterans.

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Clinical Relevance and Implications for the Veteran Population: Data from the VA Central Office indicate that 296,759 veterans are service connected for impaired hearing, which is the most common service connection among veterans (Source: Office of Policy and Planning, VA Central Office. June 2001 RCS 20-0223 and RCS 20-0227 reports; Dennis, 2001). This work provides veteran-specific

data relating to hearing loss and hearing aid use to be used as a foundation for a clinic-based cohort study aimed at developing a hearing profile of veterans and investigating the utilization of hearing health care by veterans.

61. Pattern of basilar membrane vibration in sensitive cochlea

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Objectives: To directly measure the traveling wave in sensitive living cochleae.

Methods: A scanning laser interferometer was used to measure the magnitude and phase of the basilar membrane (BM) transverse vibration along the cochlear partition. Because this instrument scanned along the cochlear partition, an instantaneous waveform of the traveling wave could be calculated from the magnitude and phase-longitudinal location curves.

Results: The entire waveform of the traveling wave was calculated from the velocity magnitude- and phase- longitudinal location data. It was found that a low-level sound of 16 kHz induces a traveling wave over a very restricted range (~500 μm) along the basilar membrane. Vibration amplitude falls to the noise floor at the apical and basal ends of the observed area (~800 μm), and an approximately 6p phase delay accumulates over this region.

Conclusions: The data indicate the sound does not propagate from the base to its resonant location along the cochlear partition as thought previously, but that it reaches its resonant location through a cochlear fluid wave, which induces a local traveling wave. Because the findings of this study will change or modify the theory of the cochlear-traveling wave, it will be of significance for rehabilitative auditory research, especially for hearing aid design, and monitoring hearing.

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62. Normative data for the perceptual-performance test of speech in noise.

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Objectives: Hearing aids are provided routinely to hearing-impaired patients. It is difficult however, to measure the efficacy of a fitting because there are numerous dimensions to consider (e.g. performance, benefit, satisfaction). These dimensions can broadly be considered to be 'objective' or 'subjective' in nature. Objective dimensions are generally measured with speech materials, while subjective evaluations can be made with ratings or questionnaires. Often, however, there are discrepancies between objective and subjective scores. Sometimes speech tests do not show performance differences between hearing aids, even when patients report distinct preferences. Conversely, there are situations in which speech tests show improved aided understanding, although the patient is dissatisfied with his or her hearing aid(s). Currently, it is difficult to reconcile conflicting data such as these, in part, because the materials and test formats used for measuring performance are so very different to those used for subjective evaluations. The aim of this study is to develop and evaluate an outcome measure (the Performance-Perceptual Test) in which both objective and subjective speech intelligibility are measured with the same test materials, test format and unit of measurement. This outcome measure will have at least two advantages over currently available tools. First, it will provide information about two dimensions of hearing-aid outcome (objective and subjective) rather than just one; second, the relationship between objective and subjective scores will provide a basis for counseling hearing-aid users.

Methods: The Performance-Perceptual Test (PPT) is run in two conditions: a Performance condition to measure objective speech understanding, and a Perceptual condition to measure subjective speech

understanding. The Hearing In Noise Test (HINT) materials and adaptive test procedures form the basis of the test. The level of the noise is fixed, the level of the speech is adjusted in 2dB steps, up or down, dependent upon the previous response. To run the Performance condition, the HINT protocol is used to measure the signal to noise ratio (S/N) at which 50% of the material is understood. In the Perceptual condition the HINT materials are also used, except that the S/N at which listeners think they can “just understand” the material is determined. Currently, normative data and test-retest reliability data is being collected, along with questionnaire data to examine face validity. In the future, the sensitivity of the PPT will be compared with the sensitivity of three other available outcomes measures and the PPT will be used to predict which hearing-aid setting a subject will prefer of three possible choices. The accuracy of prediction will be compared to actual preference following 6 to 8 weeks of hearing-aid wear.

Results: Normative data for the Performance Condition, Perceptual condition and for the discrepancy between these two will be presented, along with test-retest reliability values. In addition, analyses examining the relationship between PPT scores and questionnaire measures of hearing handicap and hearing aid satisfaction will be carried out.

