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Effect of Real-Ear Verification on Hearing Aid Benefit

Sarah Kieley Sporck

A dissertation submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

For the degree of

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Abstract

Real-ear measurements have been proven to be the most accurate measure of hearing aid verification. However, many audiologists find real-ear to be too time consuming to use consistently. One popular reason for underutilizing real-ear verification is the use of first fitting algorithms provided on manufacturer programming software. However, the predicted fittings provided on the software are not an accurate means of providing what is recommended by popular prescriptive formulas (Hawkins and Cook, 2003; Aarts and Caffee, 2005). The main reason for this discrepancy is that the software does not take into account individual anatomical differences, i.e. ear canal volume and impedance. When performing real-ear insertion gain (REIG), one must take into account individual differences by measuring the unaided response of the ear canal. When using REIG, prescriptive targets can be chosen which display the appropriate amount of gain recommended based on your patient's amount of hearing loss and natural ear canal properties. While the real-ear method of target matching has been proven to be the most accurate means of hearing aid fitting, little research has been done to determine if there is a quantifiable benefit to this method. The purpose of this study is to examine the effects of utilizing REIG throughout hearing aid fittings and adjustments. In particular, are there any differences in speech understanding in quiet and noisy conditions? Also, is there any difference in the amount of benefit the patient feels they are receiving from their hearing aids or how satisfied they are with them?

Eight subjects were tested on measures of HINT Quiet and Noise, APHAB and SADL; measures were done before and after programming was matched to NAL-NL1 targets using real ear verification. Findings indicate that programming hearing aids more

closely to prescribed targets did not necessarily correlate with improved speech understanding and patient-perceived satisfaction and benefit. However, patient feedback indicated that the preference was to have targets matched to prescriptive gains as closely as possible.

1. Introduction & Literature Review

The use of real-ear verification throughout hearing aid fittings has been a long-standing issue of debate in the realm of audiology. Research has proven that real-ear is a reliable and accurate method of verifying hearing aid gain; however, many audiologists do not use it consistently. Dillon and Keidser (2003) discussed the most popular arguments both for and against using real-ear measurements. One commonly found argument is that real-ear measurements are only considered valid when proper probe microphone placement has been achieved. This topic was discussed in detail by Dirks, Ahlstrom and Eisenberg (1996). The authors determined that when proper probe microphone insertion is consistently practiced, reliability with real-ear measurements can be obtained. In the case of real-ear insertion gain (REIG) measurements, the greatest concern is that the insertion depth remains consistent in both aided and unaided conditions. Another argument regards the importance of using real-ear measures over functional gain measures. Stelmachowicz and Lewis (1988) compared real-ear versus functional gain measures across different hypothetical patients. While they determined that there are times when functional gain is appropriate, using real-ear verification is generally a more accurate in situ measure of hearing aid performance. Dillon and Keidser (2003) determined that although there are strong arguments both for and against routine real-ear measurement, it is still considered best practice to utilize real-ear verification consistently throughout hearing aid fittings and follow-up troubleshooting. Possible exception to the rule includes when it has been repeatedly proven that manufacturer provided fitting software contains an accurate simulation of real-ear. So if the reliability and validity has been proven time and again, why do audiologists continue to underutilize real-ear verification as a standard tool in the hearing aid fitting process?

One reason many audiologists do not use real-ear is because, as mentioned above, manufacturers provide simulated measures on their programming software. Hawkins and Cook (2003) demonstrated that manufacturer simulated values were based on 2-cc coupler values for the specific model of hearing aid. These values were then transformed with what the manufacturer believed to be an appropriate Coupler Output for Flat Insertion Gain (CORFIG). This method does not take into account individual variations in ear canal volume and impedance. The authors determined that on the twelve subjects they examined, these CORFIG values were not an accurate estimate of how the hearing aid was actually performing. Simulated values tended to overestimate the amount of gain actually provided by the hearing aid, particularly in the very low and high frequencies (over 4000 Hz). Rather, they recommended that audiologists employ in situ measurements of hearing aid performance in the form of either functional gain or real-ear measures.

Aarts and Caffee (2005) expanded the work of Hawkins and Cook by employing similar methods on a larger subject population. This study compared real ear predicted values from one manufacturer’s software to in situ measures on 41 subjects. Two styles of the manufacturer’s hearing aids were programmed to two common hearing loss configurations seen in adult hearing aid users: a flat mild sensorineural loss and a mild sloping to moderately severe hearing loss. The authors reported that significant discrepancies were present between predicted and measured real-ear values, suggesting that audiologists cannot rely solely on manufacturer technology for best fitting procedures. They found the same pattern of overestimated predicted gain in the very low and high frequencies as noted by Hawkins and Cook (2003). The authors supported Hawkins and Cook's hypothesis that simulated or predicted values failed to take into account individual differences, which can be measured on real-ear systems as real-ear unaided responses (REUR). Aarts and Caffee also made the hypothesis that inaccurate fittings done with predicted real-ear values could be a catalyst for low levels of satisfaction with hearing aids.

Swan and Gatehouse (1995) measured real-ear insertion gain following first fittings performed on hearing aid manufacturer software. They found that a large percentage of their subject population failed to meet prescriptive targets on the first fitting. Following adjustments, more subjects were able to more closely meet targets, however some still failed to do so. Whether or not all of their subjects met prescriptive targets, the authors concluded that without the use of real-ear insertion gain measures, the audiologist would not have a specific idea of whether or not the hearing aid is providing the appropriate amount of gain.

Aazh and Moore (2007) took this concept a step further and examined actual differences in REUR values between software and in situ measures. Their results indicated that there was a significant difference between actually measuring unaided gain versus using premeasured values. Surprisingly, they could not find a definitive way to attribute the use of software provided values to poor fittings. However, they did identify that when comparing audiograms among subjects, those who had steeply sloping high frequency hearing losses were less likely to match target values than those who did not. Aazh and Moore also found that when making modifications to hearing aids following first fittings, hearing aids with more channels were able to more closely match target than those with fewer channels.

In clinical practice, audiologists frequently rely on patient feedback as a means of verification. Cox (2009) reported that patient feedback is actually a measure of fine tuning, not verification. Fine tuning is essentially the process of making the hearing aid perform as the patient wants it to. Verification, on the other hand, is the process of ensuring that the hearing aid is doing what the audiologist feels is best for the patient. While "low-tech" versions of verification (such as functional gain) can be performed, real-ear measures still provide the most accurate validation of hearing aid performance, as long as it is performed appropriately. Few other measures are available which can actually measure the SPL that the hearing aid is providing at the level of the ear drum.

Although real-ear measurements have been proven to be an accurate verification of hearing aid performance, certain variability does exist. One such area is the differences in prescribed target values across different real-ear systems. Ricketts and Mueller (2009) examined variations in target matching to the NAL-NL1 formula between Fonix, Verifit, and MedRx systems. Their results indicated that when programming to NAL-NL1 targets on one system, prescribed target values would not necessarily match on another system. The Verifit and MedRx systems were a fairly close match, however, the Fonix target values deviated further from the other equipment. Possible reasons for these discrepancies were whether the fitting was bilateral versus unilateral, the number of compression channels in the hearing aid, the type of output limiting employed, the input signal of the system, and the method used to analyze output. In order to practice best fitting, the authors suggested that audiologists should be careful to utilize the same real-ear system throughout the hearing aid process.

Another issue which can arise is intratester test-retest reliability. In many clinical cases, the same audiologist will always perform real-ear measurements on a patient. However, the same clinician can encounter variability between measures if they are not consistent with their procedure. Valente, Meister, Smith and Goebel (1990) tested intratester test-retest reliability on real-ear insertion gain measures. They found that as a clinician was trained in proper procedure which they consistently employed, their results became more valid. This includes proper probe tube insertion depth as well as proper placement of the patient in front of the loudspeaker.

Research has shown that the one of the most important factors of hearing aids to a consumer is improved speech understanding. Little evidence is available to prove that using real-ear measurements throughout hearing aid fittings results in improved speech understanding abilities. Kuk, Harper, and Doubek (1994) examined preferred real-ear insertion gain (REIG) values under changing speech and noise conditions. They tested twelve subjects using a measure of speech clarity. They reported that as speech and noise levels increased, subjects preferred that insertion gain values be lowered from NAL-R target values (particularly with speech). As speech understanding is most important to our patients, it is essential that we consider it when performing real-ear measures with target matching.

Although Kuk, Harper, and Doubek's study examined preferred gain levels with speech clarity, they still did not employ a measure of speech understanding. One measure of speech intelligibility is the Hearing in Noise Test (HINT). The HINT serves as a sentence speech reception threshold (sSRT), or a measure of at what level the subject can correctly identify sentences fifty percent of the time. HINT sentences can be presented in quiet or in the presence of a competing background noise. The noise can be presented with the speech stimulus or from a separate source as a means of measuring speech intelligibility in noise under varying conditions. When presenting sentences in noise, the level of the sentences is manipulated to find the subject's ideal reception threshold for speech, which is essentially the signal to noise ratio where they could identify sentences fifty percent of the time. The HINT provides a valuable means of measuring speech intelligibility to identify if patient performance improves when gain is programmed to match prescribed target values.

Although many studies have proven that real-ear measures are an accurate and essential part of best fitting procedures, not many have examined the patient's perception of using them. Leijon et al. (1990) found that when NAL targets were matched appropriately, subjects on average felt that there was too much gain and were subsequently unhappy with their hearing aids. One method of examining this is by using questionnaires which measure patient perceived satisfaction and benefit. The Abbreviated Profile of Hearing Aid Benefit (APHAB) is a measure of patient perceived benefit from their hearing aids across four scales. The first three scales (ease of communication (EC), reverberation (RV), and background noise (BN)) assess speech communication in favorable, reverberant and noisy environments. The fourth scale is a measure of aversiveness to loud sounds. The APHAB is to be filled out twice by the subject; they are to respond to each question both as aided and unaided. Thus the APHAB is a complete measure of patient perceived benefit, providing aided and unaided scores across different speech communication environments. A benefit score is then derived from the unaided and aided scores to determine how much actual benefit the subject deems they are receiving form their hearing aid(s).

Cox and Alexander (1999) argued that measuring benefit alone excludes many factors related to the patient’s perception of the hearing aid. These factors can be encompassed in measures of satisfaction. The Satisfaction with Amplification in Daily Life (SADL) scale is a complete measure of satisfaction with hearing aids. It assesses satisfaction among four subscales: Positive Effect (PE), Service and Cost (SC), Negative Features (NF) and Personal Image (PI). A global score may be obtained from the four subscales allowing the hearing aid provider to assess how satisfied a patient is with their hearing aid, as well as where specific dissatisfaction may arise.

The purpose of this study is to examine the patient-perceived effects of utilizing real-ear insertion gain and target matching to NAL-NL1 targets throughout hearing aid fittings. Specifically, does using REIG increase patient perceived satisfaction and benefit? Also, does using REIG improve performance of speech understanding in quiet as well as in different noise conditions?

2. Methods

2.1 Subjects

Eight adult hearing aid users (3 M, 5 F; mean age: 52.75) participated in this study. All subjects were fit bilaterally with either Behind-the-Ear (BTE), In-the-Ear (ITE), In-the-Canal (ITC), or Completely-In-the-Canal (CIC) hearing aids from the same manufacturer. No open fit hearing aids were used in this study. All hearing aids were middle level technology. Time of hearing aid experience ranged from six weeks to several years. All subjects were fit with their hearing aids and subsequently tested at Ear, Nose and Throat Associates of Charleston, West Virginia. All subjects had symmetrical audiogram configurations ranging from a moderate to moderately severe flat configuration to a moderate sloping to severe configuration.

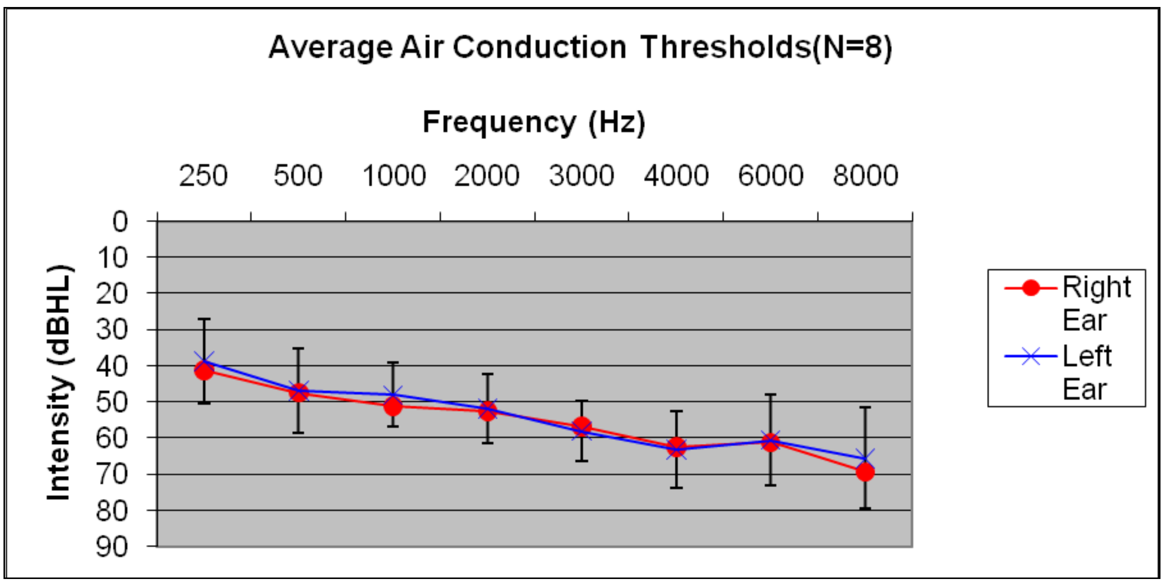


Figure 2.1: Average Air Conduction Thresholds for All Subjects (N=8). Error Bars Denote $\pm$1 SE

2.2 Fitting Procedure

All subjects were initially fit using standard procedure currently employed by the five audiologists at Ear, Nose and Throat Associates. This procedure includes a hearing aid evaluation, hearing aid fitting using first-fitting algorithms provided on manufacturer software and subsequent follow-up appointments throughout the 30 day trial. All follow-up adjustments were made based on patient feedback alone.

2.3 Testing Procedure

Each subject underwent two sessions of testing. Session one was performed with their original programming. Testing procedure for session one included the following:

1. Otoscopy
2. Pure Tone Audiogram
3. HINT in Quiet (unaided and aided)
4. HINT in Noise (0 and 90 degree azimuth, unaided and aided)
5. REIG (Audioscan RM 500 SL)
6. APHAB
7. SADL

Following session one testing, reprogramming to match NAL-NL1 targets was performed. During the reprogramming, subjects were connected to the real-ear system as well as the manufacturer software. Adjustments on the software were made while continuously running REIG. Prescribed targets were matched as closely as possible without creating feedback or patient discomfort. Once NAL-NL1 targets were matched as closely as possible, programming was saved as Program 2 in the hearing aid. Subjects were instructed to use the target-matched programming at least two hours a day, but ideally as much as possible. A three to four week adjustment period was given for the subjects to acclimatize to new programming before returning for a second session of testing. Session two test procedure included the following:

1. Otoscopy
2. HINT in Quiet (aided only)
3. HINT in Noise (0 and 90 degree azimuth, aided only)
4. REIG (Audioscan RM 500 SL)
5. APHAB
6. SADL
7. Final Questionnaire

All testing for session two was performed with the target-matched programming. Subjects were instructed to answer questions on the APHAB and SADL thinking about using their new programming created for this study. A final questionnaire was created so that subjects could give feedback comparing their original programming with the target-matched programming. Once all testing was completed, subjects were given the option to return to their original programming or keep what was created for this study.

2.3a Otoscopy

Otoscopy was performed at the beginning of each session. Otoscopy revealed normal, healthy appearing ear canals and tympanic membranes on all subjects. If the presence of cerumen was such that it would inhibit REIG measures, cerumen removal was performed by an otolaryngologist.

2.3b Audiograms

Pure-tone audiograms were performed on each subject prior to speech testing. Tested frequencies included 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. Both left and right ears were tested. Testing was performed on a GSI-61 audiometer using insert earphones. For both groups, audiogram configurations ranged from a moderate to moderately severe relatively flat configuration to a moderate sloping to severe configuration. Audiograms for all subjects may be found in Appendix A.

2.3c Speech Understanding in Quiet and Noise

The Hearing in Noise Test (HINT) was used to assess speech understanding. The HINT was first performed in quiet in order to obtain a measure of speech reception threshold. For the quiet condition, the patient was facing the speaker at zero degree azimuth. The first sentence was presented until the subject was able to repeat the whole sentence correctly. From there, nineteen more sentences were presented at varying intensities. This process was continued until twenty sentences had been presented. An average intensity level was then derived from all 20 presentations, giving the average intensity the subject needed to correctly identify sentences fifty percent of the time.

The HINT was then used in two noise conditions: zero degree azimuth and ninety degree azimuth. In the zero degree azimuth condition, both speech and noise were presented from the speaker in front of the subject. The noise was continuously presented at 60dBSPL. The intensity of the sentences was varied in the same manner as the quiet condition. Once all twenty sentences had been presented, an average intensity level was derived from all presentations, giving the average intensity the subject needed to correctly identify sentences fifty percent of the time in the presence of noise. The noise level (60dBSPL) was then subtracted from the average intensity score, giving the Reception Threshold for Speech (RTS), which is essentially the signal-to-noise ratio the subject needs to correctly identify sentences fifty percent of the time when speech and noise are presented from the same source. The figure below demonstrates speaker-subject configurations for zero degree and ninety degree azimuth conditions.

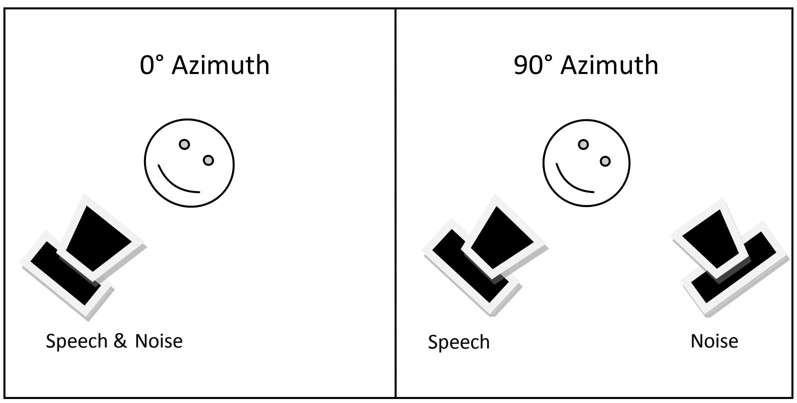


Figure 2.2: Subject-Speaker Configurations for the HINT test at zero and ninety degree azimuth

In the ninety degree condition, speech was presented from the speaker in front of the subject while noise was presented from a second speaker at a ninety degree angle to the subject. The speech and noise are presented in an identical fashion to the zero degree azimuth condition. Again, an RTS score is derived, giving the signal-to-noise ratio the subject needs to correctly identify sentences fifty percent of the time when speech and noise are presented from different sources. HINT testing materials can be found in Appendix C.

2.3d Real-Ear Insertion Gain (REIG)

Real-Ear Insertion Gain (REIG) was performed on all subjects during both testing sessions. The Audioscan RML500 SL portable system was used. Calibration was performed at the beginning of each test day. REIG testing was selected from the test menu, and the patients audiogram values were entered into the system. NAL-NL1 was selected as the prescriptive formula. Pink noise was selected as the stimulus type. In order to obtain REIG, real-ear unaided gain (REUG) was first measured at 50 dBSPL. This was performed by placing a small probe microphone tube into the ear canal matched to a marker resting just outside the tragus, to a depth of 25mm. The reference microphone was placed just below the earlobe. The subject was placed at a forty-five degree angle to the speaker. Once REUG was measured, real-ear aided gain (REAG) was measured at two stimulus levels: 50 and 65 dB SPL. These two intensity levels were selected for target matching to NAL-NL1 target curves. Once all three measures had been performed (REUG and REAG at 50 and 65 dBSPL), REIG values could be determined. Measured REIG values were noted at 500, 1000, 2000 Hz. NAL-NL1 target values were also noted at 500, 1000, 2000 Hz. Differences between measured and target values were then calculated to determine the accuracy of the hearing aid's performance. REIG outputs for pre and post target-matching can be found in Appendix B.

2.3e Subjective Measures of Hearing Aid Benefit and Satisfaction

Two questionnaires were given to the subjects after testing was completed. The first was the Abbreviated Profile of Hearing Aid Benefit (APHAB), which measures patient perceived benefit from their hearing aids. The APHAB consists of four subscales:

Ease of Communication, Background Noise, Reverberation, and Aversiveness to Sound. Each subject was asked to answer each question on the APHAB twice; first as aided and second as unaided. The APHAB is measured as a percent score, meaning that a lower percent indicates that the subject has problems on the specific subscale a lower percentage of the time, while a higher percent indicates problems on the subscale a greater percentage of the time. A global score is then derived across the four subscales to determine the amount of overall benefit the subject feels they are receiving from their hearing aids. APHAB Materials can be found in Appendix D.

The second questionnaire was the Satisfaction with Amplification in Daily Life (SADL), which measures patient perceived satisfaction with their hearing aids. The SADL is also measured across four subscales: Positive Effect, Service and Cost, Negative Features, and Personal Image. The SADL is measured on a “SADL Scale”, which is measured numerically from one to seven. A higher SADL score indicates a greater level of satisfaction with hearing aids, while a lower SADL score indicates a lower level of satisfaction with hearing aids. Again, a global score was derived across the four subscales to determine the amount of benefit the subject feels they are receiving from their hearing aids. SADL materials can be found in Appendix E.

3. Results

Each subject underwent two sessions of testing. Session one was preformed with original hearing aid settings which were obtained using manufacturer-provided first-fitting algorithms. Session one will be referred to as “Aided Original” when discussed throughout the results section. Session two was preformed with hearing aid settings which were matched to NAL-NL1 targets using REIG. Session two will be referred to as “Aided with Real-Ear” throughout the results section. All raw data can be found in Appendix G.

3.1 REIG

During the Aided Original session, each subject was asked to place their hearing aid volume and programming as they normally would for everyday conversation. Prior to any subsequent testing, REIG was ran to determine how closely the patient’s hearing aid settings matched prescribed NAL-NL1 targets. REIG values were compared to NAL-NL1 targets at 500, 1000, and 2000 Hz. Four thousand Hz was not used for comparison as too much variability was present. Following Aided Original session testing, the subject’s hearing aids were reprogrammed using REIG to more closely match prescribed NAL-NL1 targets. Figure 3.1 displays values both before and after reprogramming in respect to dB SPL difference from NAL-NL1 target values.

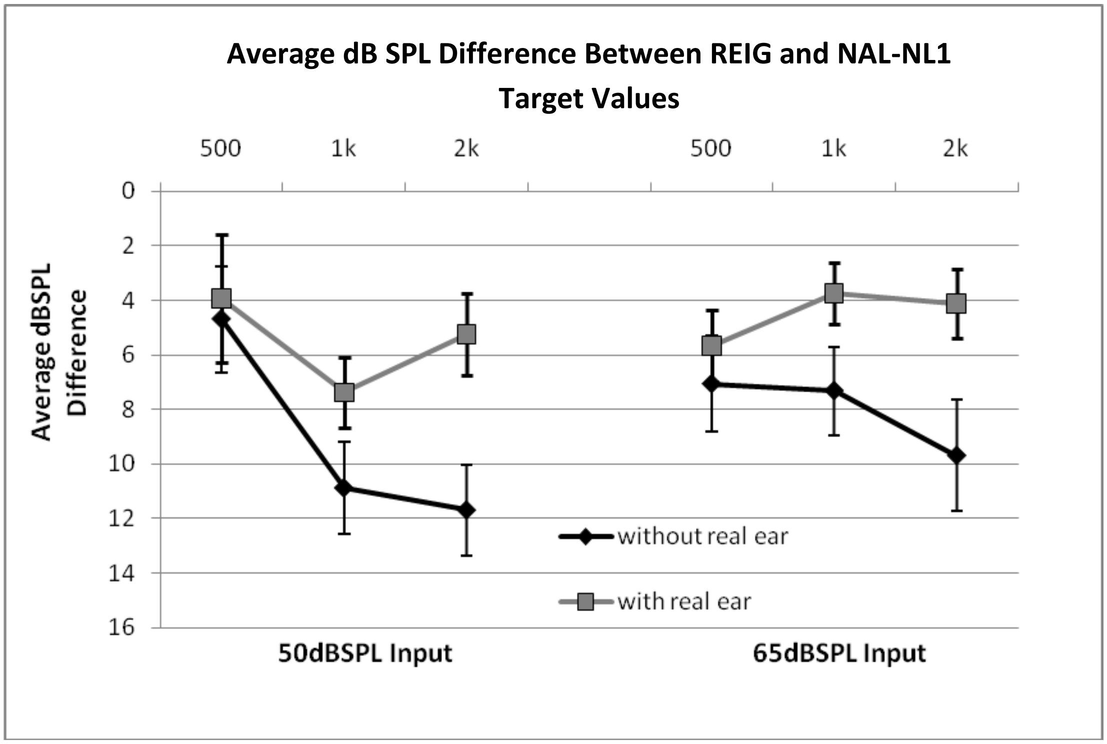


Figure 3.1: Average dBSPL Difference Between Measured REIG Values and Predicted NAL-NL2 Target Values in the Aided Original and Aided with Real-Ear Conditions. Error Bars denote ±1 SE

When looking at Figure 3.1, lines with diamond-shaped data points represent the dBSPL difference values for the Aided Original condition , and lines with square-shaped data points represent the dBSPL difference values for the Aided with Real-Ear condition. As seen above, little difference was present at 500 Hz for soft (50dBSPL) or average (60dBSPL) stimulation. At 1000 Hz a slight difference was present; however the largest difference was seen at 2000Hz for both soft and average input levels.

3.2 Speech Understanding in Quiet

Speech intelligibility was assessed using the HINT, and was first tested in quiet. Quiet HINT testing was performed in the Aided Original session both with and without amplification. During the Aided with Real-Ear session quiet HINT testing was only done with amplification. Results for HINT in quiet scores in the unaided, Aided Original condition, and Aided with Real-Ear condition can be seen in Figure 3.2.

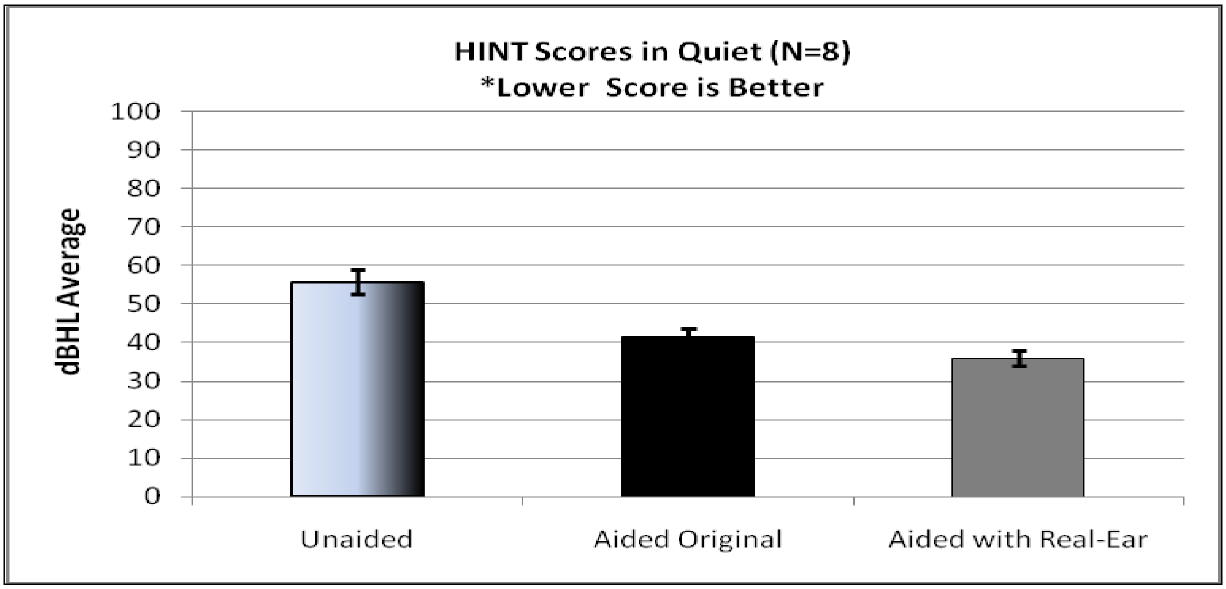


Figure 3.2: HINT in Quiet Scores for Unaided, Aided Original and Aided with Real-Ear Conditions. Error Bars denote ±1 SE

When looking at Figure 3.2, it is important to understand that a lower score is better. HINT in Quiet scores can essentially be thought of as a measure of Speech Reception Threshold (SRT), or the softest level a person can correctly repeat speech stimuli fifty percent of the time. When examining the data in Figure 3.2, it is clear that scores became lower as subjects were given the opportunity to utilize amplification. A one-way analysis of variance (ANOVA) resulted in a significant main effect ($F(2) = 17.61$, $p < .005$), indicating significant improvement between unaided and aided scores. The one-way ANOVA found no significant effect between the Aided Original and Aided with Real-Ear conditions, with $p=0.259$.

3.3 Speech Understanding in Noise

Following HINT in Quiet, speech intelligibility in the presence of background noise was assessed using the HINT in Noise. Two noise conditions were examined in order to understand the benefit of spatially separating the signal from the noise. First, the signal and noise were presented from the same sound source, labeled the 0 degree azimuth condition. The 0 degree azimuth condition was tested both with and without amplification during the Aided Original session. During that session, the subject was asked to set their programs and volume as they normally would for everyday listening. Following reprogramming to match NAL-NL1 targets, speech intelligibility in noise was re-assessed. During the Aided with Real-Ear session testing was only done with amplification, being sure that the program created to match targets was in use.

Following the 0 degree condition, speech intelligibility was assessed when the signal and noise were presented from separate sound sources, labeled the 90 degree azimuth condition. As before, this condition was tested both with and without amplification in the Aided Original session, and only with amplification during the Aided with Real-Ear session. Also with the 0 degree condition, during the Aided Original session subjects were asked to set their program and volume as they would for everyday conversational listening, and during the Aided with Real-Ear session to the programming created for this study. Figure 3.3 displays results for the HINT in 0 degree and 90 degree azimuth conditions as unaided, Aided Original, and Aided with Real-Ear.

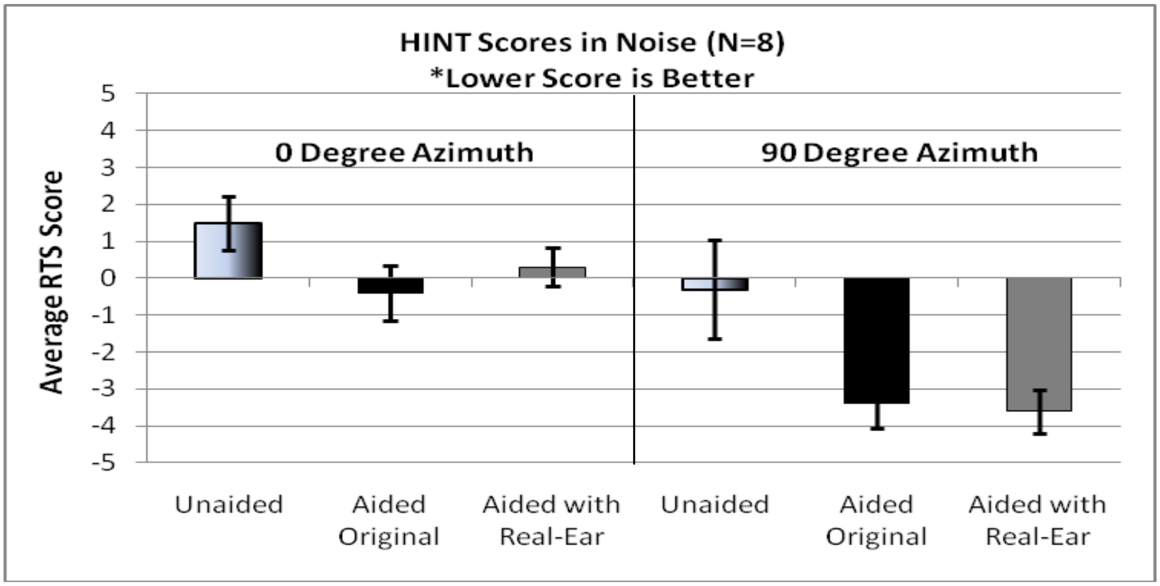


Figure 3.3: HINT scores in Unaided, Aided Original and Aided with Real-Ear Conditions at 0 and 90 degree Azimuth. Error Bars denote +1 SE

As with the HINT in Quiet, a lower score indicates better speech intelligibility. The HINT in Noise is measured as Reception Threshold for Speech (RTS), which is essentially the signal to noise ratio needed to correctly repeat speech stimuli fifty percent of the time. A negative RTS score means that the speech stimulus was softer than the noise, while a positive score indicates the noise was louder. Looking at the data in Figure 3.3, it is clear that performance was better across all three conditions in 90 degree azimuth. A one-way ANOVA resulted in a significant main effect of condition (F (2) =5.414, $p < 0.05$), indicating an improvement in scores as aided versus unaided. A significant azimuth effect was also found (F=18.632, $p < 0.05$), correlating with a significant improvement in the 90 degree azimuth condition. No significance was seen in the 90 degree azimuth between the Aided Original and Aided with Real-Ear scores, with p=0.962.

In order to examine interaction effects between HINT scores in quiet and noise, a multivariate analysis of variance (MANOVA) was ran. Because HINT quiet and noise scores are measured on two different scales (SRT and RTS, respectively), normative values were subtracted from all raw scores in order to obtain unified data. The MANOVA examined three areas: the effect of listening condition (quiet, 0 degree, 90 degree), the effect of aided condition (unaided, Aided Original, Aided with Real-Ear), and the effect of listening by aided conditions. Results of the effect of listening showed that there was a significant effect with $F(2,14) = 76.8$, $p < 0.01$. Wilks Lambda value showed that listening condition was responsible for 96% of variance. Results of the effect of aided condition showed no significant effect with $p=0.655$. Wilks Lambda value showed that aided condition was responsible for 87% of variance. When examining the interaction of listening by aided, no significant effect was found with $p = 0.420$, with a Wilks Lambda values showing the interaction of both conditions was responsible for 93% of variance. In summary, a significant effect of the listening condition was found, indicating that performance improved given the listening condition; however, the three aided conditions did not play a significant role.

To examine this point further, a MANOVA was ran comparing only the Aided Original and Aided with Real-Ear conditions in the two HINT Noise conditions (0 and 90 degree azimuth). Again, a significant effect of listening condition was found with $F(2,14) = 36.79$, $p<0.001$. As before, no significant effect was found of aided conditions ($p=0.007$) or with listening by aided conditions ($p=0.163$). Wilks Lambda value for listening by aided resulted in 53% percent of variance being due to the interaction between the two conditions. In order to determine which listening condition yielded better scores, the raw data was examined. As discussed before, a significant improvement was seen in the 90 degree azimuth condition, indicating that there was a significant improvement in that listening condition, but it was not be attributed to the aided condition.

3.4 Satisfaction & Benefit

Following measures of speech intelligibility, patient-perceived satisfaction and benefit were measured. Two questionnaires were used to assess this:

1. Abbreviated Profile of Hearing Aid Benefit (APHAB)

2. Satisfaction with Amplification in Daily Life (SADL)

3.4a APHAB

The APHAB was administered during both sessions. During the Aided Original session, subjects were asked to fill out the questionnaire answering each question twice – once as when wearing their hearing aids, and once when not. During the Aided with Real-Ear session, subjects were asked to answer questions as only with their hearing aids. The APHAB is measured across four subscales:

1. Ease of Communication (EC)

2. Background Noise (BN)

3. Reverberation (RV)

4. Aversiveness to Sounds (AS)

Following completion of the survey, scores were calculated using the APHAB scoring software. Average unaided, aided and benefit scores were calculated. Figure 3.4 displays results for APHAB scores across the four subscales in unaided, Aided Original and Aided with Real-Ear conditions.

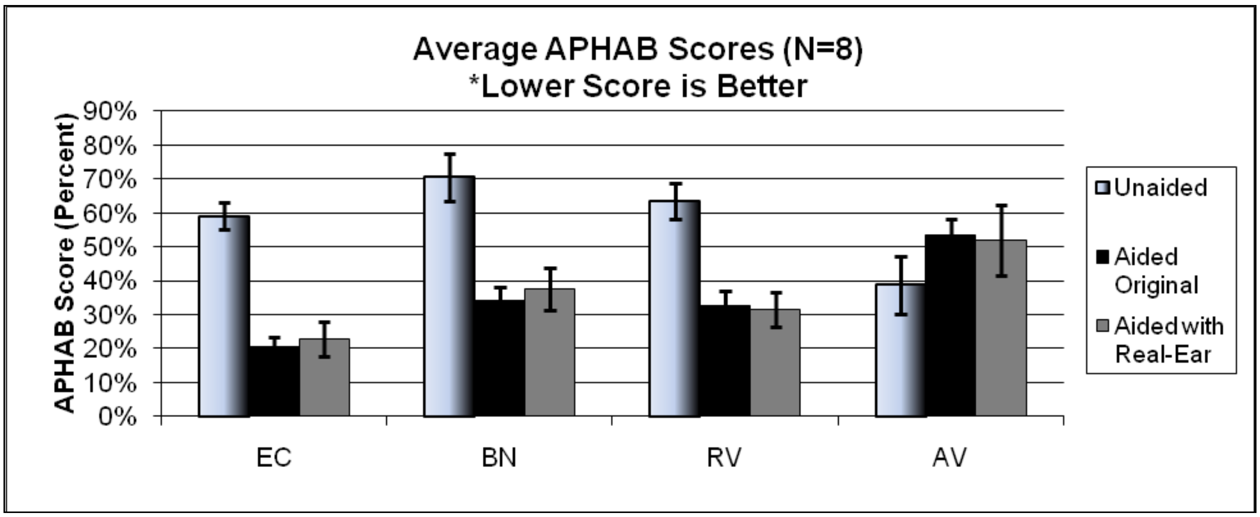


Figure 3.4: Average APHAB Scores Across the Four APHAB Subscales (EC, BN, RV, AV) in the Unaided, Aided Original and Aided with Real-Ear Conditions. Error Bars denote ±1 SE

Traditionally, the APHAB examines two areas: Speech Perception and Loudness. Speech perception is rated in the first three subscales (EC, BN, RV) and loudness is rated in the fourth (AV). Among the speech perception subscales, it is expected that a lower APHAB score will be present in an aided condition. In the loudness subscale, there is often a higher score in the aided condition, indicating that loud sounds are more bothersome when wearing one's hearing aid. The data found in this study follows this traditional pattern. As with the HINT, a MANOVA was ran to examine interaction effects between aided conditions and subscale. Again, normative values were subtracted from normative data. Also, the Aversiveness scale was flipped to be a “Nonaversiveness” measure so that data was more unified. This time, the effect of subscale, the effect of aided condition, and the effect of subscale by aided condition were examined. There was no significant effect found of the subscale condition (p=0.556). Wilks Lambda value showed that 55% of variance was due to the difference between subscales. There was also no significant effect of aided condition (p=0.721). Wilks Lambda value showed that 10% of variance was due to aided condition. Finally, no significant interaction was found in the subscale by aided (p=0.271), with a Wilks Lambda value indicating 60% of variance was due to the interaction between subscale and aided conditions. This indicates that no significant differences were found in responses based on aided conditions or across subscales.

3.4b SADL

The SADL was the second questionnaire used to assess patient-perceived satisfaction or benefit with their hearing aids. Like the APHAB, the SADL was administered during both sessions. During the Aided Original session, subjects were asked to fill out the questionnaire answering each question once, thinking about their current (original) hearing aid settings. During the Aided with Real-Ear session, subjects were asked to answer questions thinking about their new (with real-ear) hearing aid settings. The SADL is measured across four subscales:

1. Positive Effect (PE)

2. Service & Cost (SC)

3. Negative Features (NF)

4. Personal Image (PI)

Following completion of the survey, scores were calculated using the SADL scoring software. Average unaided, aided and global scores were evaluated. Figure 3.5 shows results for SADL scores across the four subscales in the Aided Original and Aided with Real-Ear conditions.

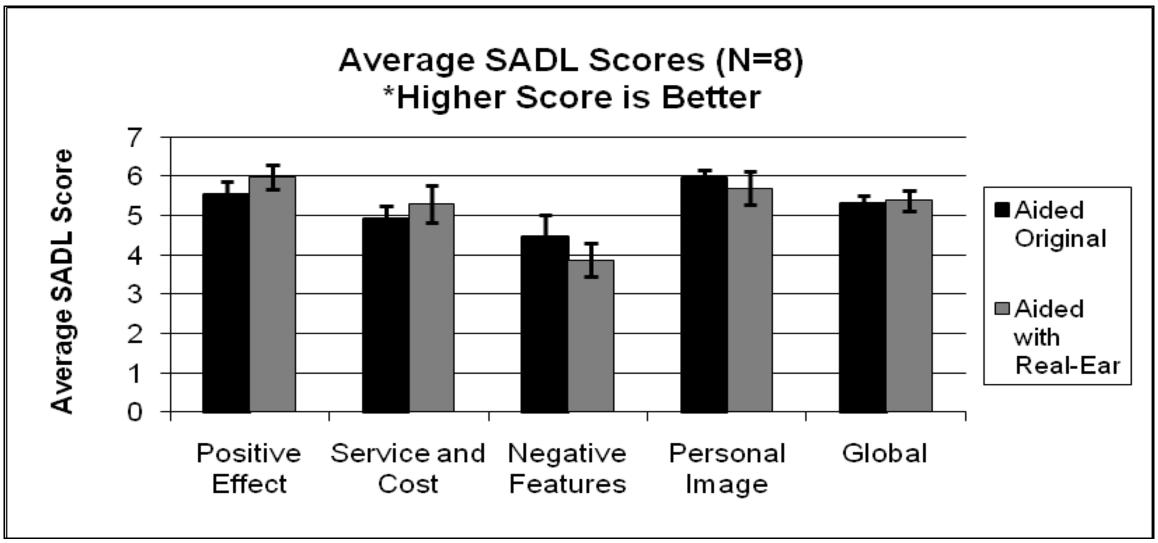


Figure 3.5: Average SADL Scores Across the Four SADL Subscales (PE, SC, NF, PI) as well as Global Scores in the Aided Original and Aided with Real-Ear Conditions. Error Bars denote ±1 SE

When looking at the SADL scores, little difference is seen between the Aided Original and Aided with Real-Ear conditions. A MANOVA was ran to examine interactions between subscales and aided conditions. Again, normative values were subtracted from scores to unify data. Like the APHAB, effects of subscale, aided condition , and subscale by aided condition were examined. Tests of subscale showed no significant effect (p=0.345), with a Wilks Lambda value showing 97% of variance was due to subscale. Tests of aided condition showed no significant effect (p=0.813). No significant effect was found when examining interaction between subscale and aided conditions (p=0.008), with a Wilks Lambda value showing 71% of variance being due to the interaction between subscale and aided conditions. This indicates that there was no significant difference in scores between the two aided conditions or across subscales. Thus, there was no significant effect of improvement in satisfaction and benefit scores when matching hearing aids to NAL-NL1 targets.

3.5 Final Questionnaire

At the end of the Aided with Real-Ear session, subjects were asked to fill out a simple questionnaire created for this study. Questions were as follows:

1. Which hearing aid program did you prefer, your original or the one that was created for this study?
2. Please list some specific reasons for your preference.

Of the eight subjects, six listed the study (target-matched) programming as their preference. Some specific reasons for this preference were improved clarity of speech and hearing in the presence of background noise. The two subjects who listed their original programming as their preference cited loudness as the reason they disliked the target-matched settings. Depending on their preference, hearing aide settings were either left alone or returned to their original programming.

4. Discussion

The aim of this study was to determine the specific benefit a patient will receive when having their hearing aids programmed as closely to NAL-NL1 targets as possible with the aid of real ear measurement. Research included in the literature review demonstrated that using real-ear verification is the most effective means of meeting prescribed targets. Using this method on a group of subjects who had previously experienced programming without real-ear verification provided insight on subjective measures of satisfaction and benefit. Beyond that, measures of speech intelligibility provided that ability to correlate changes made with programming to performance on the HINT in quiet and noise.

4.1 Discrepancy in hearing aid gain with and without real ear verification:

Real-Ear Insertion Gain (REIG) was tested twice: before (participants' original hearing aid gain programmed without real ear verification) and after programming to match NAL-NL1 targets as closely as possible with the aid of real ear verification. Initially, REIG values were found to be on average 6 to 12dBSPL under prescribed NAL-NL1 target values for 50dBSPL and 65dBSPL input. The work of Hawkins and Cooke (2003) demonstrated that on average, especially in the higher frequencies (above 1000Hz), actual insertion gain measures were approximately 10dBSPL under NAL-NL1 prescribed measures. Aarts and Caffee (2005) expanded the previous study, finding that at 50dBSPL input, actual insertion gain values were on average close to target at 500 Hz, about 5dBSPL below target at 1000 Hz, and approximately 10 to 15dBSPL below NAL-NL1 targets at 2000Hz and above. These discrepancies closely resemble those found in this study when comparing original real-ear insertion gain values to NAL-NL1 predicted values. Following reprogramming to more closely match prescriptive targets, minor discrepancies were seen at 500 Hz, with the greatest difference being seen at 2000 Hz. The goal of the NAL-NL1 prescriptive method is to make speech intelligible while keeping sounds comfortable. The emphasis of gain is on the middle frequencies. When 500 Hz was raised significantly, patients often reported too much loudness or that their own voice sounded unnatural. When manipulating 1000 Hz and 2000 Hz, patients were more flexible with the amount of possible increased gain. This is likely due to the fact that NAL-NL1 method provides emphasis on these frequencies to begin with, with a goal of maximizing speech intelligibility. In addition, increased gain in the mid frequency region is less noticeable than any gain adjustment at low or high frequencies.

In correlating the REIG target matched programming to patient feedback, a trend of improved clarity of speech and greater audibility in background noise were reported. This agrees well with the fact that 2000 Hz was the greatest area of increase across manipulated frequencies. When providing more gain to the middle frequencies, it would be expected that speech intelligibility would improved (Byrne D, 2001) (Ching TY, 2001). This also correlates well with HINT scores.

4.2 Reception Threshold for Speech in Quiet:

HINT scores in Quiet yielded two significant effects: a main effect between unaided and both aided conditions (with and without real ear verification), as well as an effect between listening conditions (between 0 and 90 degree azimuths). A significant main effect is to be expected as research has long proven that there is a great benefit in speech intelligibility when wearing hearing aids (in a person with hearing loss) (Dillon, 2001). The second significant factor, between both aided conditions, was a more interesting finding. There was a 5dBHL difference between the Aided Original to Aided with Real-Ear conditions, with the lower score being in the second condition. This showed that as subjects' hearing aids are programmed more closely to target, they will be able to correctly understand speech in quiet situations at a softer level. The HINT score in quiet is a direct reflection of the improved audibility achieved by providing the additional gain while attempting to match the NAL-NL1 targets. However, real-life situations are almost never completely quiet, so the HINT in Noise was of more interest in regards to relating findings to clinical application.

4.3 Reception Threshold for speech in the presence of Noise:

As mentioned before, the HINT in Noise was performed at two azimuth conditions: 0 degree and 90 degree. Again, a significant main effect was found between unaided and aided conditions. The surprising find in this condition is that no significant benefit was found between the Aided Original and Aided with Real-Ear conditions. The likely reason for this is the difficulty of the task. The 0 degree azimuth condition proved to be far more difficult than the 90 degree azimuth condition among the unaided and both aided conditions (Dillon, 2001). On average, subjects needed the speech signal to be louder than the noise in order to correctly repeat it. Research examining the advantages of binaural listening has proven that being able to separate the sources of noise and speech signal improves understanding (Henkin Y, 2007) (Dillon, 2001). During this study, the 0 degree condition was so difficult that subjects struggled no matter what the aided condition. However, a much different scenario was found when the speech and noise were spatially separated.

The 90 degree azimuth condition replicates a situation where the speech and the noise are spatially separated by 90 degrees with speech originating in front of the listener. This condition is an easier task compared to the 0 degree condition as reported in studies involving directional hearing aid microphones (Ricketts, 2000), and normative data for the HINT (Nielson et al., 1993). As before, a significant main effect was found between unaided and aided conditions, which we would expect. What was more interesting is that subjects did far better in the 90 degree azimuth condition than the 0 degree azimuth, particularly in the Aided Original and Aided with Real-Ear conditions (see Figure 3.3 in the results section). MANOVA results indicated that there was a significant improvement when changing listening conditions from 0 to 90 degree azimuth. This indicates, as mentioned before, that there is an improvement in speech intelligibility when speech and noise are spatially separated.

Overall, in the HINT conditions, subjects were better at correctly repeating HINT sentences when using amplification. Interestingly, subjects did so poorly across the board in the 0 degree azimuth noise condition that no significant benefit to using real-ear verification with target matching could be determined. When moving from the difficult 0 degree condition to the 90 degree condition, a significant improvement in scores was seen. However, the differences in aided conditions could not be attributed to a change in listening condition. Therefore, results show that there was an improvement in speech intelligibility when using amplification; however it was dependent upon listening environment. One consideration is that there may have been an effect of learning. As subjects were familiarized to HINT testing during the Aided Original session, they had an advantage of learning effect during the Aided with Real-Ear session. This could have played as a factor in the HINT Quiet and 90 degree azimuth scores, where subjects did slightly better in the Aided with Real-Ear condition, although no significant difference was found.

4.4 APHAB

Aside from speech intelligibility, subjective measures of satisfaction and benefit were used to determine any patient-perceived improvement in programming hearing aids closer to NAL-NL1 targets. Remember that the APHAB measures two things: speech perception and loudness. When comparing APHAB scores among all three aided conditions, no significant difference was found between subscales. However, when looking at the loudness subscale a lower score was obtained with unaided answers, indicating that loud sounds become more bothersome when the subjects are wearing their hearing aids. It is important to note that no significant difference was found between aided conditions, showing that there is no greater aversion to sound when hearing aids are programmed closely to NAL-NL1 targets.

4.5 SADL

The SADL was used to assess a subjective measure of satisfaction. The SADL was only measured with aided responses, so the only comparison is made between the

Aided Original and Aided with Real-Ear conditions. Across all subscales, including the global score, no significant difference was found between aided conditions. This indicates that there was no difference in how satisfied subjects were with their hearing aids when programming was matched closely to NAL-NL1 targets.

4.6 APHAB & SADL

While no significant difference in satisfaction and benefit were found between Aided Original and Aided with Real-Ear settings, it cannot be said that patients didn't prefer the target matched settings over their original. It is important to remember that satisfaction and benefit can be measured on a large scale, and as it is a subjective measure, that scale may vary for patient to patient. So while no significant difference was found, it does not necessarily correlate with patient feedback. Due to this discrepancy, a simple questionnaire to compare both aided conditions was created.

4.7 Subjective Preference of Participants

The final questionnaire asked two important questions: Which programming did you prefer, and why? Across all seven subjects, five reported that they preferred the target-matched settings. Reasons why included improved clarity of speech, less trouble in background noise, and greater comfort. This correlates well with our findings regarding speech intelligibility in quiet and noise. The two subjects who preferred their original settings cited loudness as the reason for their choice. They reported that the target-matched settings were just too loud in all settings, and they did not feel comfortable using the programming in everyday situations.

Given this information, it is important to recall that this questionnaire had one major flaw: subjects were not blinded as to what programming was experimental and what was their original. Therefore, it is possible that users who preferred new settings could be experiencing a “wow” effect. (Bentler RA, 2003)

5. Conclusion

This study aimed to examine the actual benefit received by patients when their hearing aids are programmed as close to prescribed NAL-NL1 targets as possible using real-ear verification. The participants benefited in the area of speech intelligibility. In particular, in quiet situations as well as noisy situations when speech and noise are spatially separated. While no significant difference in patient perceived satisfaction and benefit were found, patient feedback indicated that for most subjects, there was a great improvement in speech intelligibility and comfort when using target-matched programming.