Conclusions: Pilot testing and previous studies (e.g. Saunders & Haggard, 1992) suggest that the proposed 12 to 15 minute test will be short enough and simple enough to use routinely in the Audiology clinic and will provide clinicians with an improved tool to evaluate the efficacy of a hearing-aid fitting or a hearing-aid program.

Funding Acknowledgment: This study is funded by VA RR&D grant # C2709I

Saunders, G.H. & Haggard, MP. (1992) The assessment of ‘Obscure Auditory Dysfunction’ (OAD) – 2.: Case-control analysis of determining factors. *Ear Hear* 13, 241-254

63. Effects of ear canal volume on in-situ measurement

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Objectives: During audiometric measurements made with insert earphones or with supra aural earphones, the decibel sound-pressure level (dB SPL) in the external auditory meatus typically is not measured. Clinically, these measurements are made using decibel hearing-level (dB HL) values, that are based upon averages and do not take into account the individual variation of the patient’s ear canal. Probe-microphone measurements of hearing-aid gain has achieved widespread clinical utilization in recent years. During the hearing-aid fitting process, audiologists precisely measure in-situ the dB SPL of the hearing-aid output across the frequency range. The hearing aid then is adjusted to match the target predicted by the fitting strategy chosen by the audiologist. Even though output is measured in dB SPL, most hearing-aid gain targets are based upon dB HL measurements.

One of the largest sources of individual variation that could affect the in-situ dB SPL is the volume at the ear canal. The smaller the volume, the higher the sound pressure level, even when the dB HL remains constant. If the dB SPL at the tympanic membrane is not monitored during audiometric testing, this could lead to gross under or over estimates of actual threshold. For subjects with small ear-canal volumes (infants and children), the in-situ dB SPL could be higher than predicted from the dB HL measured during testing. This could lead to threshold results that are worse than the patient’s actual threshold. Then, when the audiologist fits the hearing aid based upon targets from dB HL threshold measurements, the hearing-aid gain would be inadequate. For subjects, with larger-than-normal volumes (older adults), the actual thresholds could be better than measured. This, in turn, could lead to over-amplification. The purpose of this study is to examine the statistical relations between ear-canal volume and in-situ dB SPL measurements. This could lead to the development of correction factors for hearing-aid gain targets based on ear-canal volume measurements. The hearing-impaired veteran population would benefit from more precise hearing-aid fittings.

Methods: In order to ensure that a range of ear-canal volumes are included, this study will draw 10 subjects each from 3 different age groups. A group of 10 infants from a facility outside the VA Hospital will be included, however that portion of the project is not affiliated with the VA because it involves minors. The two adult populations will be 20 veterans, aged 20 to 99, and divided into 2 groups: adults (aged 20 to 60) and older adults (aged 61 to 99). Ear-canal volumes will be measured using acoustic immittance measurements in order to determine ear canal volume. Then, the in-situ dB SPL will be measured with a probe microphone threaded through an insert earphone. An audiometer (AudioPro, model ADS2), will produce a frequency sweep at 70 dB HL through the insert earphone. The probe microphone then measures the in-situ level of that sweep in dB SPL.

Results and Conclusions: Preliminary data analysis shows a negative correlation between in-situ Sound Pressure Level and tympanometric volume in the adult subjects. Across the frequencies tested, four of these correlations appear to be significant at the .05 level. Further analyses, results and clinical applications will be presented at the poster session.

Funding Acknowledgment: This project is a requirement of Ms. Sowards' doctoral degree in Audiology. Ms. Sowards' Au.D. Residency is funded by the National Center for Rehabilitative Auditory Research (Center Grant # S-970160) at the Portland, Oregon VAMC. Mentoring and research is being conducted at the National Center for Rehabilitative Auditory Research.

64. Virtual audiometric instrumentation: interactive software laboratory course

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Objectives: Technological instruction in the discipline of audiology requires significant resources in personnel as well as laboratory space and equipment. The goal of this project is to facilitate

technical instruction in audiology by providing an interactive software program that uses virtual audiometric instrumentation. The software can be used as a stand-alone laboratory course, or individual modules in the software can be used to supplement the technical aspects of courses that include topics such as hearing aids, evoked potentials, and immittance. The basic modules will also provide instruction for undergraduate speech and hearing science courses and basic instrumentation.