This study should be considered as evidence of the actual benefit of using real-ear verification in clinical practice. If patients are complaining of trouble understanding speech in the presence of noise, or wanting to understand speech more clearly, this method of fitting hearing aids should be considered as a means to remedy the issue. This study can also be considered a jumping off point for future research in the area of real-ear verification, such as the difference in programming between new and experienced clinicians. Overall, the message is that real-ear verification is not only an effective means of matching prescribed target values, but also an effective means of improving patient-perceived speech intelligibility and comfort.

Appendix A

Informed Consent

INFORMED CONSENT

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Ms. Sarah Sporck and Dr. Ayasakanta Rout from James Madison University (JMU). Ms. Sporck is a doctoral student in the audiology program at JMU; Dr. Rout is a professor at JMU who specializes in research related to hearing aids. The purpose of this study is to determine if a new hearing aid fitting technique results in improved benefit and user satisfaction. This study will help us to provide better services to future hearing aid users. This study will also contribute to the student's completion of her doctoral dissertation.

Potential Risks & Benefits

The investigator does not perceive more than minimal risks from your involvement in this study. The tests used in this study are commonly used clinical procedures in audiology. Potential benefits from participation in this studying include increased benefit and satisfaction with your hearing aids.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. This study consists of two tests which will be performed at Ear, Nose and Throat Associates of Charleston, WV. The first test will require you to be comfortably seated in a hearing test suite and listen to sentences in background noise presented from a loudspeaker at a comfortable listening level. Your task will be to repeat what you hear. The second test requires you to listen to sound presented to your ear both with and without your hearing aid in place. A probe microphone will be comfortably placed in your ear canal during this test. Once again, the sound will be presented through the probe microphone at a comfortable listening level. Your only requirement will be to sit quietly for the short duration of this test. Finally, you will be asked to complete three surveys prior to your test session. The Abbreviated Profile of Hearing Aid Benefit (APHAB) assesses a hearing wearer's perceived level of benefit from amplification. The Satisfaction with Amplification in Daily Life (SADL) and Expected Consequences of Hearing Aid Ownership (ECHO) are used in conjunction; the SADL measures daily satisfaction with amplification while the ECHO assesses expected outcomes of a hearing aid prior to fitting. These surveys will assist the researchers in determining how much benefit you are receiving from your hearing aids, as well as how satisfied you are with them. The doors of the sound booth will be closed during the entire session and the researcher will be on hand during the session for any assistance. The entire test protocol including both tests and signing your consent form is expected to take approximately one hour.

Confidentiality

The results of this research will be presented at professional conferences. While individual responses are obtained and recorded anonymously and kept in strict confidence, aggregate data will be presented representing averages or generalizations about the responses as a whole. No identifiable information will be collected from the participant and no identifiable responses will be presented. All data will be stored in a secure location accessible only to the researcher. The researcher retains the right to use and publish non-identifiable data. At the end of the study, all records will be shredded. Final aggregate results will be made available to participants upon request.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

Ms. Sarah Sporck
Communication Sciences and Disorders
James Madison University
sporcksk@jmu.edu

Dr. Ayasakanta Rout
Communication Sciences and Disorders
James Madison University
Telephone: (540) 568-3867
routax@jmu.edu

Questions about Your Rights as a Research Subject

Dr. David Cockley
Chair, Institutional Review Board
James Madison University
(540) 568-2834
cocklede@jmu.edu

Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

______________________________________ Sarah Sporck ________________

Number of Participant | Name of Researcher (Printed)

____

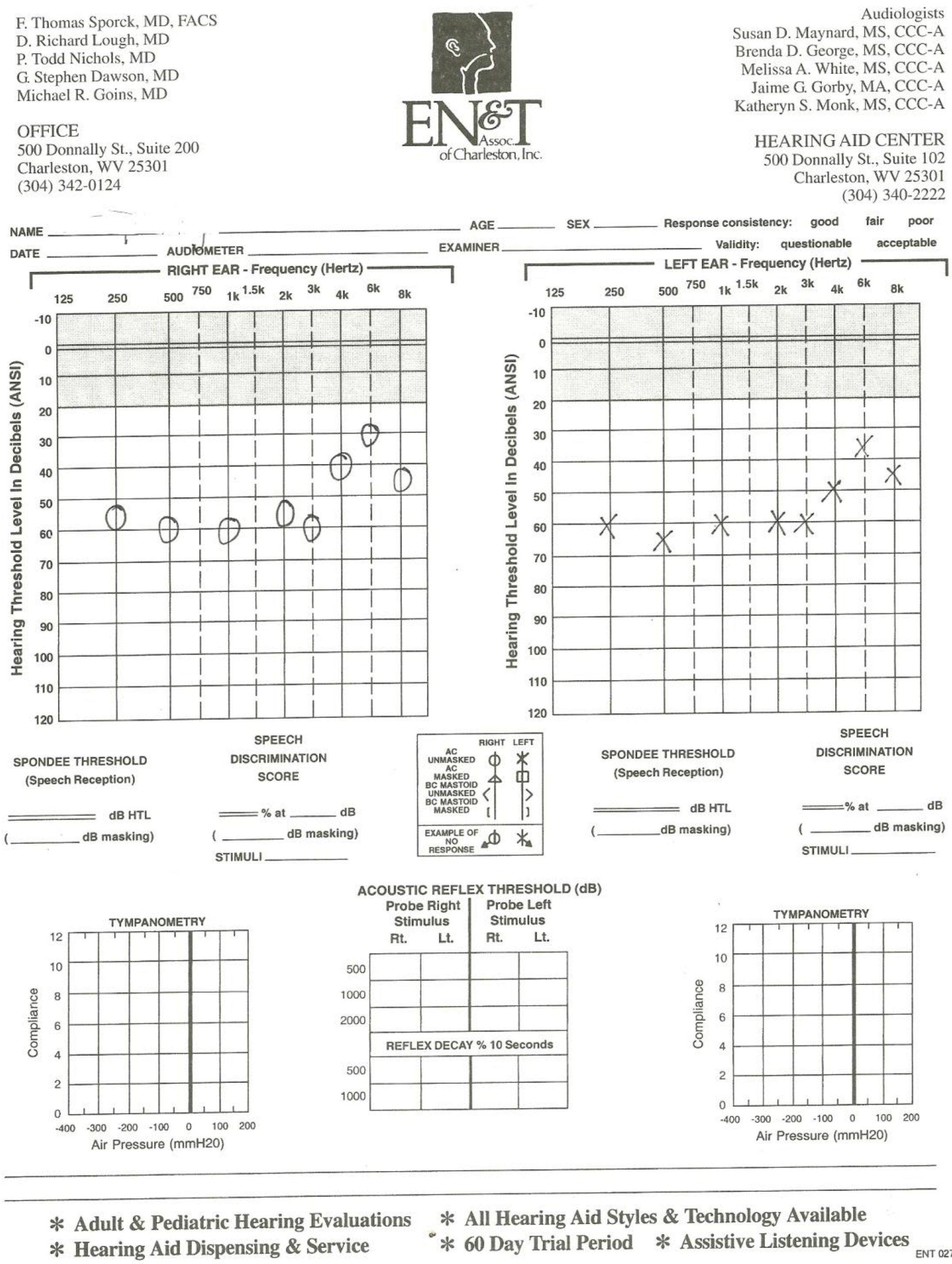
Name of Researcher (Signed)

____

Date | Date

Appendix B

Audiograms



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NAME ______ AGE ______ SEX ______ Response consistency: good fair poor

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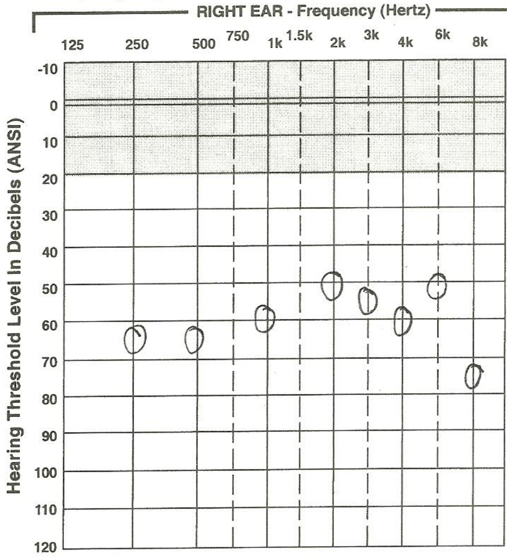

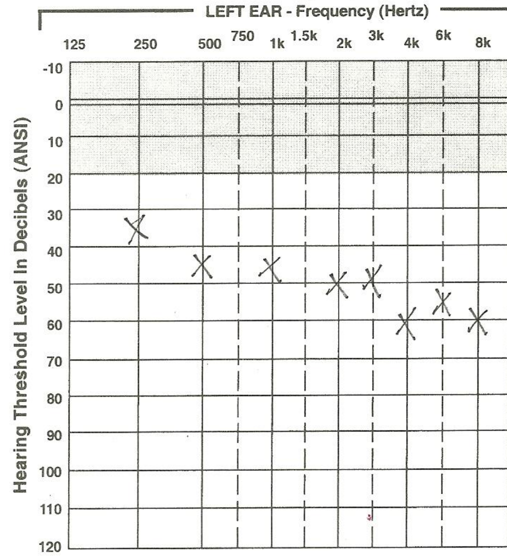

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL
(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB
(______ dB masking)
STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL
(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB
(______ dB masking)
STIMULI ______

ACOUSTIC REFLEX THRESHOLD (dB)

	Probe Right Stimulus Rt.	Probe Right Stimulus Lt.	Probe Left Stimulus Rt.	Probe Left Stimulus Lt.
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2000				
REFLEX DECAY % 10 Seconds				
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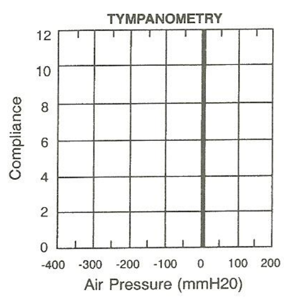

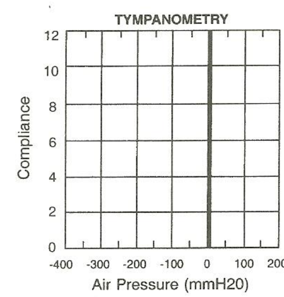

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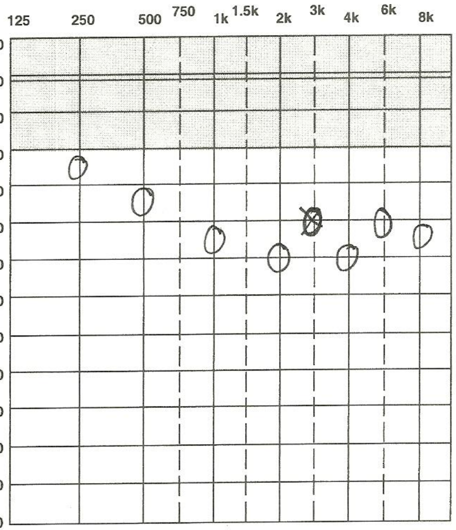
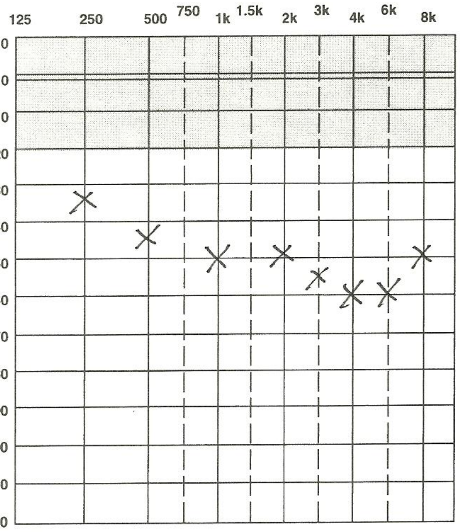
RIGHT EAR - Frequency (Hertz)



LEFT EAR - Frequency (Hertz)



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(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

(______ dB masking)

SPEECH DISCRIMINATION SCORE

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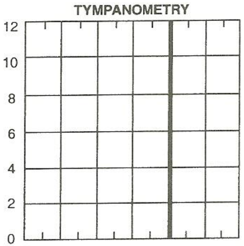
(______ dB masking)

STIMULI ______

TYMPANOMETRY



ACOUSTIC REFLEX THRESHOLD (dB)

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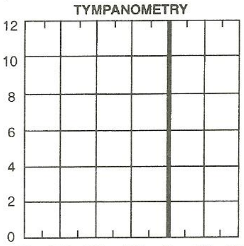

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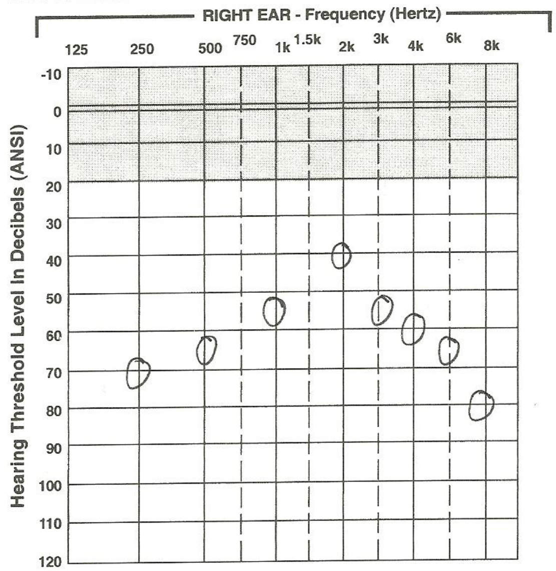
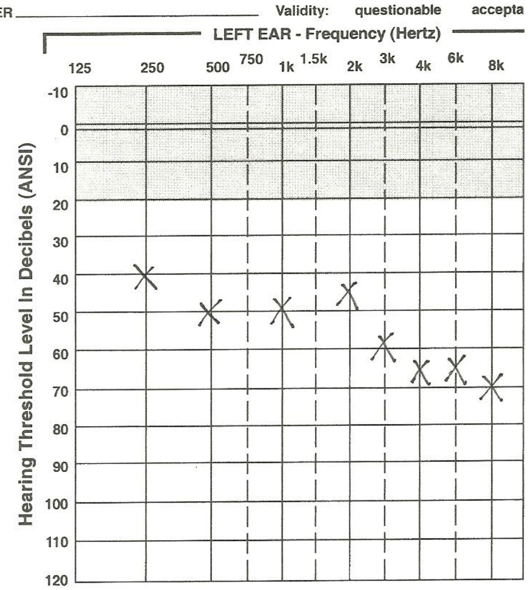
DATE ______ AUDIOMETER ______ EXAMINER ______ Validity: questionable accepta





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SPEECH DISCRIMINATION SCORE
______ % at ______ dB
(______ dB masking)
STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

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SPEECH DISCRIMINATION SCORE
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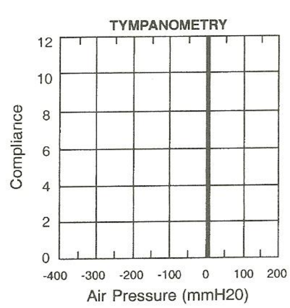

ACOUSTIC REFLEX THRESHOLD (dB)

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REFLEX DECAY % 10 Seconds				
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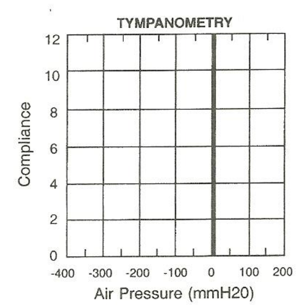

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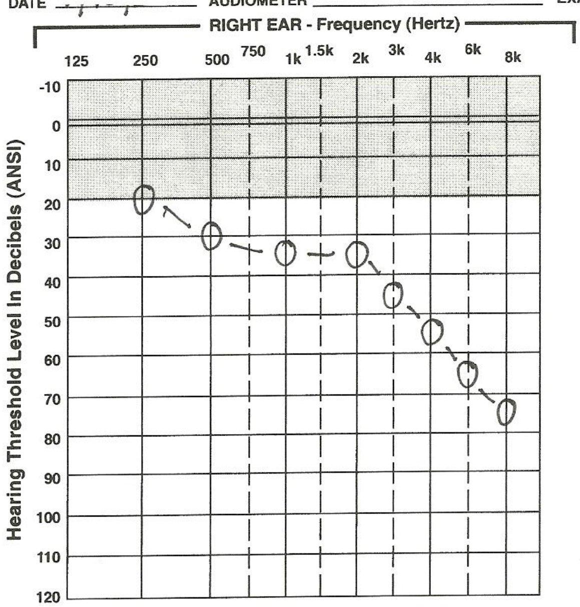
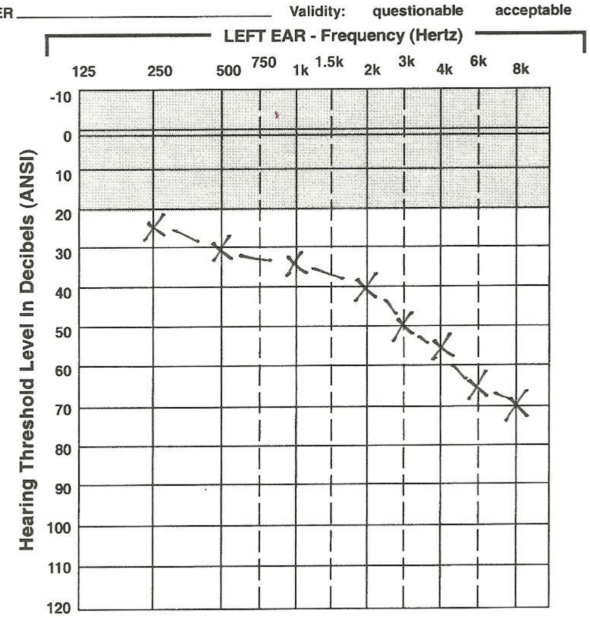
DATE ________ AUDIOMETER ________ EXAMINER ________ Validity: questionable acceptable





SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

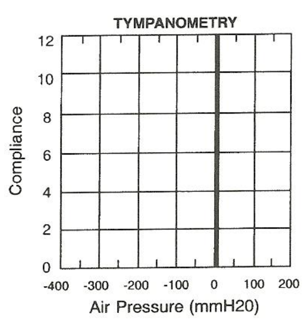
(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

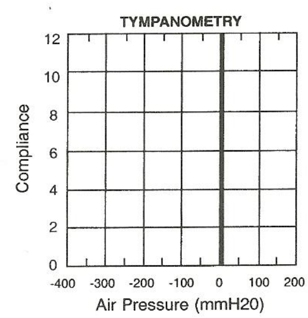


ACOUSTIC REFLEX THRESHOLD (dB)

	Probe Right Stimulus Rt.	Probe Right Stimulus Lt.	Probe Left Stimulus Rt.	Probe Left Stimulus Lt.
500				
1000				
2000				

REFLEX DECAY % 10 Seconds

500				
1000				



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Melissa A. White, MS, CCC-A
Jaime G. Gorby, MA, CCC-A
Katheryn S. Monk, MS, CCC-A

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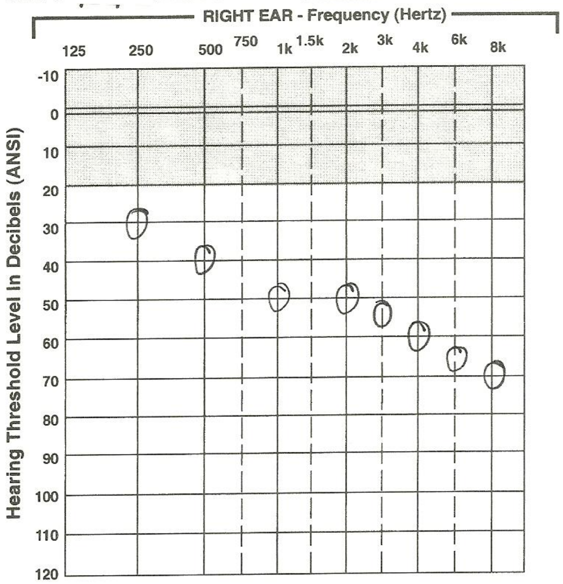
500 Donnally St., Suite 102
Charleston, WV 25301
(304) 340-2222

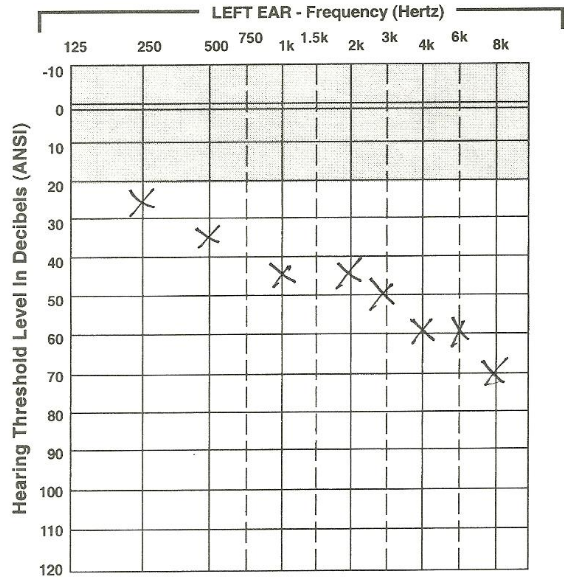
NAME ______ AGE ______ SEX ______ Response consistency: good fair poor

DATE ______ AUDIOMETER ______ EXAMINER ______ Validity: questionable acceptable

RIGHT EAR - Frequency (Hertz)



LEFT EAR - Frequency (Hertz)



SPONDEE THRESHOLD (Speech Reception)

______ dB HTL
______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB
(______ dB masking)
STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

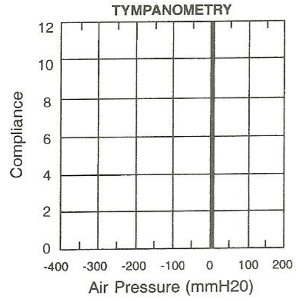
SPONDEE THRESHOLD (Speech Reception)

______ dB HTL
(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB
(______ dB masking)
STIMULI ______

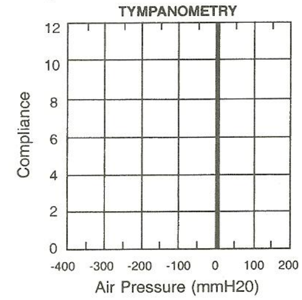
TYMPANOMETRY



ACOUSTIC REFLEX THRESHOLD (dB)

	Probe Right Stimulus Rt.	Probe Right Stimulus Lt.	Probe Left Stimulus Rt.	Probe Left Stimulus Lt.
500				
1000				
2000				
REFLEX DECAY % 10 Seconds				
500				
1000				

TYMPANOMETRY



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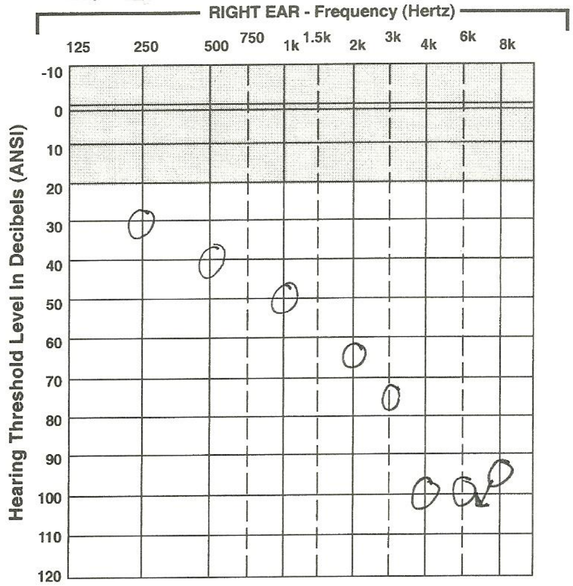
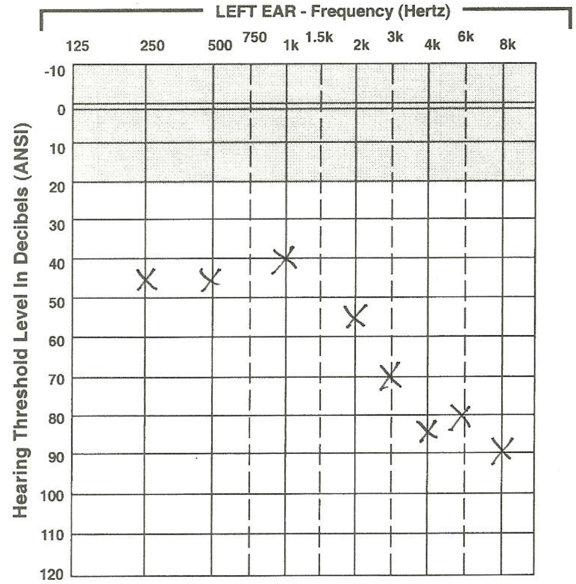
NAME ________ AGE ______ SEX ______ Response consistency: good fair poor

DATE ______ AUDIOMETER ______ EXAMINER ______ Validity: questionable acceptable





SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

(______ dB masking)

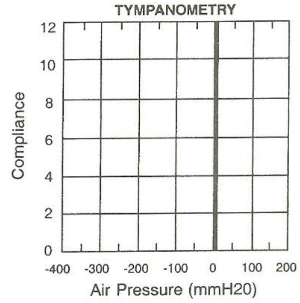
SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

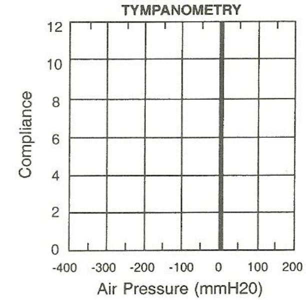
TYMPANOMETRY



ACOUSTIC REFLEX THRESHOLD (dB)

	Probe Right Stimulus Rt.	Probe Right Stimulus Lt.	Probe Left Stimulus Rt.	Probe Left Stimulus Lt.
500				
1000				
2000				
REFLEX DECAY % 10 Seconds				
500				
1000				

TYMPANOMETRY



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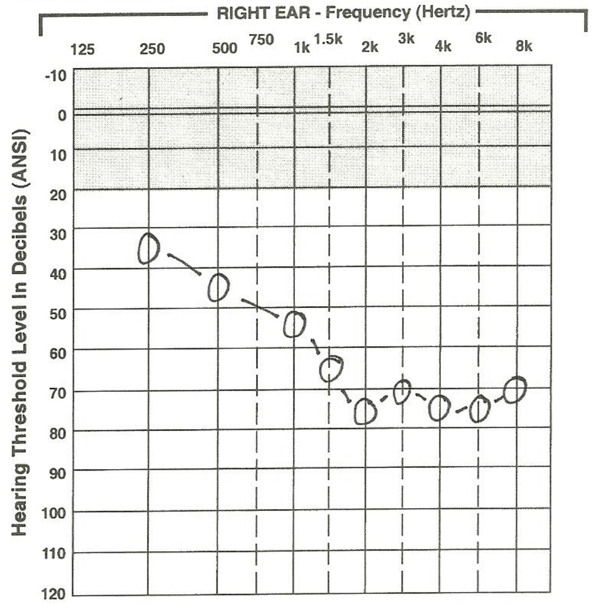
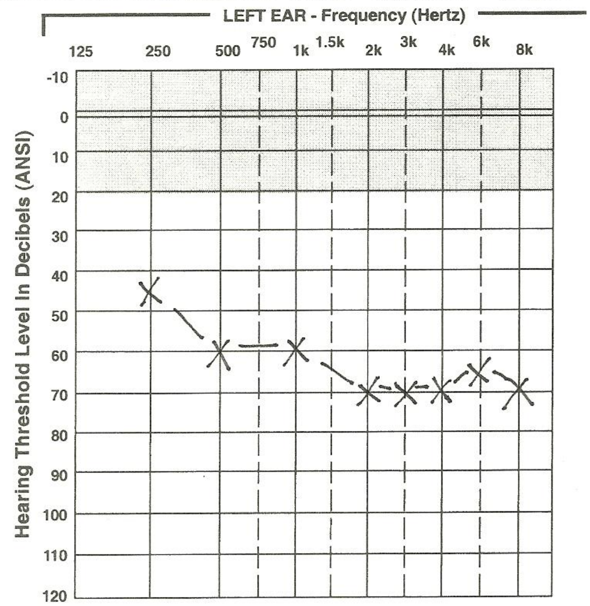
NAME ______ AGE ______ SEX ______ Response consistency: good fair poor

DATE ______ AUDIOMETER ______ EXAMINER ______ Validity: questionable acceptable





SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

(______ dB masking)

STIMULI ______

	RIGHT	LEFT
AC UNMASKED	O	X
AC MASKED	△	□
BC MASTOID UNMASKED	<	>
BC MASTOID MASKED	[	]
EXAMPLE OF NO RESPONSE		

SPONDEE THRESHOLD (Speech Reception)

______ dB HTL

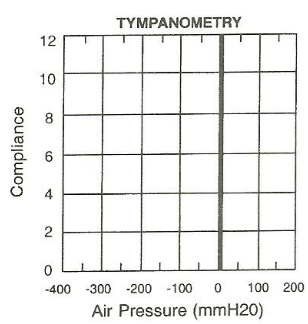
(______ dB masking)

SPEECH DISCRIMINATION SCORE

______ % at ______ dB

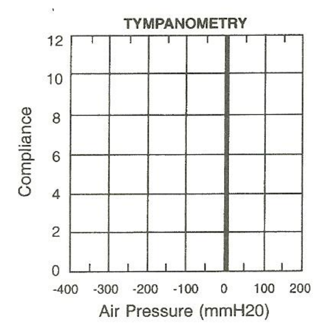
(______ dB masking)

STIMULI ______



ACOUSTIC REFLEX THRESHOLD (dB)

	Probe Right Stimulus Rt.	Probe Right Stimulus Lt.	Probe Left Stimulus Rt.	Probe Left Stimulus Lt.
500				
1000				
2000				
REFLEX DECAY % 10 Seconds				
500				
1000				



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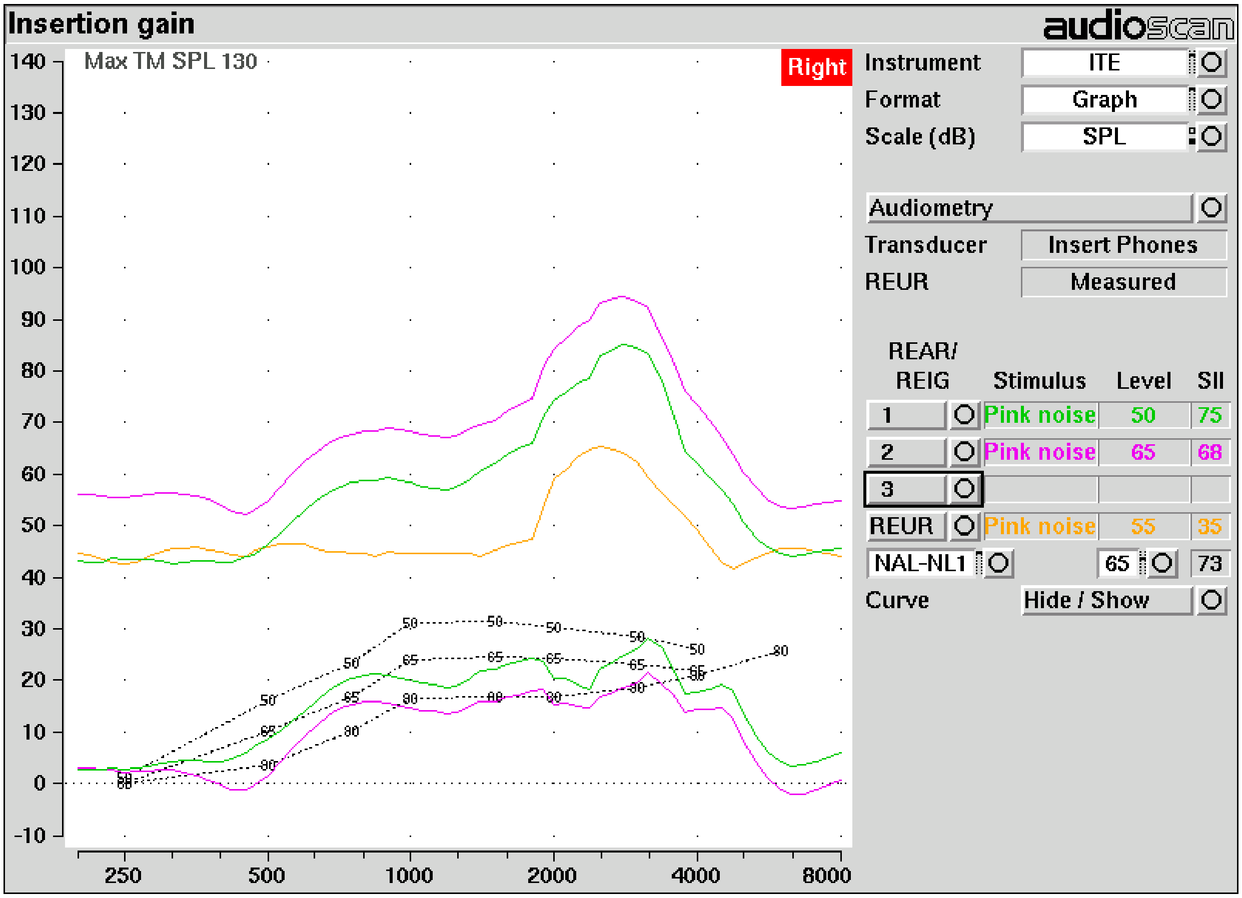
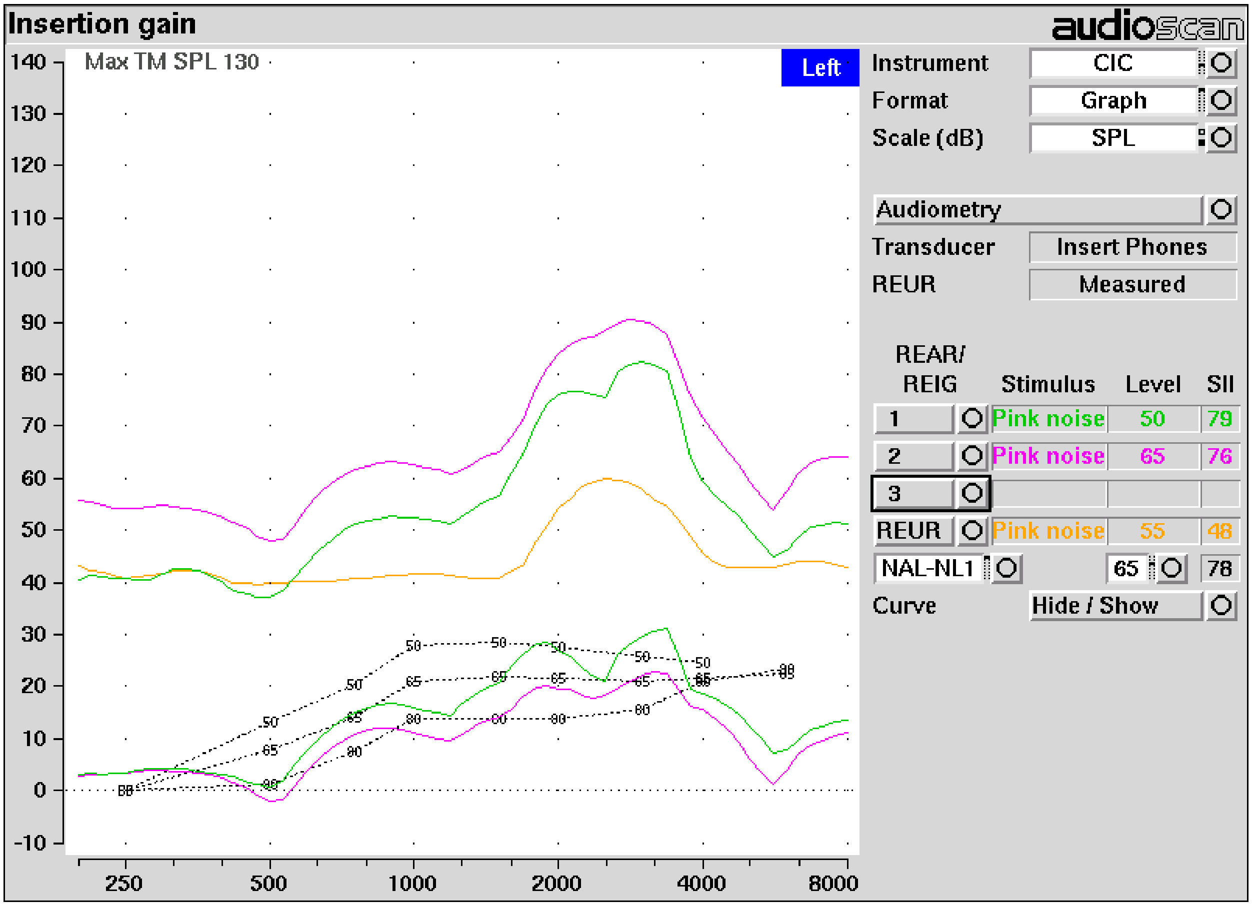
Appendix C

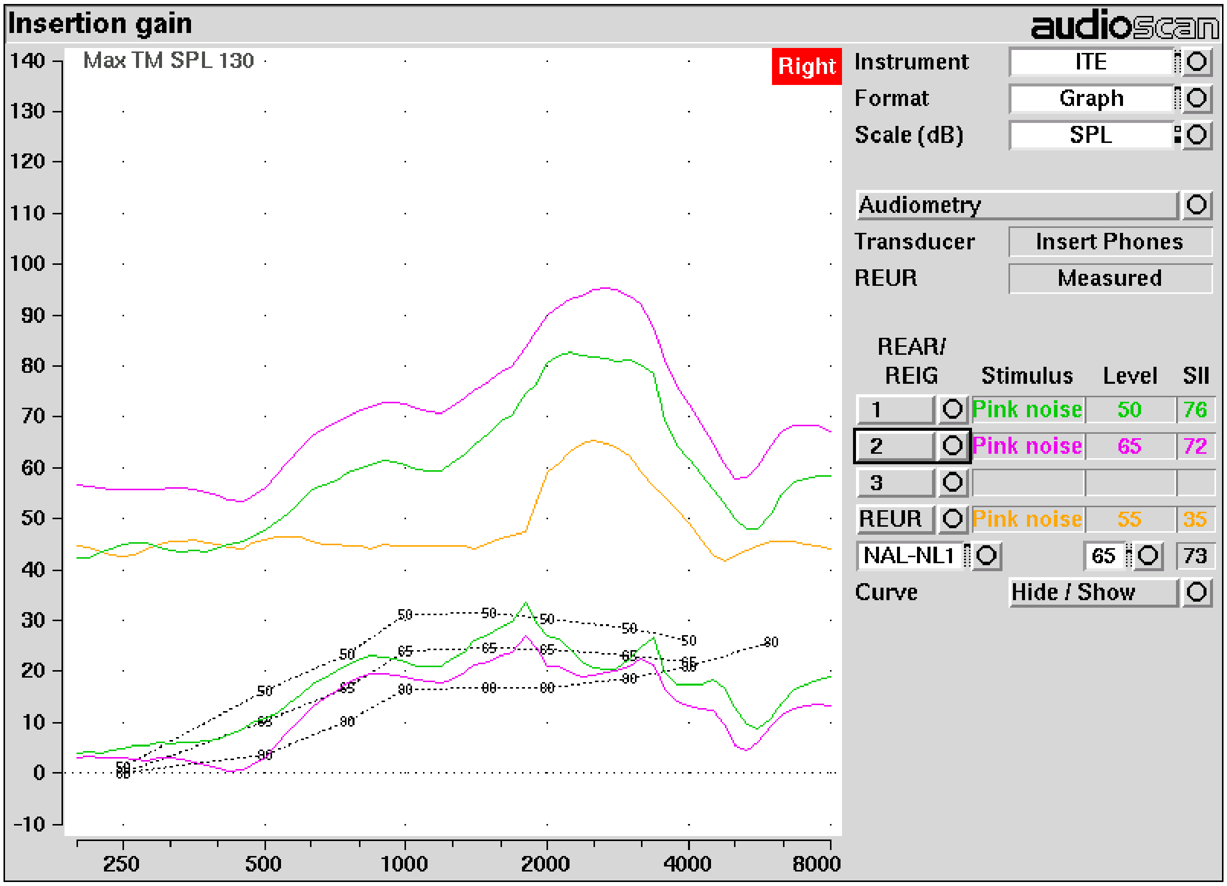
Real Ear Insertion Gain Measures

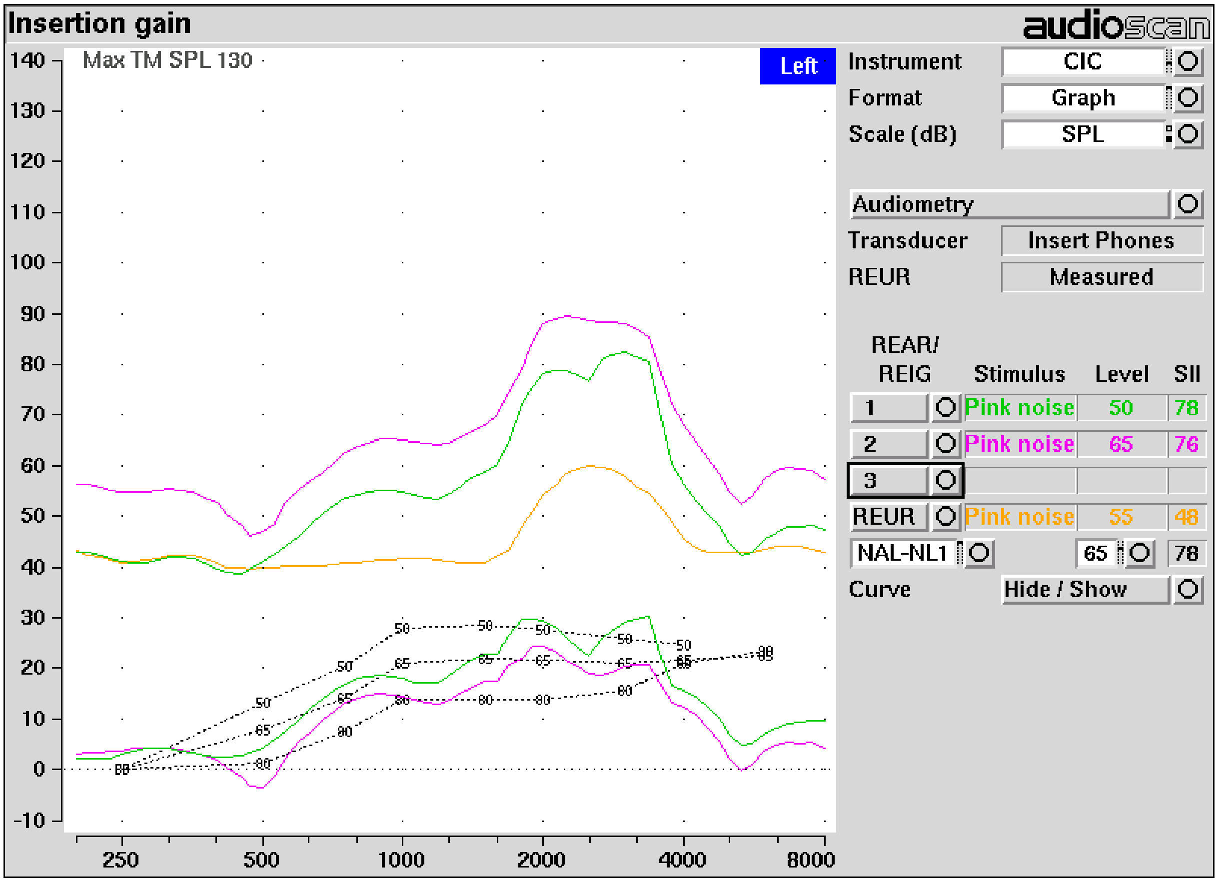
Subject 1 – Aided Original




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument CIC
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG Stimulus Level SII
1 Pink noise 50 79
2 Pink noise 65 76
3
REUR Pink noise 55 48
NAL-NL1 65 78
Curve Hide / Show
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
250 500 1000 2000 4000 8000

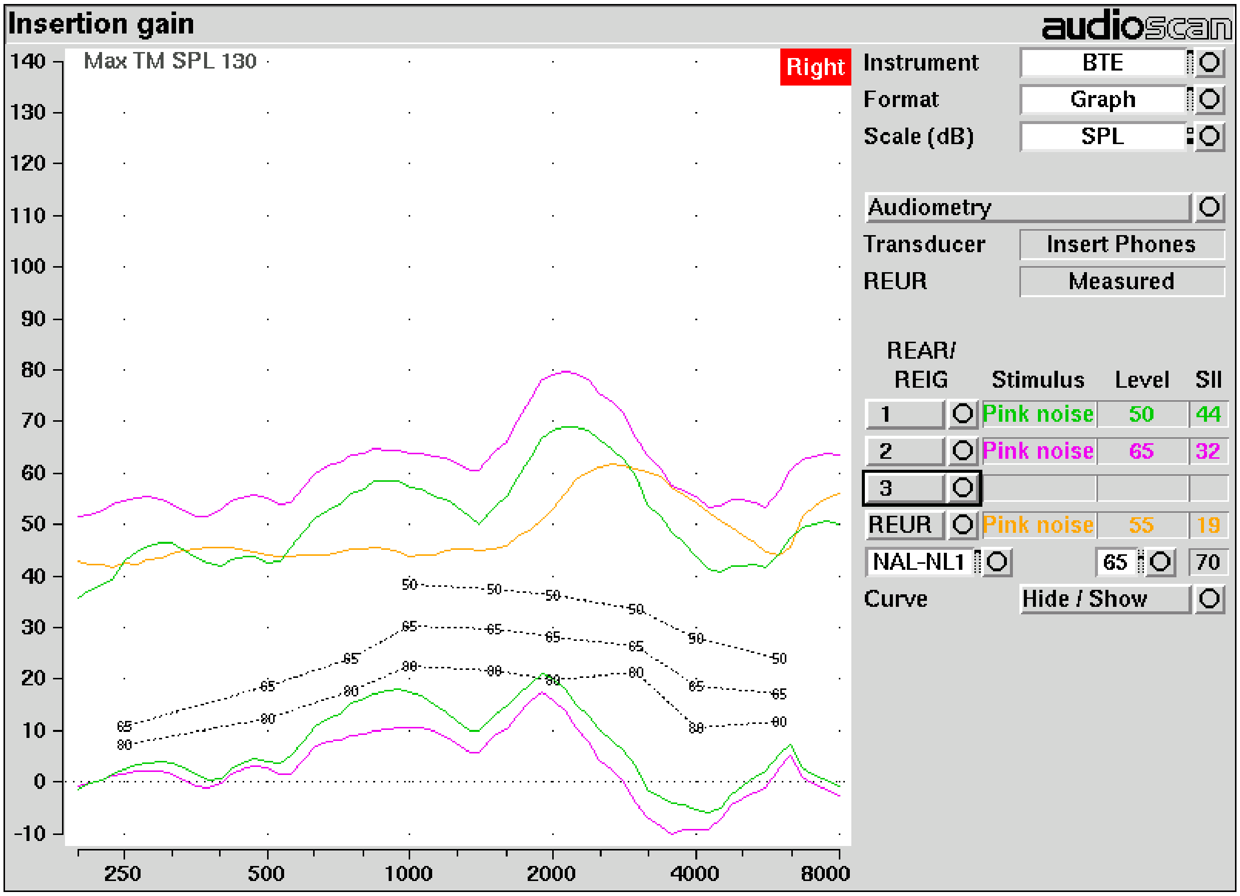
Subject 1 – Aided with Real-Ear

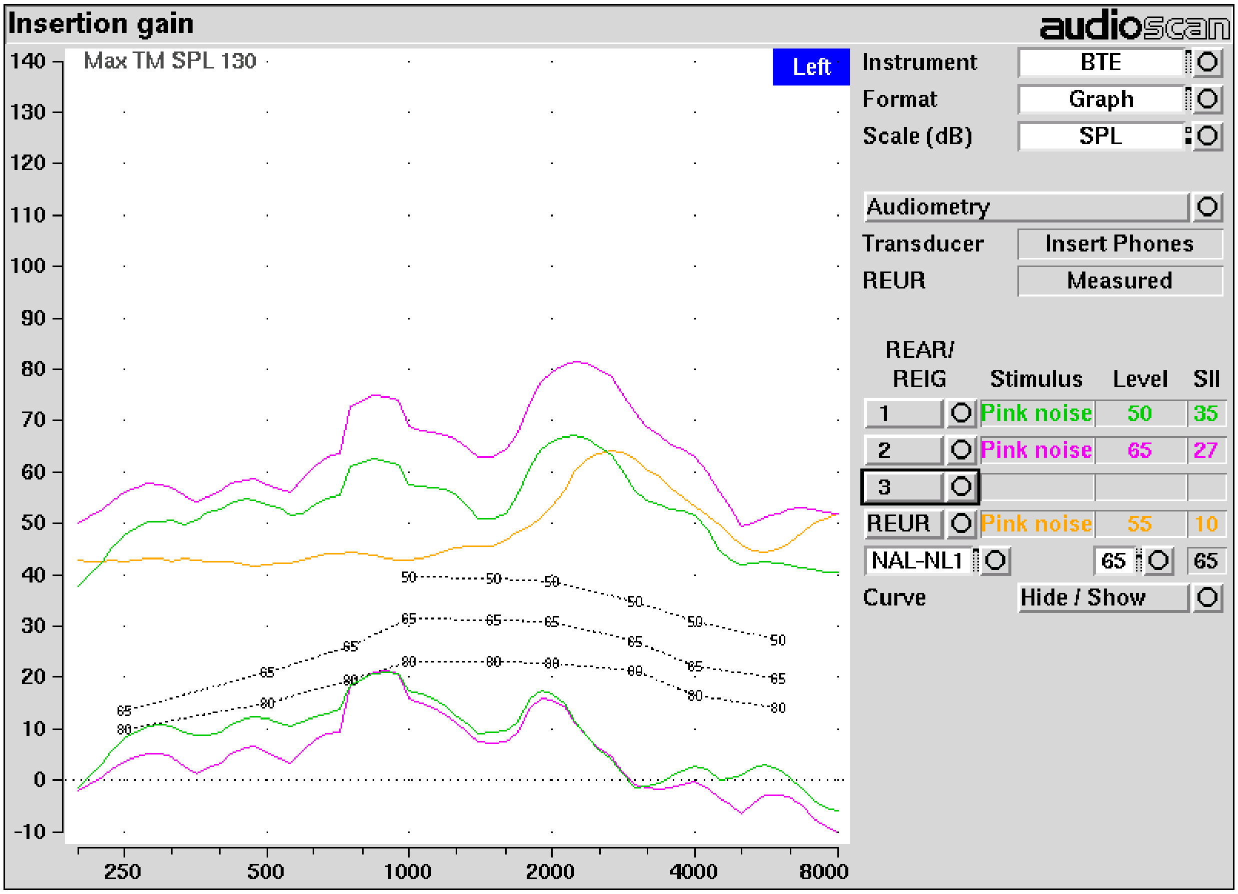




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument
CIC
Format
Graph
Scale (dB)
SPL
Audiometry
Transducer
Insert Phones
REUR
Measured
REAR/
REIG
Stimulus
Level
SII
1
Pink noise
50
78
2
Pink noise
65
76
3
REUR
Pink noise
55
48
NAL-NL1
65
78
Curve
Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