Methods: The project involves a total of 55 modules organized into seven separate content areas. Of the seven content areas, four will make up the basic stand-alone instrumentation course (Core Modules), while the remaining three content areas will be used for advanced audiometric instruction (Advanced Modules). Modules include testing components throughout, providing the student with ongoing feedback concerning his/her performance. In addition to virtual, interactive representations of the instrumentation under study, the program also provides information and exercises to promote understanding of the scientific concepts underlying the measurements for which the instrumentation is intended.

The effectiveness of the project will be evaluated in three ways. First, surveys of clinical supervisors at local audiology practicum sites; second, pre-post examinations for each module of the software at two different university programs, third, a comprehensive examination at the beginning and end of the interactive virtual instrumentation course used as a stand-alone laboratory course.

Results: The project is in the alpha testing stage with graduate and undergraduate students at two university program sites (Washington State University in Spokane and Idaho State University in Pocatello). Demonstrations will be offered at the RR&D Conference in February.

Conclusions: The ability to use virtual instrumentation will improve university programs and provide a wide range of technological experience for students. The transfer of knowledge and skills in instrumentation learned on the computer to the clinical setting will improve the training of new clinicians and enable experienced clinicians to update their skills in new areas of diagnosis and treatment. Improved clinical skills will result in an improvement in the care of patients with a range of auditory disorders.

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65. Improved clinical system for automated tinnitus evaluation

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Objectives: Traditionally, quantification of tinnitus symptoms has relied on a subjective report from the patient. Subjective reporting provides some information about the perceived characteristics of a patient's tinnitus, but limits the clinician's ability to effectively monitor the impact of treatment. The necessity of a standardized tinnitus measurement system is evident when considering the growing prevalence of tinnitus. A report from the Department of Veterans Affairs noted that between September 1998 and September 2001 the number of cases of veterans service-connected for tinnitus increased by 47,171 (from 115,238 to 162,409). Furthermore, the lack of a standard measurement system inhibits the opportunity to compare data collected from different clinical sites.

Ongoing work at our laboratory has been dedicated to development of an automated system for quantifying tinnitus loudness and pitch. A primary objective of our current research is to make the measurement system more clinically useful, by improving efficiency of testing.

Methods: The automated tinnitus testing system has been upgraded to allow subject control of the acoustic stimuli using a rotary knob. Projects utilizing this automated system include assessing the system's ability to collect reliable results from patients with tinnitus in a timely manner, development of a valid test for tinnitus "malingering," and direct clinical application and assessment. Subjects with and without tinnitus are being recruited for the collection of repeated measurements using the automated system.

Results/Conclusions: At this time the automated system is in the testing phase. Results from testing subjects with the system will be collected and analyzed by the time of the conference. For the conference it is proposed that the system be presented in a demonstration type format. This type of display would allow other professionals the opportunity to gain a working knowledge of how the upgraded system functions to accomplish the tasks of providing an expeditious tool for standardized tinnitus measurement.

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66. Decreased speech recognition performance with increased presentation level: the NIDCD/VA hearing aid clinical trial

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Objectives: The overall objective of the multi-center study, which involved eight VA Medical Centers, was the comparative performance of three hearing aid circuits (peak clipping, compression limiting, and wide dynamic range compression). Three types of outcome measures (speech intelligibility, sound quality, and subjective ratings) were studied. The focus of this report is on one aspect of the speech intelligibility measure, viz., the Connected Speech Test (CST) (Cox, Alexander, & Gilmore, 1987).