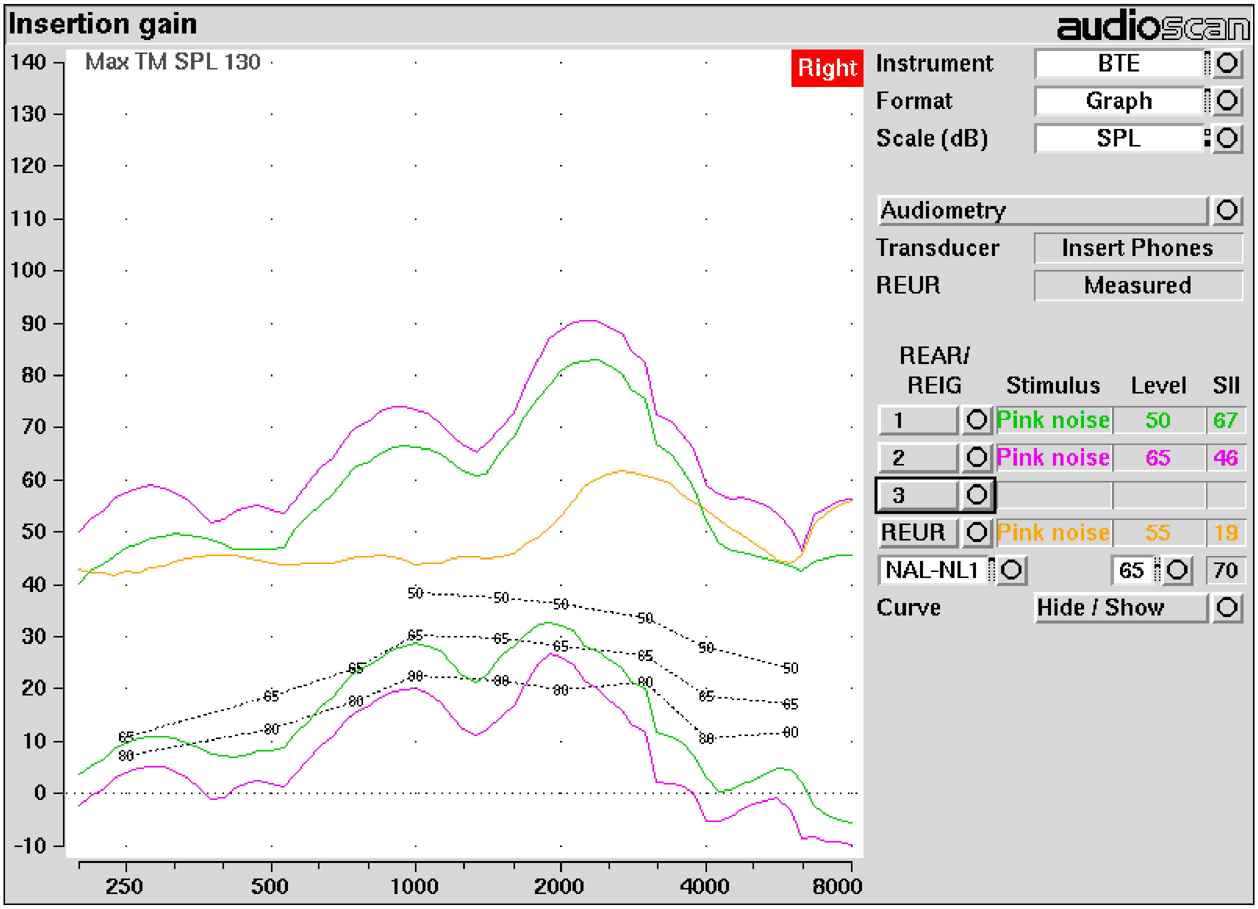
Subject 2 – Aided Original

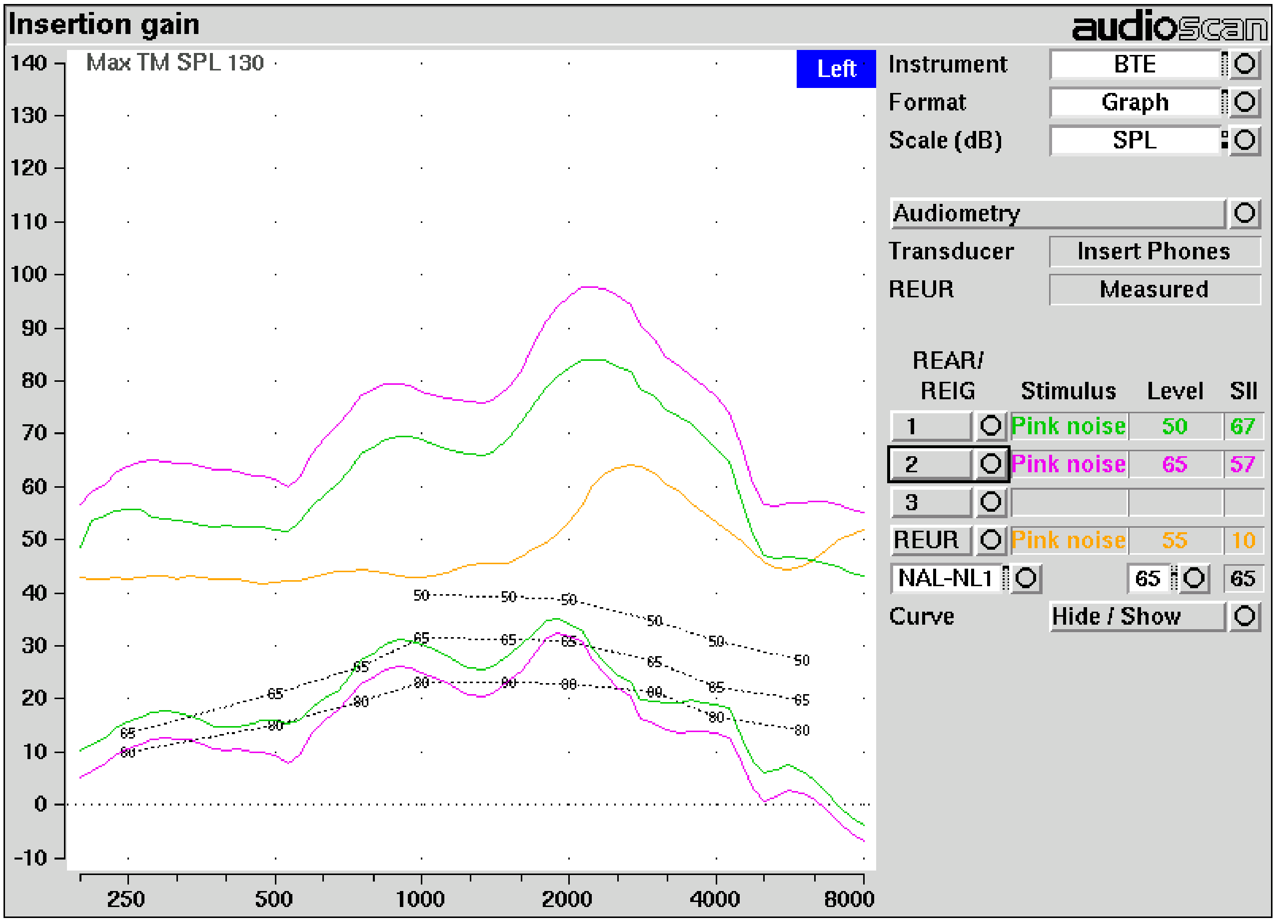




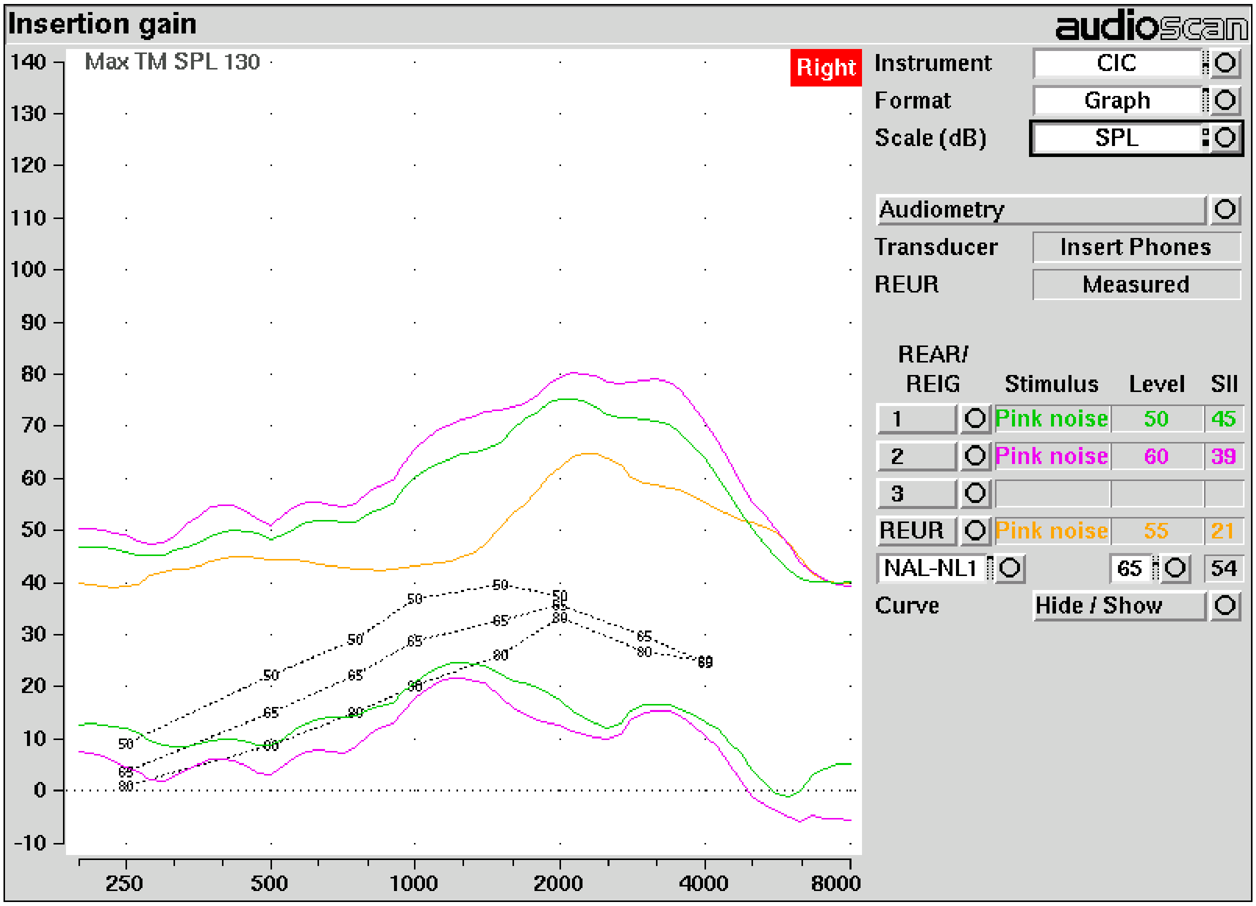
Insertion gain
audioscan
Max TM SPL 130
Left
Instrument BTE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 35
2 Pink noise 65 27
3
REUR Pink noise 55 10
NAL-NL1 65 65
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

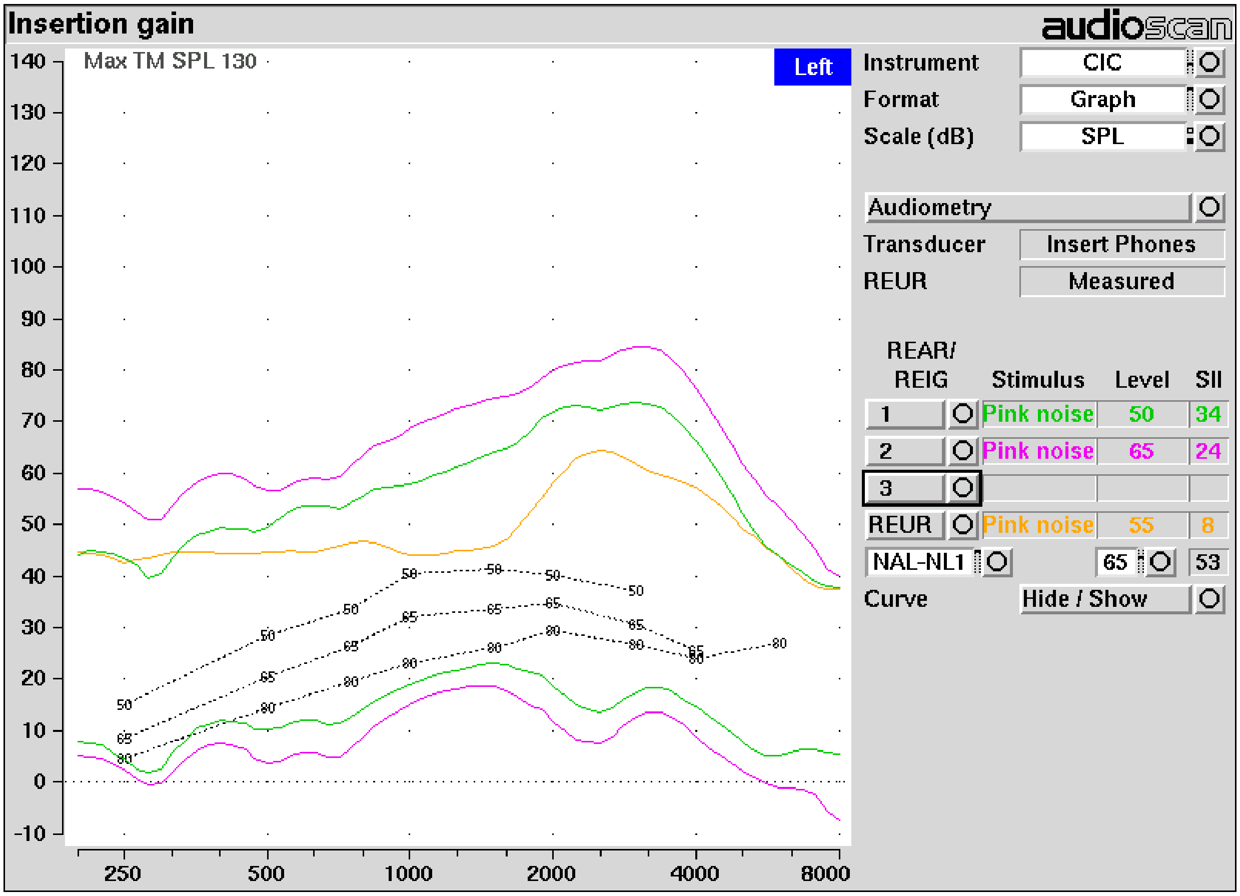
Subject 2 – Aided with Real-Ear



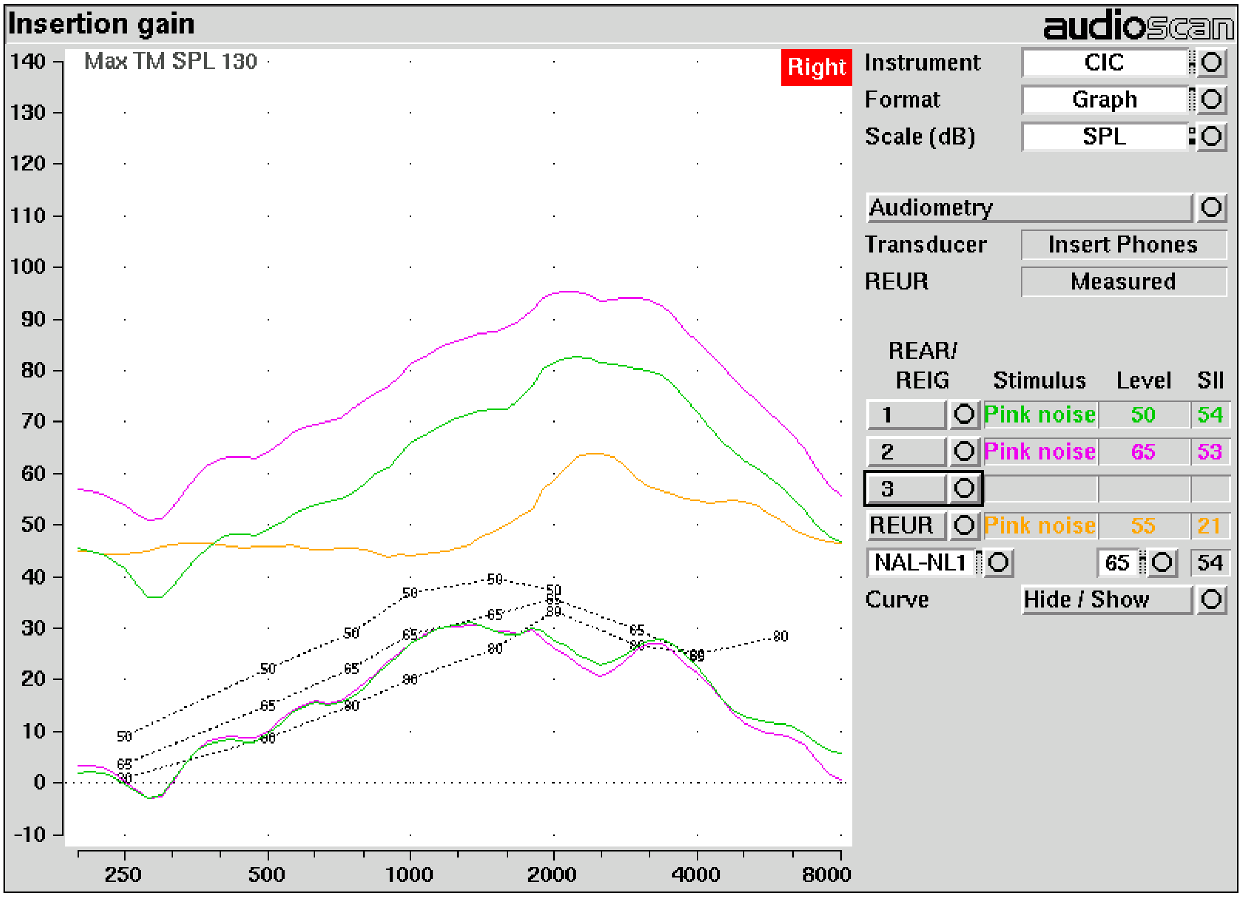

Insertion gain
audioscan
Max TM SPL 130
Left
Instrument BTE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 67
2 Pink noise 65 57
3
REUR Pink noise 55 10
NAL-NL1 65 65
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

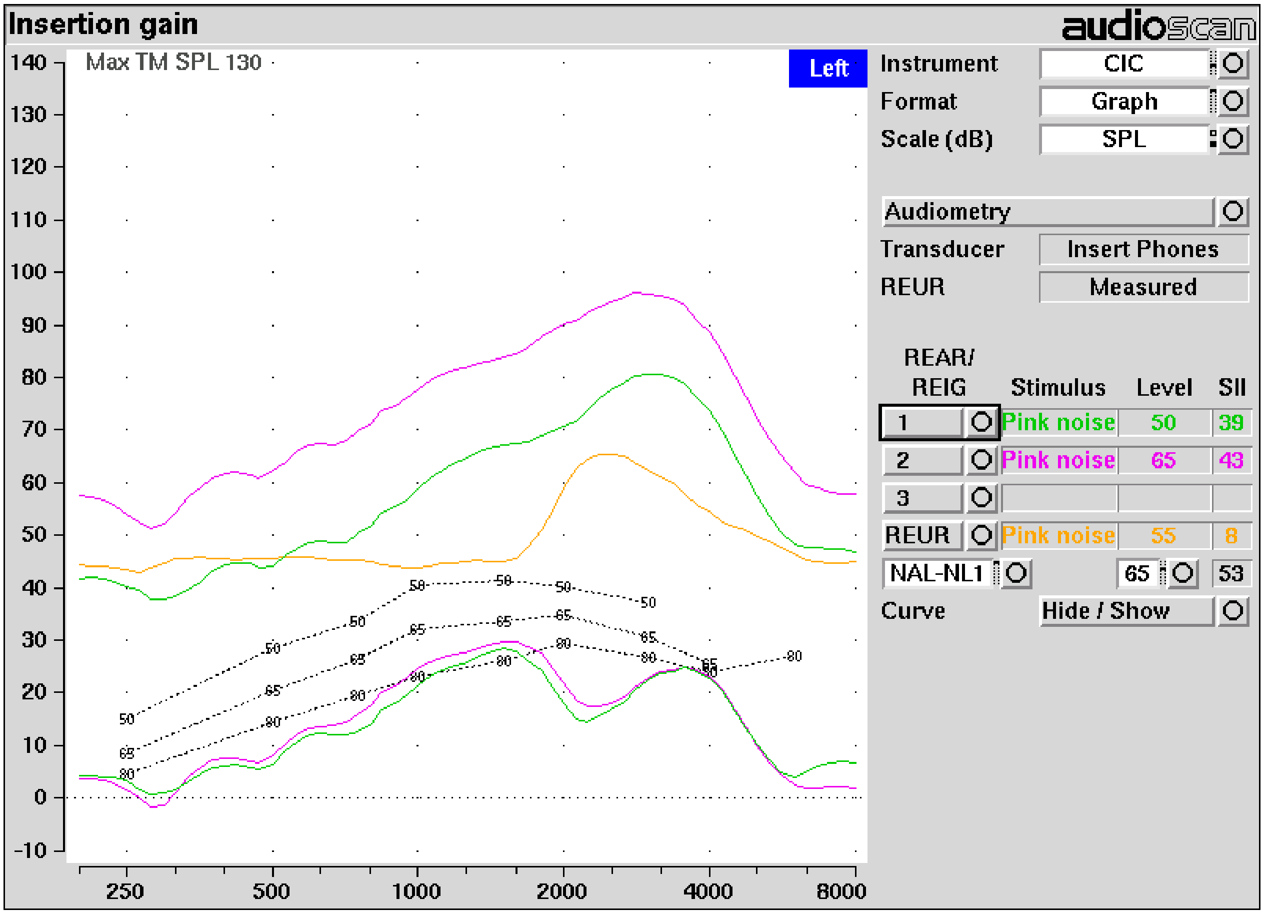
Subject 3 – Aided Original



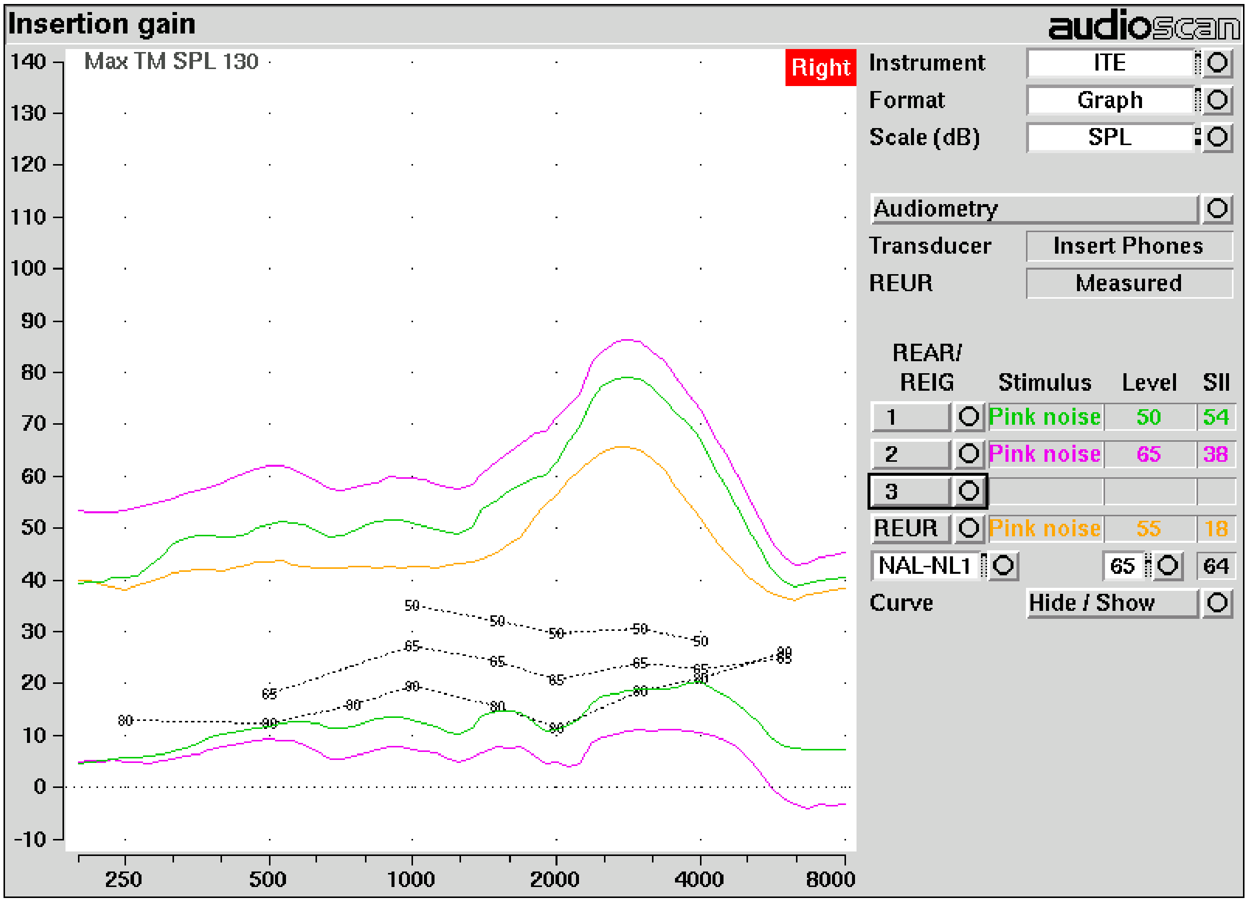

Insertion gain
audioscan
Max TM SPL 130
Left
Instrument
CIC
Format
Graph
Scale (dB)
SPL
Audiometry
Transducer
Insert Phones
REUR
Measured
REAR/ REIG
Stimulus
Level
SII
1
Pink noise
50
34
2
Pink noise
65
24
3
REUR
Pink noise
55
8
NAL-NL1
65
53
Curve
Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

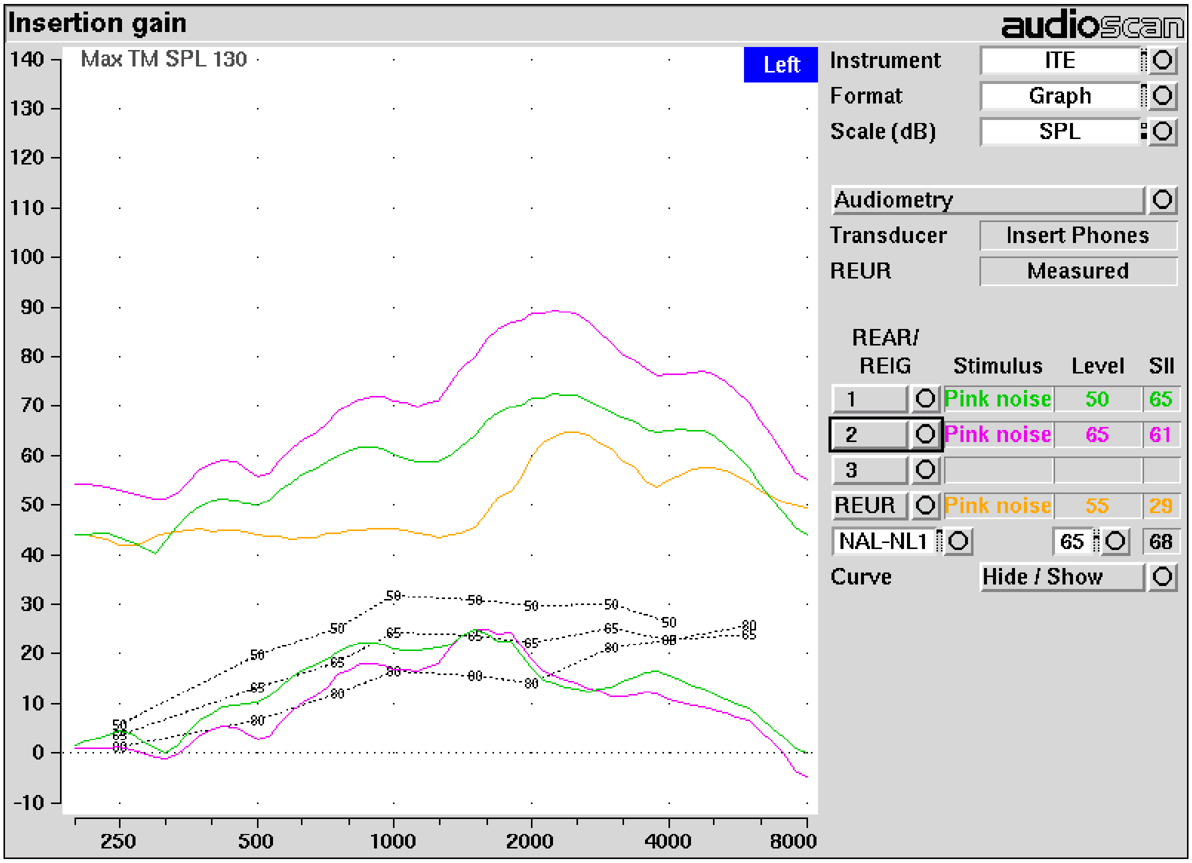
Subject 3 – Aided with Real-Ear




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument CIC
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 39
2 Pink noise 65 43
3
REUR Pink noise 55 8
NAL-NL1 65 53
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

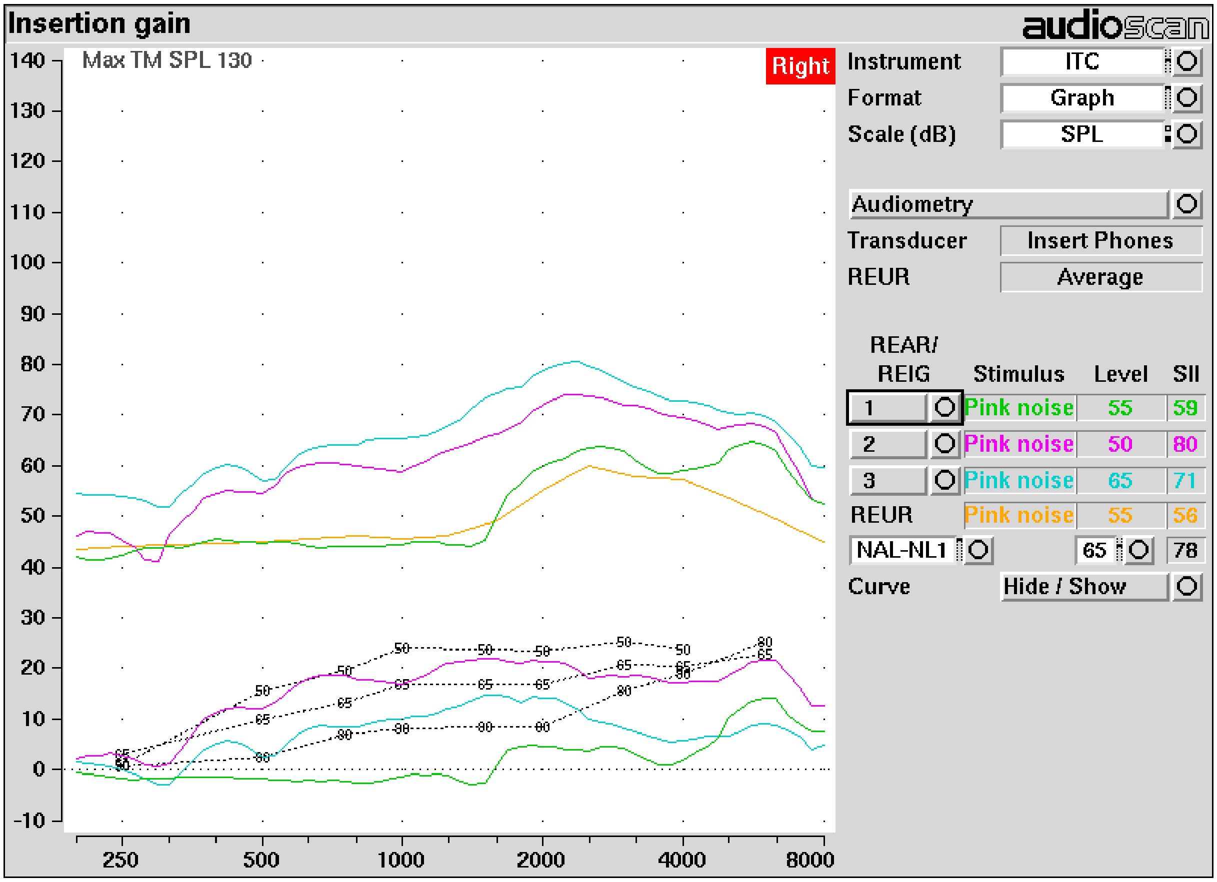
Subject 4 – Aided Original

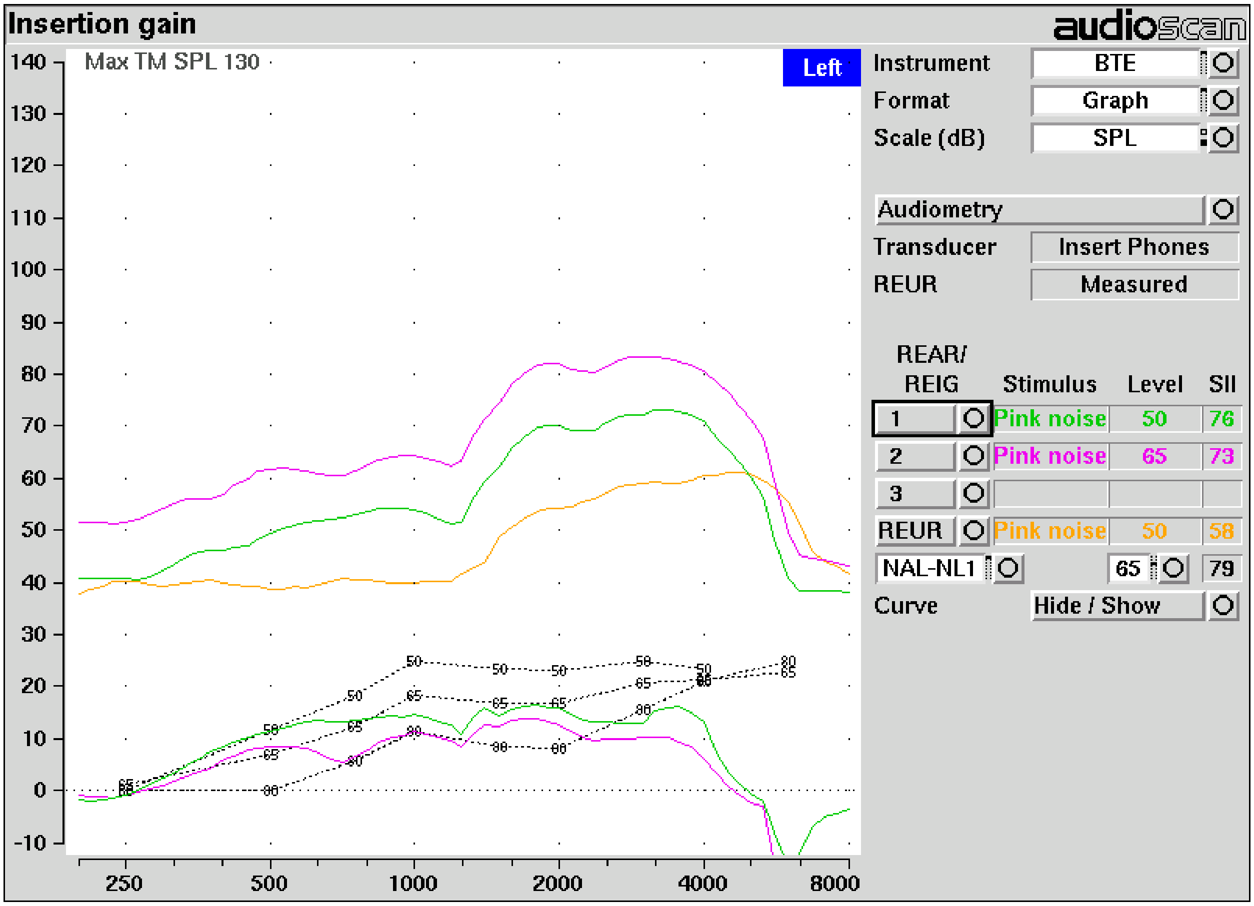




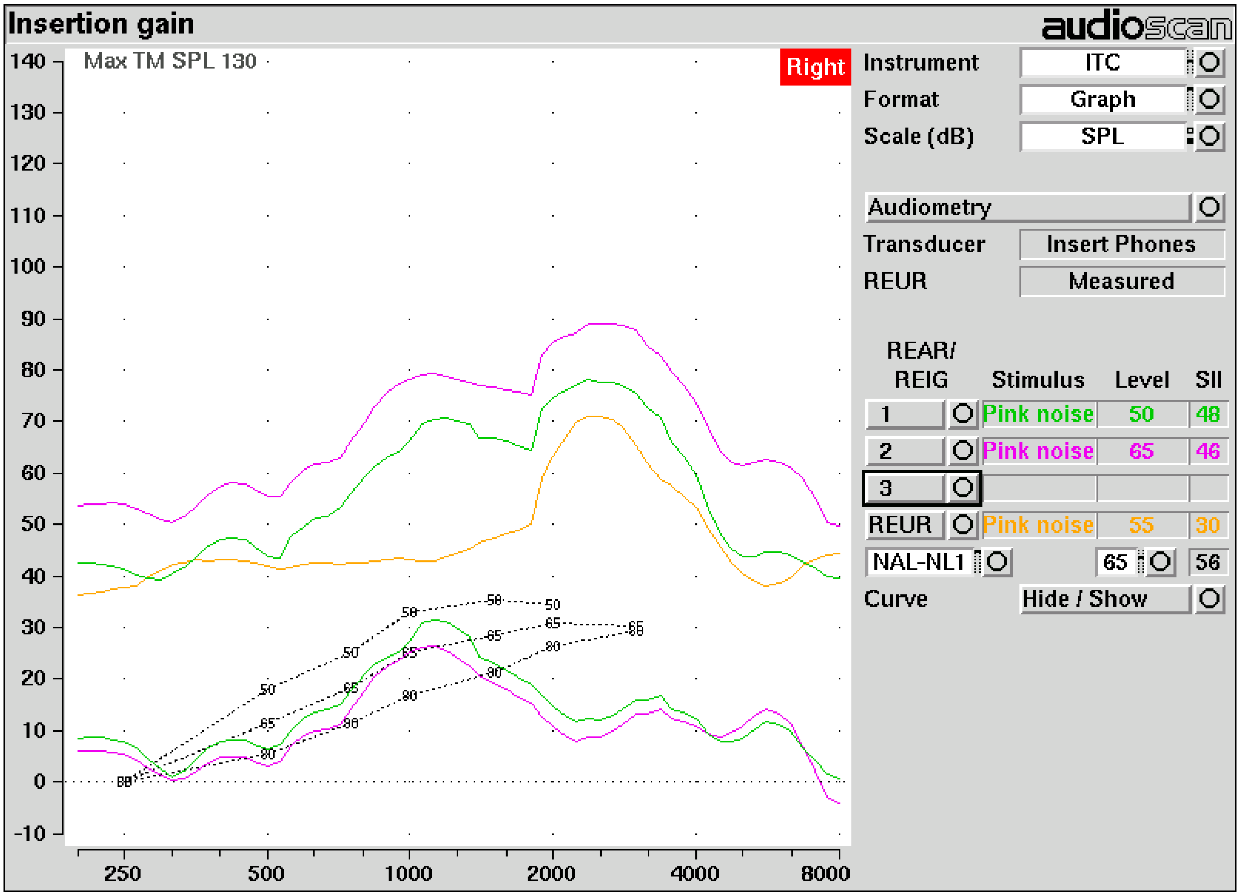
Insertion gain
audioscan
Max TM SPL 130
Left
Instrument ITE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 65
2 Pink noise 65 61
3
REUR Pink noise 55 29
NAL-NL1 65 68
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

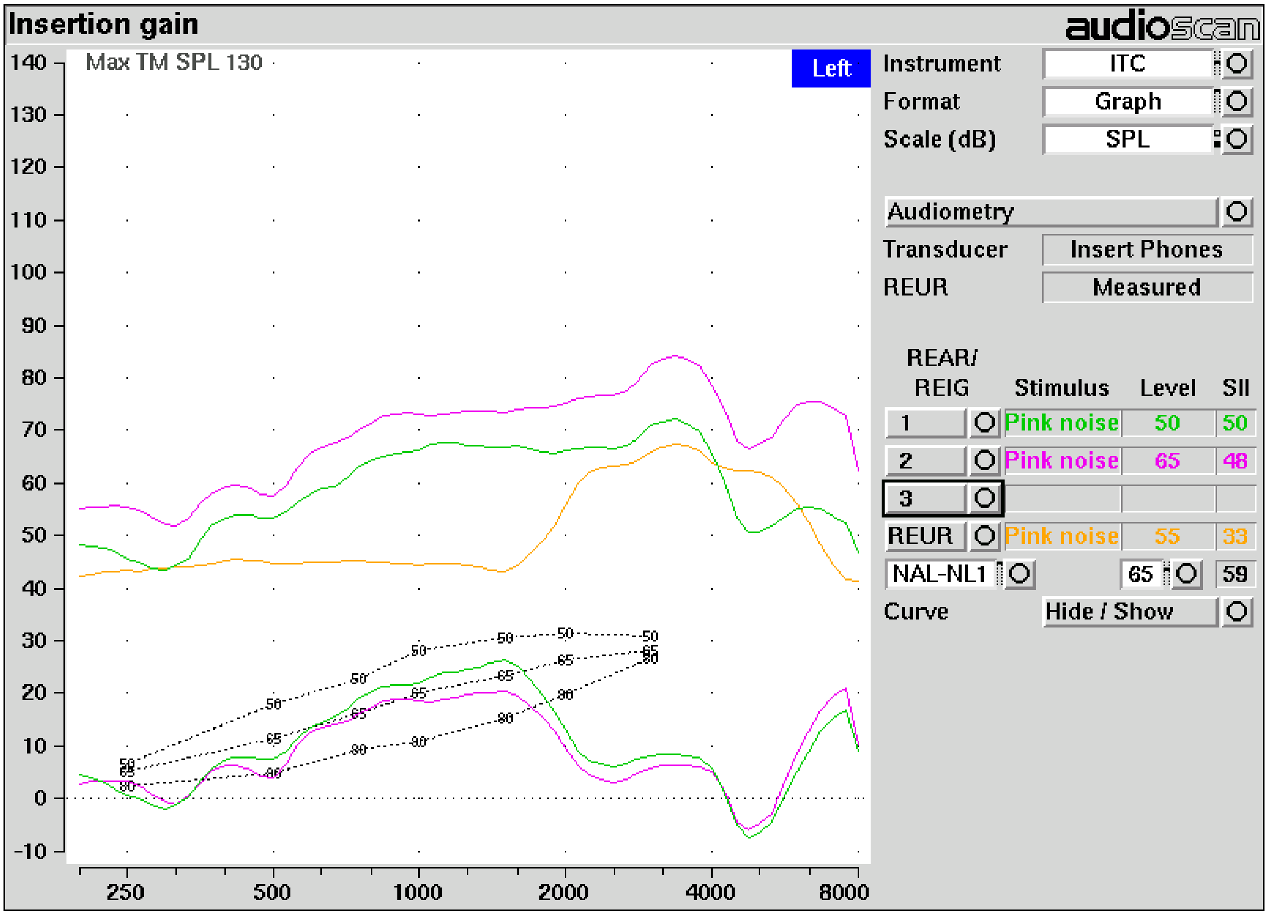
Subject 4 – Aided with Real-Ear




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument BTE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 76
2 Pink noise 65 73
3
REUR Pink noise 50 58
NAL-NL1 65 79
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

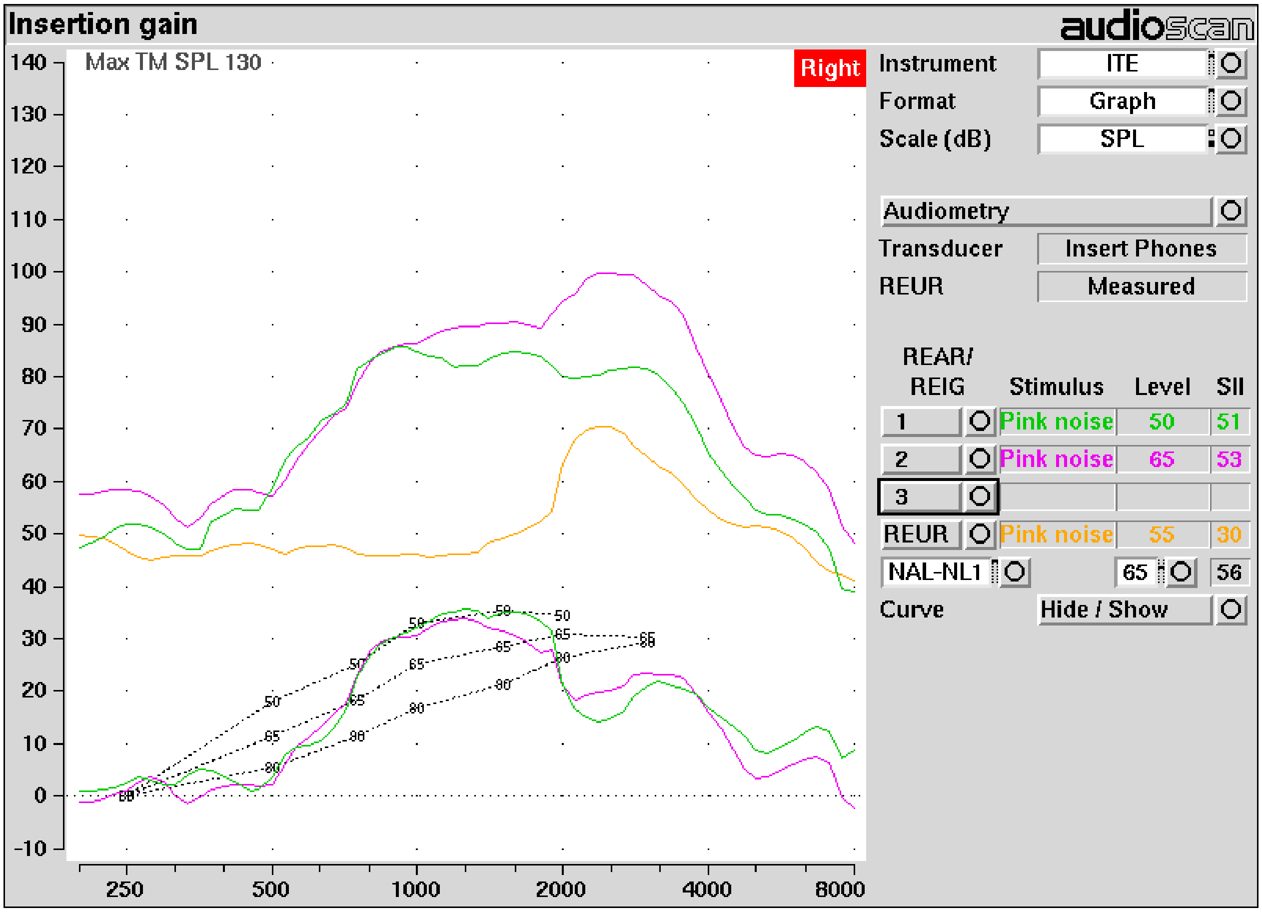
Subject 5 – Aided Original

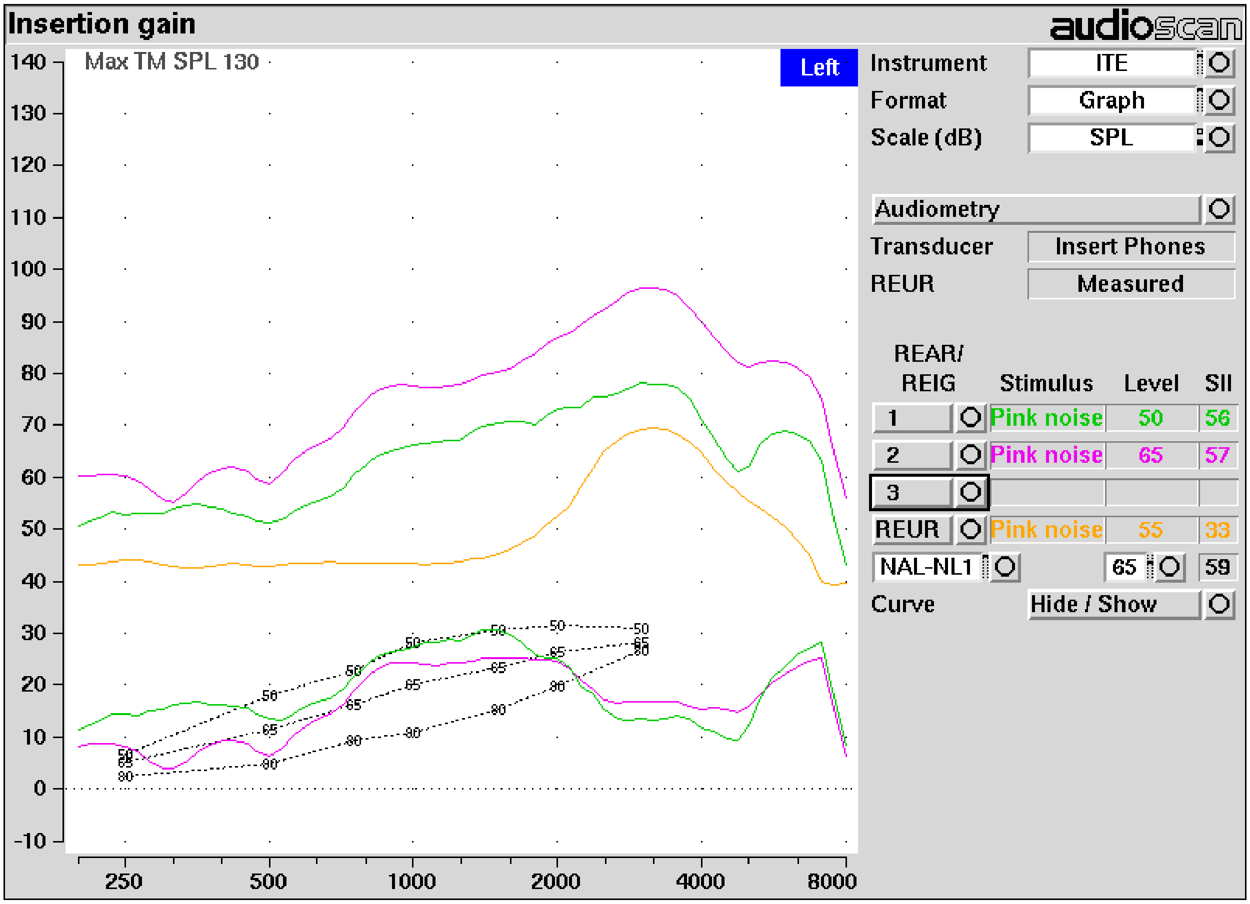




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument ITC
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 50
2 Pink noise 65 48
3
REUR Pink noise 55 33
NAL-NL1 65 59
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