Methods: Speech recognition on the CST in background babble was measured on each of 360 listeners (mean = 67 years) with hearing loss. Each listener was evaluated three times in 3 month intervals on both aided and unaided conditions. The CST was administered in ten different listening conditions—three S/B ratios (-3, 0, and 3 dB) at each of three speech levels (soft speech at 52-dB SPL, conversational speech at 62-dB SPL, and loud speech at 74-dB SPL) and in quiet at 74-dB SPL. Testing was in a sound field with the CST coming from a speaker at 0° (1 m) and the competing message from speakers located at 45° and 315°. Complete data were available on 256 subjects. For each listener, the recognition performances for the three signal-to-babble ratios were averaged at each of the presentation levels. A linear regression then was computed

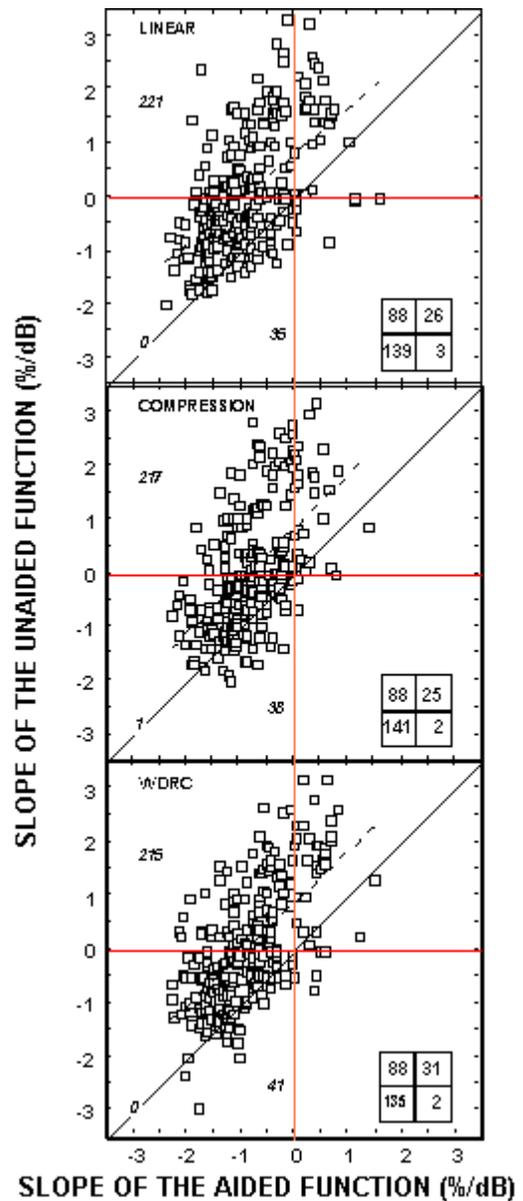
for performance across the three levels with the slopes of the regressions (%/dB) used for data interpretation. Positive slopes indicated that recognition performance increased as presentation level increased, whereas negative slopes indicated that recognition performance decreased as presentation level increased.

Results: Of the 1536 regressions computed for the data in Figure 1, 425 of the slopes (27.7%) were positive and 1111 of the slopes (72.3%) were negative. For the dependent variable (slopes) a mixed-model ANOVA was performed on the 256 subjects with the unaided and aided conditions as the within subjects factor and circuit type as the between subjects factor. The unaided and aided conditions were significantly different [$F(1,768) = 791.8; p < 0.0001$], whereas the circuit types were not significantly different [$F(2,768) = 0.168; p > 0.05$]. In the unaided conditions 53-56% of the listeners showed a decrease in performance as the level of the speech in multi-talker babble was increased between 52- and 74-dB SPL. In the aided conditions 87-90% of the listeners showed a decrease in recognition as the level of the speech in multi-talker babble increased from 52- to 74-dB SPL.

Conclusions: This increase in the percent of subjects with negative slopes under the aided condition is understandable when viewed on the continuum of stimulus presentation level. For the unaided conditions, the presentation levels were 52-, 62-, and 74-dB SPL. For the aided conditions, the presentation levels were 52-, 62-, and 74-dB SPL plus the gain provided by the hearing aid.

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Clinical Relevance and Implications for the Veteran Population: The findings suggest the importance of function gain in a background of noise as an outcome measure with hearing aid interventions.



Bivariate plot of the individual subject ($n = 256$) slope data for the recognition performance functions across presentation level for the unaided conditions (ordinate) and the aided condition (abscissa). Each of the three panels illustrates data for the three hearing aid circuits. The diagonal line represents equal slopes for the aided and unaided conditions; the number of data points above, on, and below the diagonal line are indicated in italics. A second set of numbers at the lower right of each panel reflects the number of slopes in the respective quadrants of each panel. Linear regressions (dashed lines) were fit to the data.