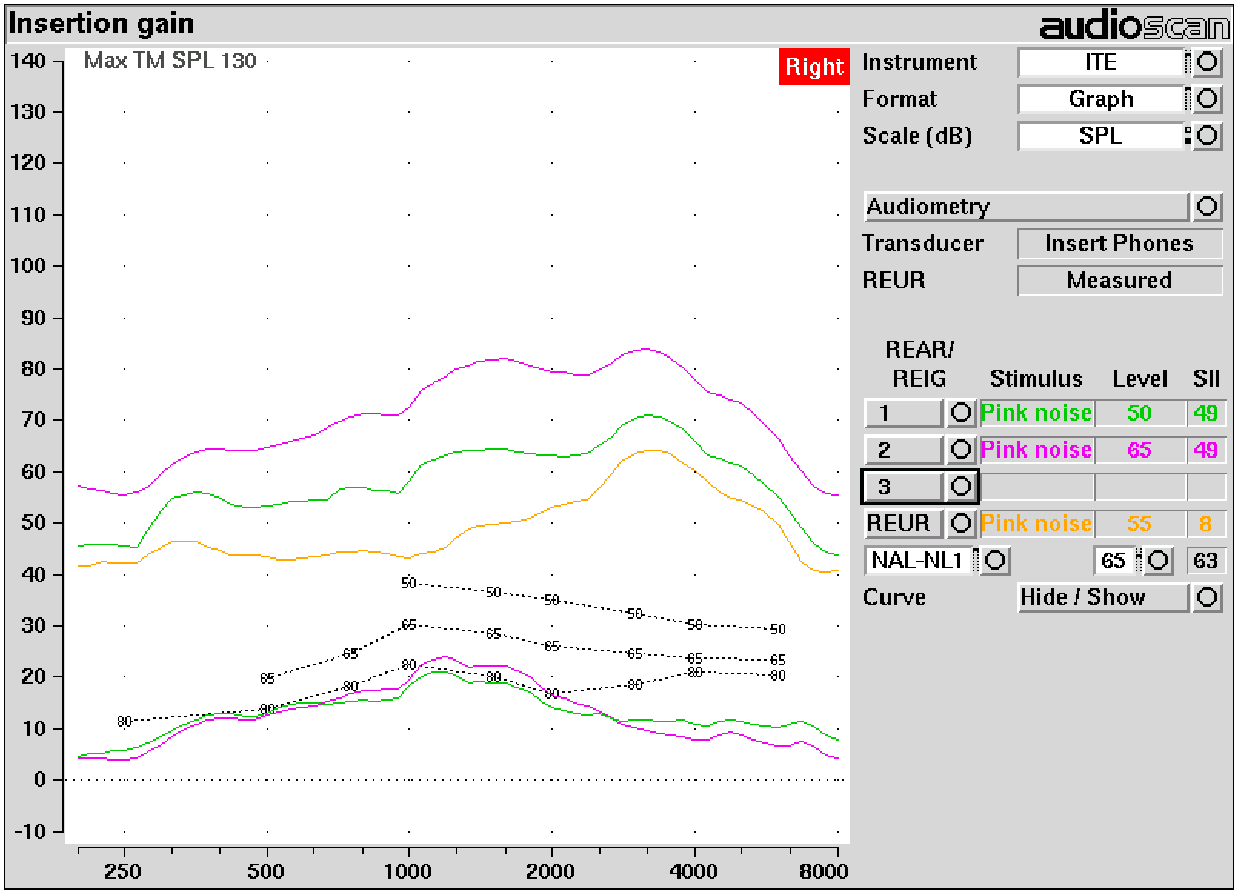
Subject 5 – Aided with Real-Ear

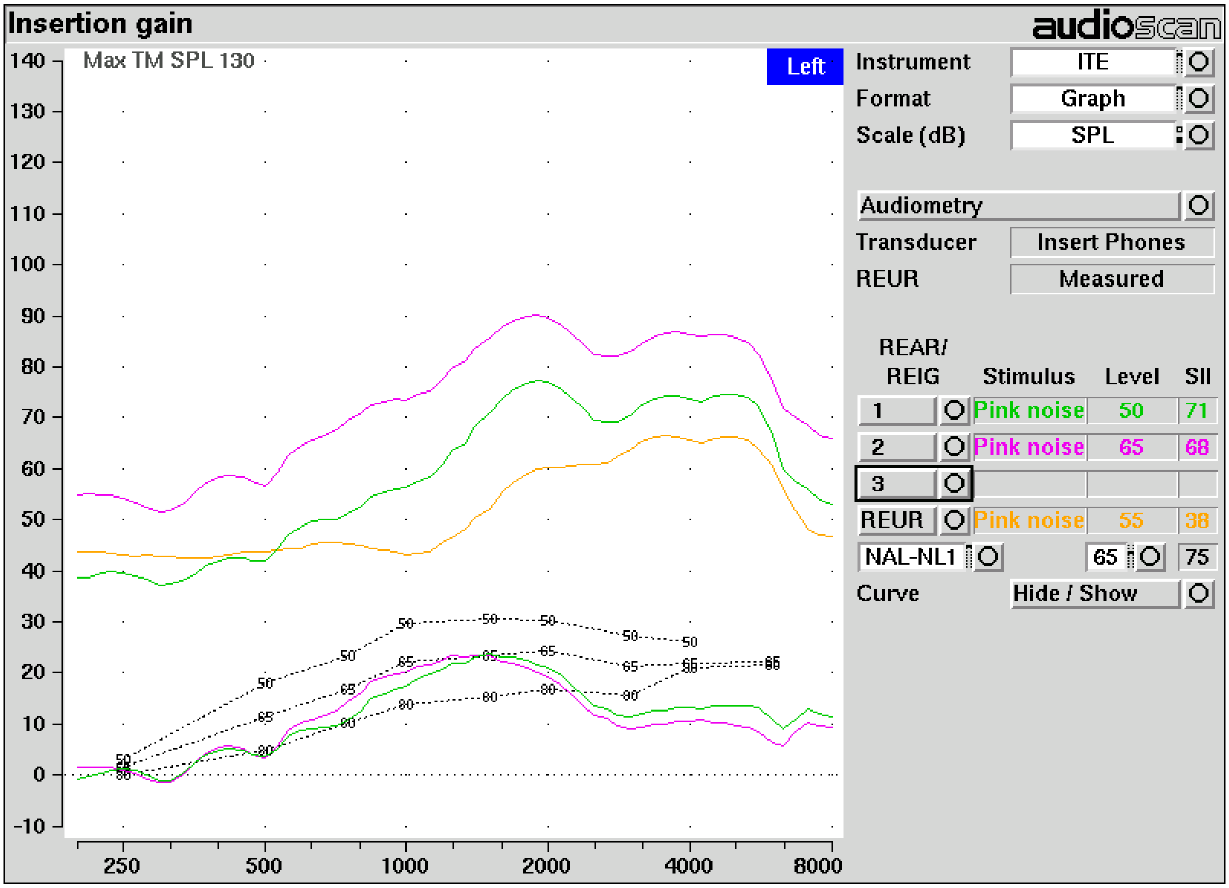




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument ITE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 56
2 Pink noise 65 57
3
REUR Pink noise 55 33
NAL-NL1 65 59
Curve Hide / Show
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000

Subject 6 – Aided Original




Insertion gain
audioscan
Max TM SPL 130
Left
Instrument ITE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Insert Phones
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 71
2 Pink noise 65 68
3
REUR Pink noise 55 38
NAL-NL1 65 75
Curve Hide / Show
140
130
120
110
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70
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40
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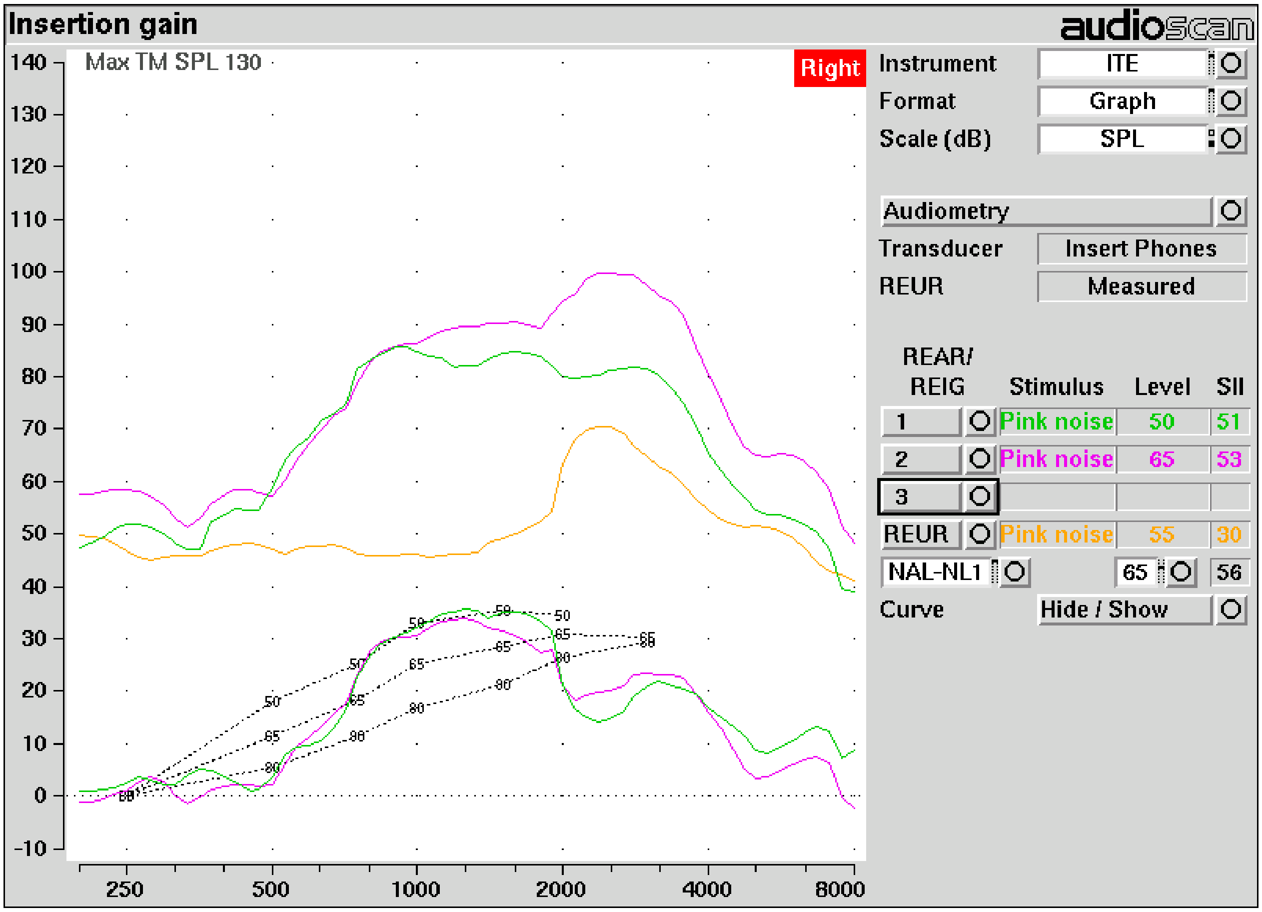
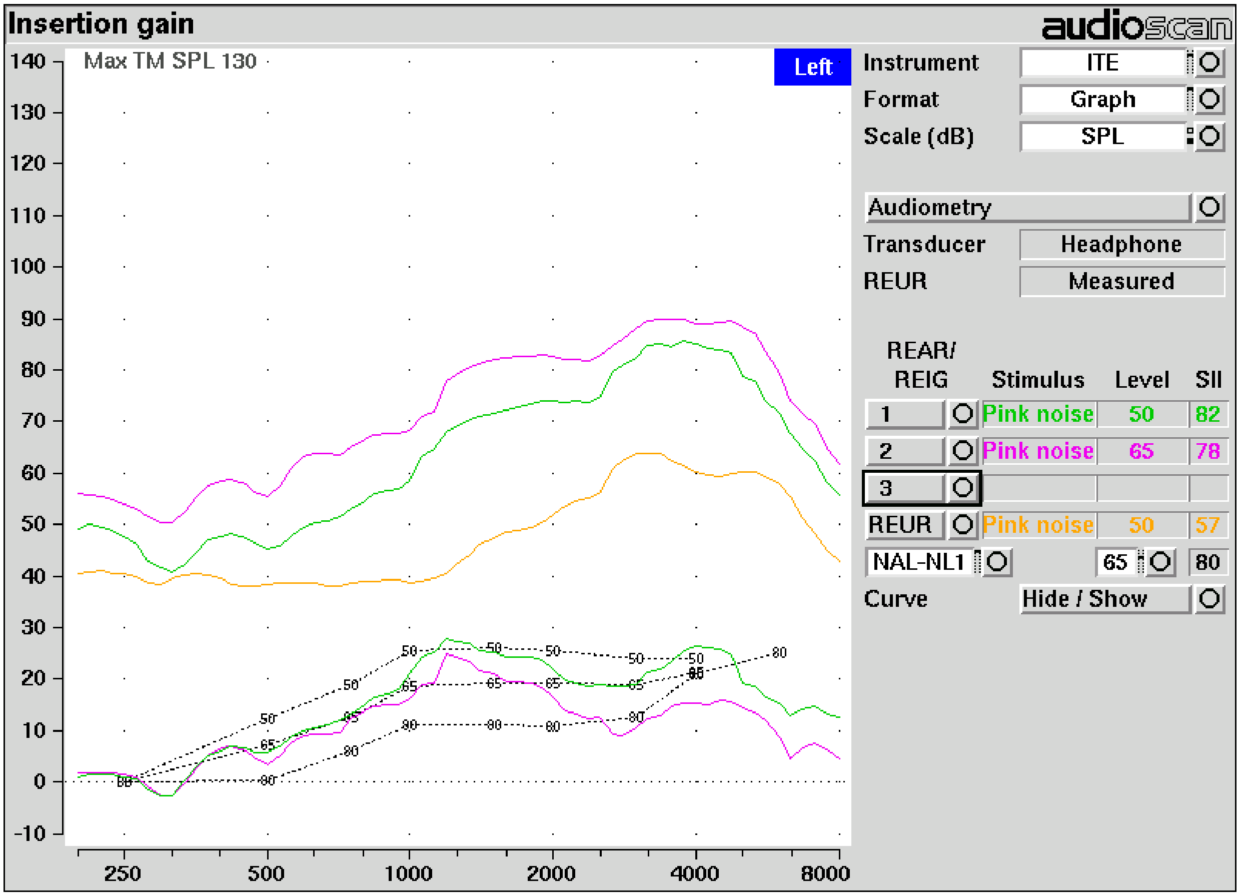
20
10
0
-10
250
500
1000
2000
4000
8000

Subject 6 – Aided with Real-Ear

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audioscan
Max TM SPL 130
Left
Instrument ITE
Format Graph
Scale (dB) SPL
Audiometry
Transducer Headphone
REUR Measured
REAR/ REIG
Stimulus
Level
SII
1 Pink noise 50 82
2 Pink noise 65 78
3
REUR Pink noise 50 57
NAL-NL1 65 80
Curve Hide / Show
140
130
120
110
100
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80
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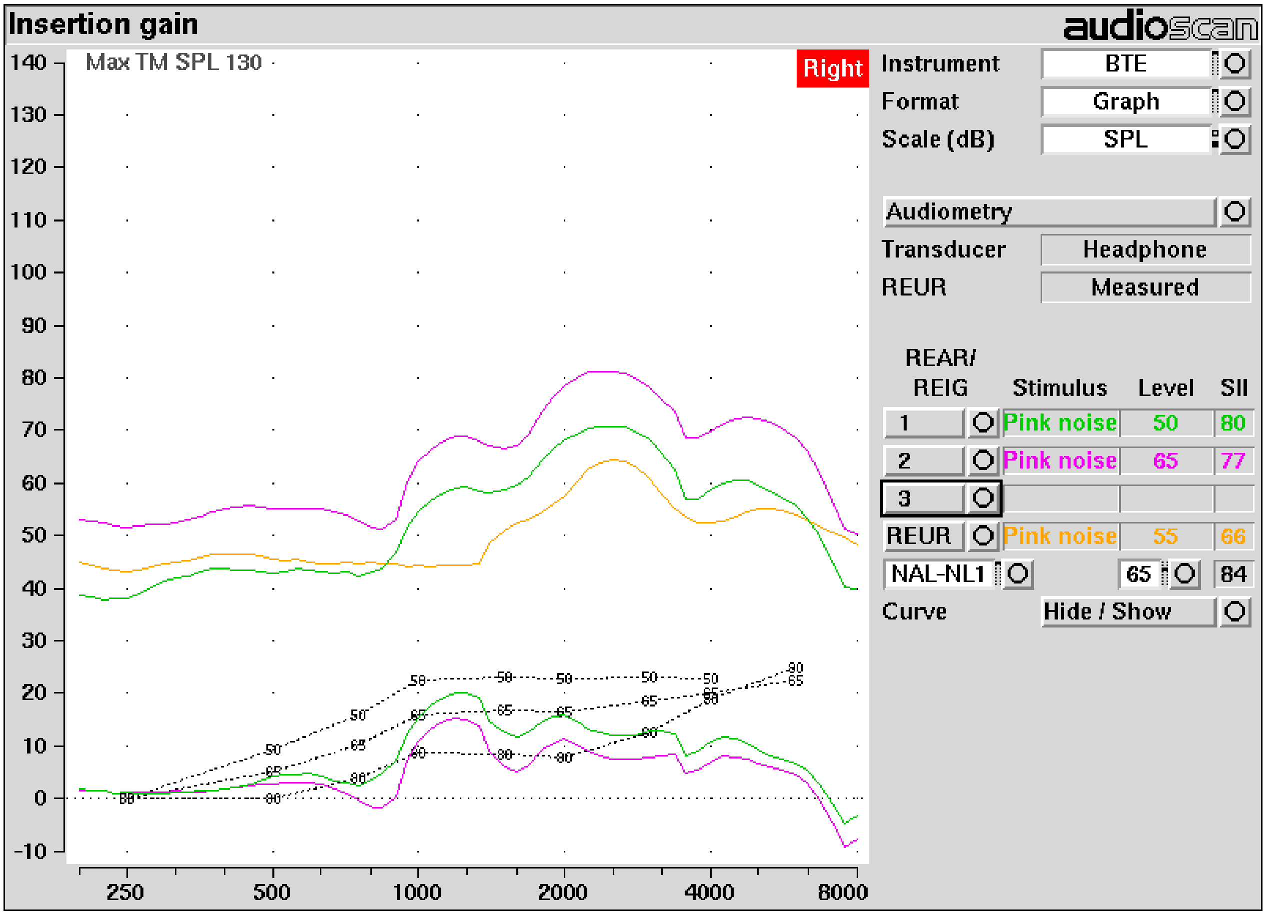
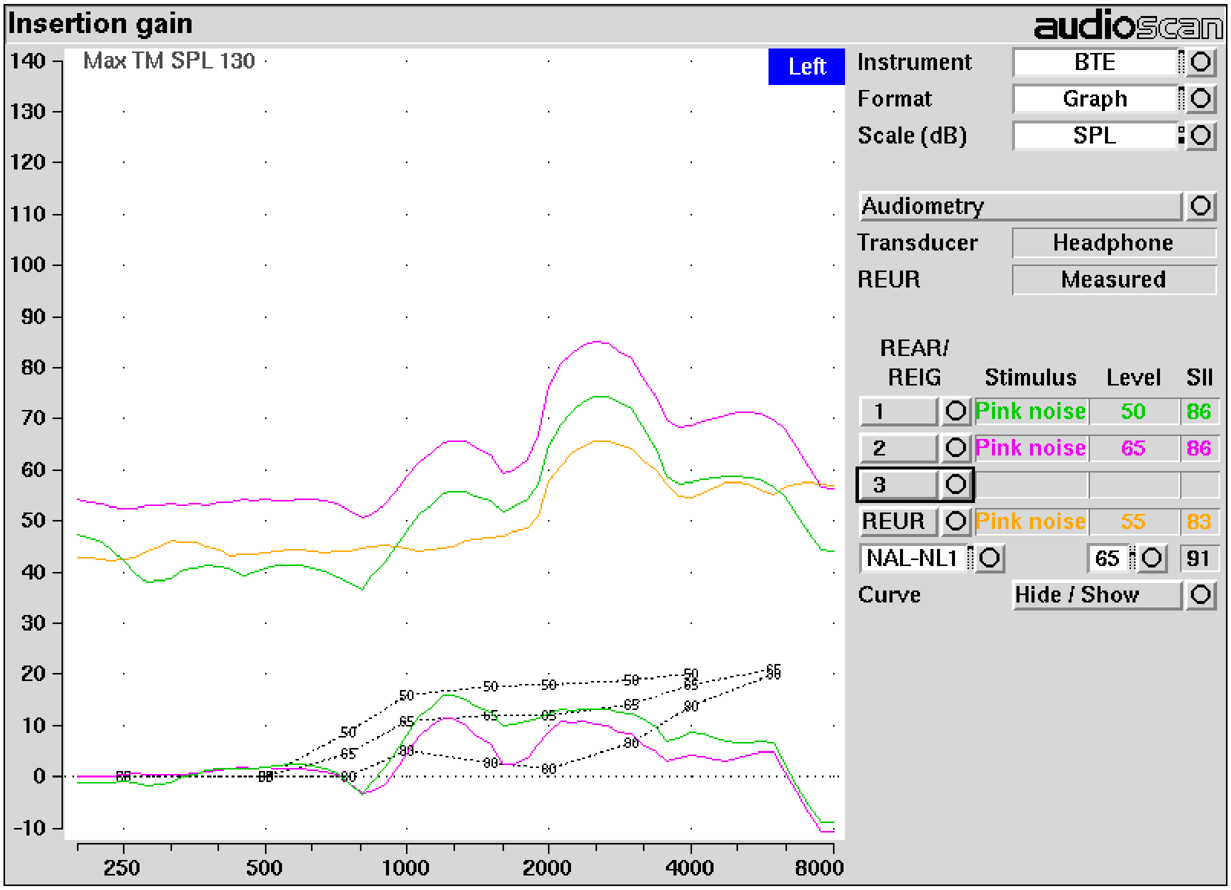
Subject 7 – Aided Original





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audioscan
Max TM SPL 130
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-10
250
500
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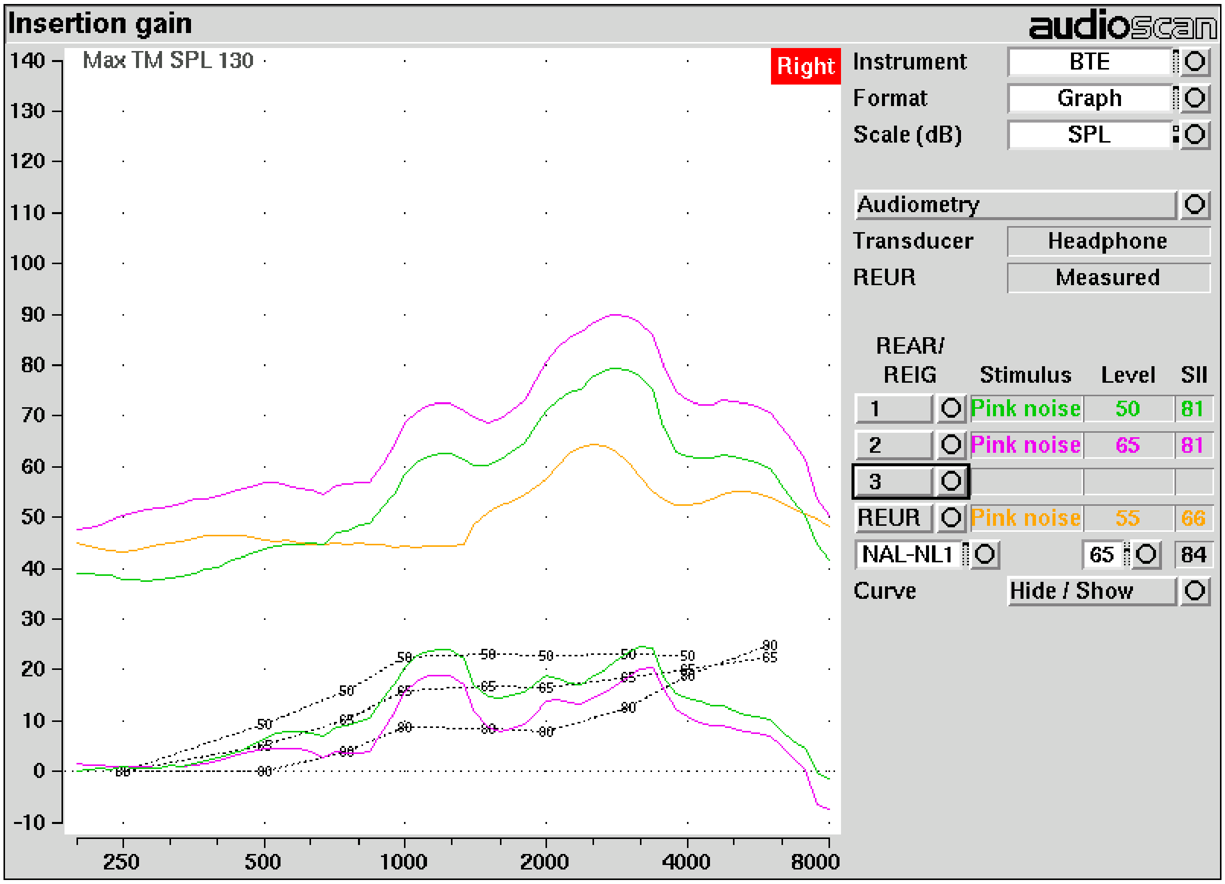
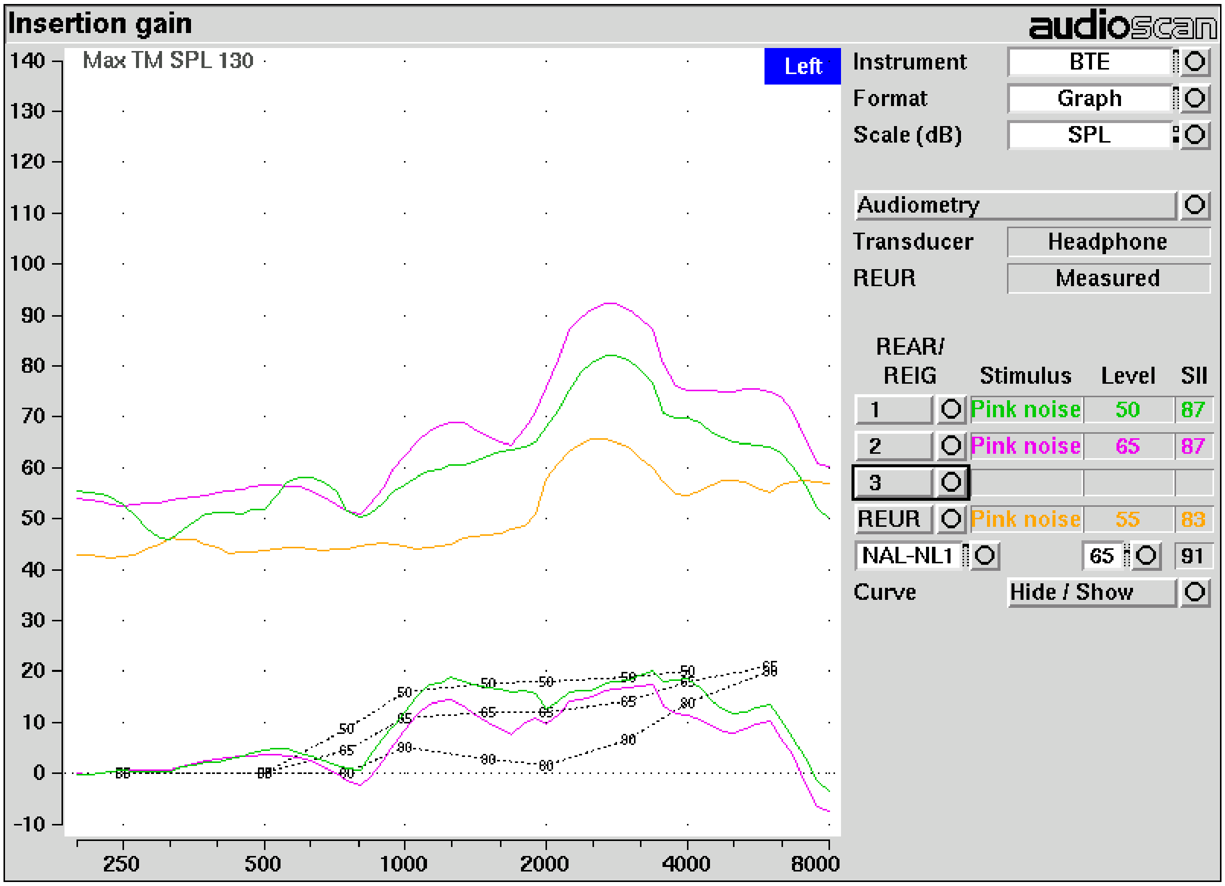
2000
4000
8000
Instrument
BTE
Format
Graph
Scale (dB)
SPL
Audiometry
Transducer
Headphone
REUR
Measured
REAR/
REIG
Stimulus
Level
SII
1
Pink noise
50
86
2
Pink noise
65
86
3
REUR
Pink noise
55
83
NAL-NL1
65
91
Curve
Hide / Show

Subject 7 – Aided with Real-Ear

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Instrument
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Format
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Scale (dB)
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Audiometry
Transducer
Headphone
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Measured
REAR/ REIG
Stimulus
Level
SII
1
Pink noise
50
87
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Pink noise
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87
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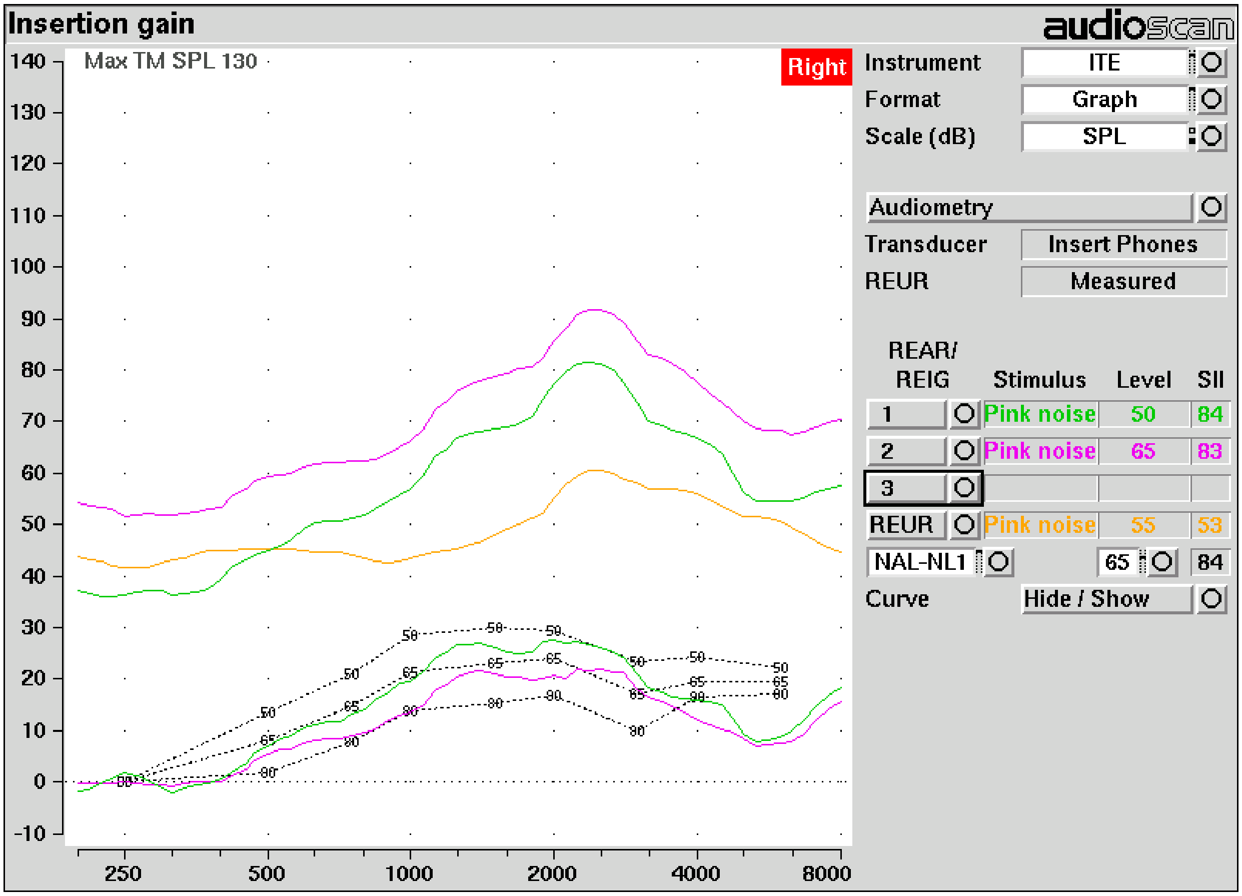
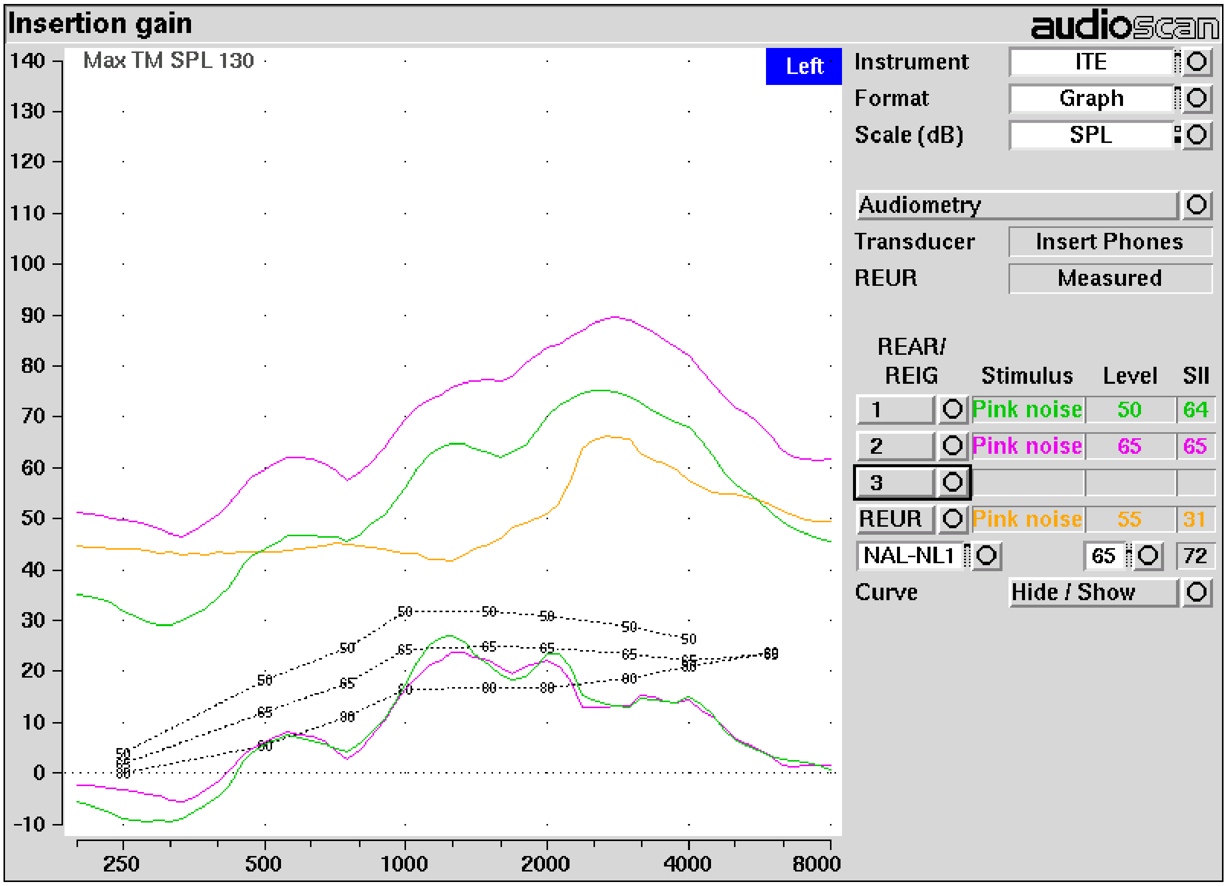
REUR
Pink noise
55
83
NAL-NL1
65
91
Curve
Hide / Show

Subject 8 – Aided Original

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audioscan
Max TM SPL 130
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500
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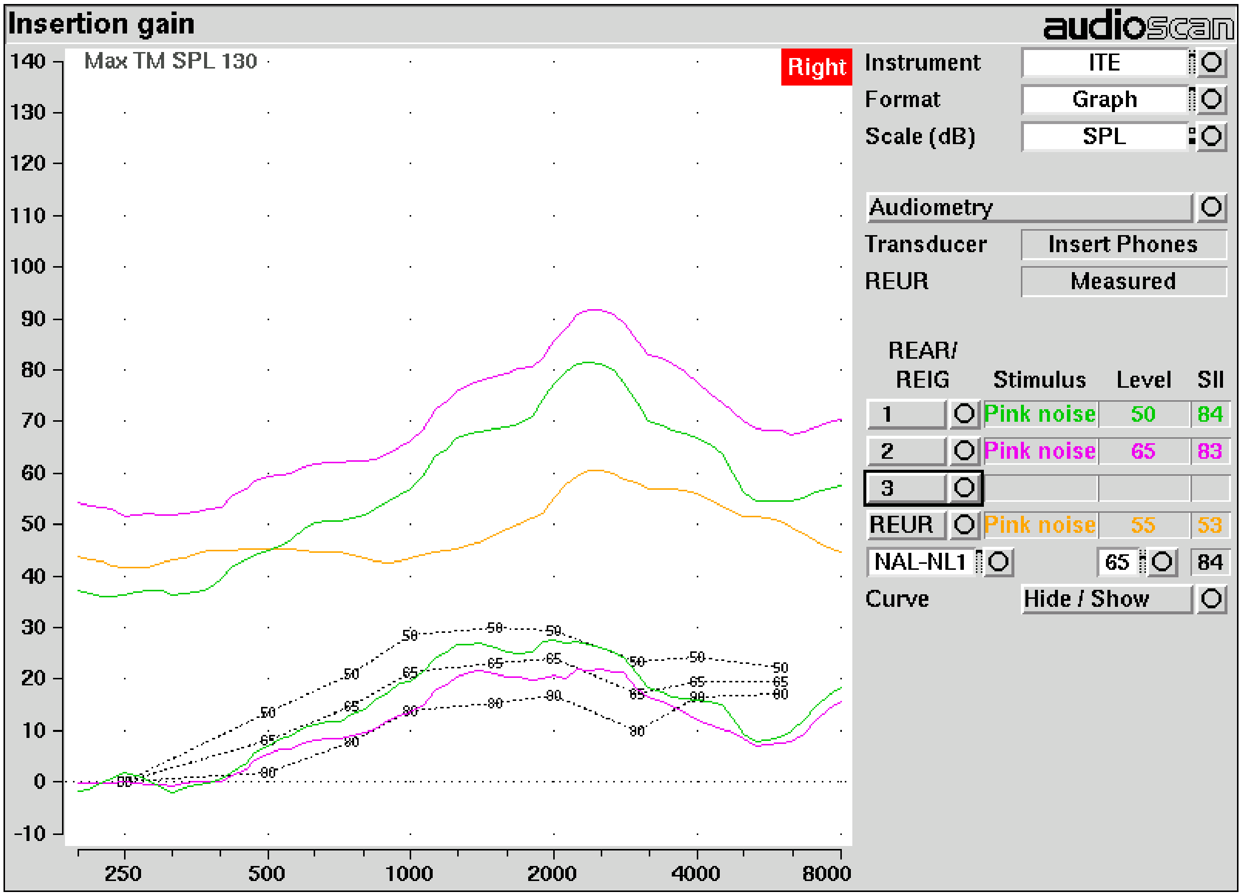
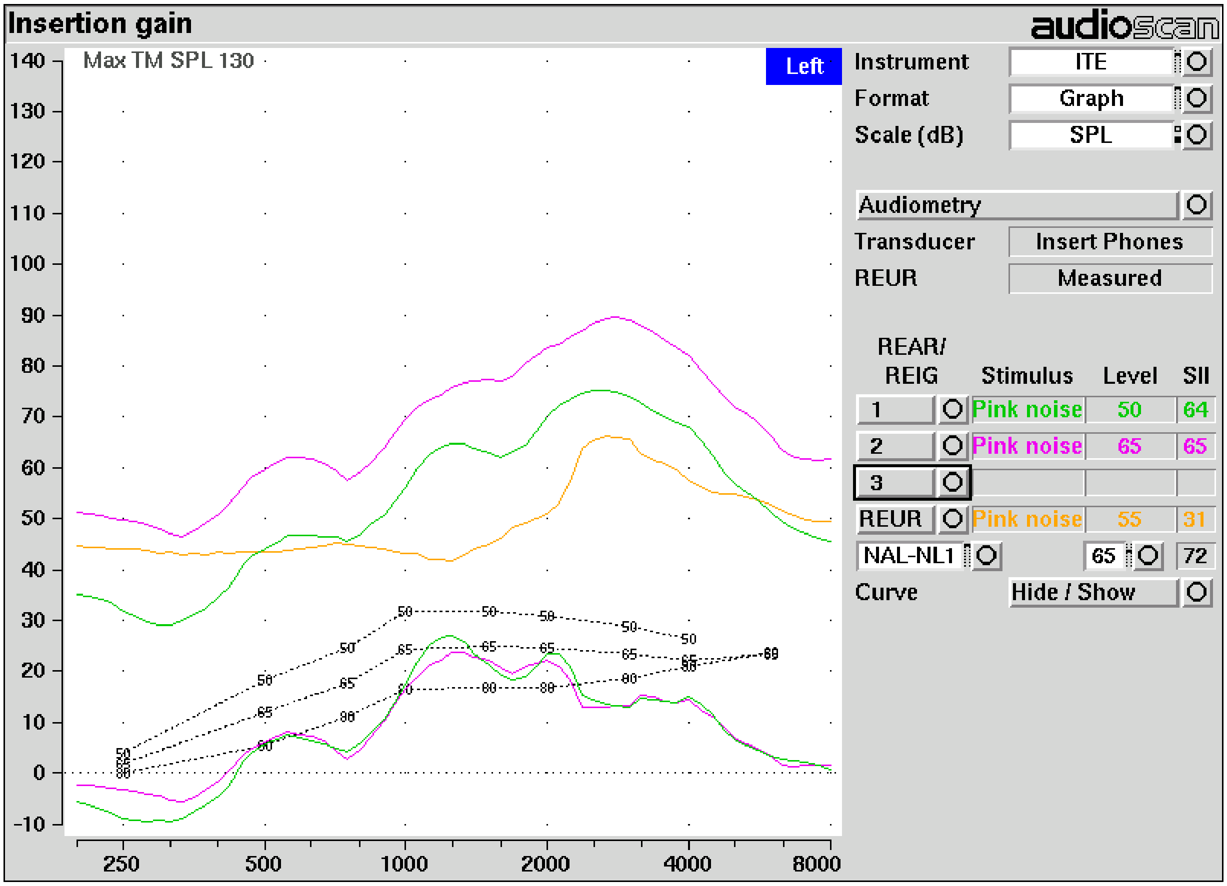
4000
8000
Instrument
ITE
Format
Graph
Scale (dB)
SPL
Audiometry
Transducer
Insert Phones
REUR
Measured
REAR/
REIG
Stimulus
Level
SII
1
Pink noise
50
64
2
Pink noise
65
65
3
REUR
Pink noise
55
31
NAL-NL1
65
72
Curve
Hide / Show

Subject 8 – Aided with Real-Ear

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Instrument
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Format
Graph
Scale (dB)
SPL
Audiometry
Transducer
Insert Phones
REUR
Measured
REAR/
REIG
Stimulus
Level
SII
1
Pink noise
50
64
2
Pink noise
65
65
3
REUR
Pink noise
55
31
NAL-NL1
65
72
Curve
Hide / Show

Appendix D

HINT Materials

APPENDIX B

HINT Sentence Lists

Note: Acceptable variations in responses are in parentheses.

List 1

1. (A/the) boy fell from (a/the) window.
2. (A/the) wife helped her husband.
3. Big dogs can be dangerous.
4. Her shoes (are/were) very dirty.
5. (A/the) player lost (a/the) shoe.
6. Somebody stole the money.
7. (A/the) fire (is/was) very hot. (5)
8. She's drinking from her own cup.
9. (A/the) picture came from (a/the) book.
10. (A/the) car (is/was) going too fast.

List 2

1. (A/the) boy ran down (a/the) path.
2. Flowers grow in (a/the) garden.
3. Strawberry jam (is/was) sweet.
4. (A/the) shop closes for lunch.
5. The police helped (a/the) driver.
6. She looked in her mirror.
7. (A/the) match fell on (a/the) floor.
8. (A/the) fruit came in (a/the) box.
9. He really scared his sister.
10. (A/the) tub faucet (is/was) leaking.

List 3

1. They heard (a/the) funny noise.
2. He found his brother hiding.
3. (A/the) dog played with (a/the) stick.
4. (A/the) book tells (a/the) story.
5. The matches (are/were) on (a/the) shelf.
6. The milk (is/was) by (a/the) front door.
7. (A/the) broom (is/was) in (a/the) corner.
8. (A/the) new road (is/was) on (a/the) map.
9. She lost her credit card.
10. (A/the) team (is/was) playing well.

List 4

1. (A/the) little boy left home.
2. They're going out tonight.
3. (A/the) cat jumped over (a/the) fence.
4. He wore his yellow shirt.
5. (A/the) lady sits in her chair.
6. He needs his vacation.
7. She's washing her new silk dress.
8. (A/the) cat drank from (a/the) saucer.
9. Mother opened (a/the) drawer.
10. (A/the) lady packed her bag.

List 5

1. (A/the) boy did (a/the) handstand.
2. They took some food outside.
3. The young people (are/were) dancing.
4. They waited for an hour.
5. The shirts (are/were) in (a/the) closet.
6. They watched (a/the) scary movie.
7. The milk (is/was) in (a/the) pitcher.
8. (A/the) truck drove up (a/the) road.
9. (A/the) tall man tied his shoes.
10. (A/the) letter fell on (a/the) floor.

List 6

1. (A/the) silly boy (is/was) hiding.
2. (A/the) dog growled at the neighbors.
3. (A/the) tree fell on (a/the) house.
4. Her husband brought some flowers.
5. The children washed the plates.
6. They went on vacation.
7. Mother tied (a/the) string too tight.
8. (A/the) mailman shut (a/the) gate.
9. (A/the) grocer sells butter.
10. (A/the) baby broke his cup.

List 7

1. The cows (are/were) in (a/the) pasture.
2. (A/the) dishcloth (is/was) soaking wet.
3. They (have/had) some chocolate pudding.
4. She spoke to her eldest son.
5. (An/the) oven door (is/was) open.
6. She's paying for her bread.
7. My mother stirred her tea.
8. He broke his leg again.
9. (A/the) lady wore (a/the) coat.
10. The cups (are/were) on (a/the) table.

List 8

1. (A/the) ball bounced very high.
2. Mother cut (a/the) birthday cake.
3. (A/the) football game (is/was) over.
4. She stood near (a/the) window.
5. (A/the) kitchen clock (is/was) wrong.
6. The children helped their teacher.
7. They carried some shopping bags.
8. Someone (is/was) crossing (a/the) road.
9. She uses her spoon to eat.
10. (A/the) cat lay on (a/the) bed.

List 9

1. School got out early today.
2. (A/the) football hit (a/the) goalpost.
3. (A/the) boy ran away from school.
4. Sugar (is/was) very sweet.
5. The two children (are/were) laughing.
6. (A/the) fire truck (is/was) coming.
7. Mother got (a/the) sauce pan.
8. (A/the) baby wants his bottle.
9. (A/the) ball broke (a/the) window.
10. There (is/was) a bad train wreck.

List 10

1. (A/the) boy broke (a/the) wooden fence.
2. (An/the) angry man shouted.
3. Yesterday he lost his hat.
4. (A/the) nervous driver got lost.
5. (A/the) cook (is/was) baking (a/the) cake.
6. (A/the) chicken laid some eggs.
7. (A/the) fish swam in (a/the) pond.
8. They met some friends at dinner.
9. (A/the) man called the police.
10. (A/the) truck made it up (a/the) hill.

List 11

1. (A/the) neighbor's boy (has/had) black hair.
2. The rain came pouring down.
3. (An/the) orange (is/was) very sweet.

Name/ID:

Date:

List #:

Noise Level:

Condition:

(1)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

SIGNAL

LEVEL

Comments:

5	
6	
7	
8	
9	
10	
11	

total / 7 =

5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	

total / 17 =

Appendix E

APHAB Materials

ABBREVIATED PROFILE OF HEARING AID BENEFIT

NAME: ______________________ ☐ Male ☐ Female TODAY'S DATE: ___/___/___
Last First

INSTRUCTIONS: Please circle the answers that come closest to your everyday experience. Notice that each choice includes a percentage. You can use this to help you decide on your answer. For example, if a statement is true about 75% of the time, circle "C" for that item. If you have not experienced the situation we describe, try to think of a similar situation that you have been in and respond for that situation. If you have no idea, leave that item blank.

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

	Without Hearing Aid	With Hearing Aid
1. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.	A B C D E F G	A B C D E F G
2. I miss a lot of information when I'm listening to a lecture.	A B C D E F G	A B C D E F G
3. Unexpected sounds, like a smoke detector or alarm bell are uncomfortable.	A B C D E F G	A B C D E F G
4. I have difficulty hearing a conversation when I'm with one of my family at home.	A B C D E F G	A B C D E F G
5. I have trouble understanding the dialogue in a movie or at the theater.	A B C D E F G	A B C D E F G
6. When I am listening to the news on the car radio, and family members are talking, I have trouble hearing the news.	A B C D E F G	A B C D E F G
7. When I'm at the dinner table with several people, and am trying to have a conversation with one person, understanding speech is difficult.	A B C D E F G	A B C D E F G
8. Traffic noises are too loud.	A B C D E F G	A B C D E F G
9. When I am talking with someone across a large empty room, I understand the words.	A B C D E F G	A B C D E F G
10. When I am in a small office, interviewing or answering questions, I have difficulty following the conversation.	A B C D E F G	A B C D E F G
11. When I am in a theater watching a movie or play, and the people around me are whispering and rustling paper wrappers, I can still make out the dialogue.	A B C D E F G	A B C D E F G
12. When I am having a quiet conversation with a friend, I have difficulty understanding.	A B C D E F G	A B C D E F G

(Continued on back)

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

	Without Hearing Aids	With Hearing Aids
13. The sounds of running water, such as a toilet or shower, are uncomfortably loud.	A B C D E F G	A B C D E F G
14. When a speaker is addressing a small group, and everyone is listening quietly, I have to strain to understand.	A B C D E F G	A B C D E F G
15. When I'm in a quiet conversation with my doctor in an examination room, it is hard to follow the conversation.	A B C D E F G	A B C D E F G
16. I can understand conversations even when several people are talking.	A B C D E F G	A B C D E F G
17. The sounds of construction work are uncomfortably loud.	A B C D E F G	A B C D E F G
18. It's hard for me to understand what is being said at lectures or church services.	A B C D E F G	A B C D E F G
19. I can communicate with others when we are in a crowd.	A B C D E F G	A B C D E F G
20. The sound of a fire engine siren close by is so loud that I need to cover my ears.	A B C D E F G	A B C D E F G
21. I can follow the words of a sermon when listening to a religious service.	A B C D E F G	A B C D E F G
22. The sound of screeching tires is uncomfortably loud.	A B C D E F G	A B C D E F G
23. I have to ask people to repeat themselves in one-on-one conversation in a quiet room.	A B C D E F G	A B C D E F G
24. I have trouble understanding others when an air conditioner or fan is on.	A B C D E F G	A B C D E F G

Please fill out these additional items.

HEARING AID EXPERIENCE:	DAILY HEARING AID USE	DEGREE OF HEARING DIFFICULTY (without wearing a hearing aid):
☐ None	☐ None	☐ None
☐ Less than 6 weeks	☐ Less than 1 hour per day	☐ Mild
☐ 6 weeks to 11 months	☐ 1 to 4 hours per day	☐ Moderate
☐ 1 to 10 years	☐ 4 to 8 hours per day	☐ Moderately-Severe
☐ Over 10 years	☐ 8 to 16 hours per day	☐ Severe

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Hearing Aid Research Lab

Appendix F

SADL Materials

SATISFACTION WITH AMPLIFICATION IN DAILY LIFE

NAME ______________________________ DATE OF BIRTH ___/___/___ TODAY'S DATE ___/___/___

INSTRUCTIONS

Listed below are questions on your opinions about your hearing aid(s). For each question, please circle the letter that is the best answer for you. The list of words on the right gives the meaning for each letter.

Keep in mind that your answers should show your general opinions about the hearing aids that ***you are wearing now or have most recently worn.***

A Not At All
B A Little
C Somewhat
D Medium
E Considerably
F Greatly
G Tremendously

1.	Compared to using no hearing aid at all, do your hearing aids help you understand the people you speak with most frequently?	A B C D E F G
2.	Are you frustrated when your hearing aids pick up sounds that keep you from hearing what you want to hear?	A B C D E F G
3.	Are you convinced that obtaining your hearing aids was in your best interests?	A B C D E F G
4.	Do you think people notice your hearing loss more when you wear your hearing aids?	A B C D E F G
5.	Do your hearing aids reduce the number of times you have to ask people to repeat?	A B C D E F G
6.	Do you think your hearing aids are worth the trouble?	A B C D E F G
7.	Are you bothered by an inability to get enough loudness from your hearing aids without feedback (whistling)?	A B C D E F G
8.	How content are you with the appearance of your hearing aids?	A B C D E F G
9.	Does wearing your hearing aids improve your self-confidence?	A B C D E F G
10.	How natural is the sound from your hearing aids?	A B C D E F G
11.	How helpful are your hearing aids on MOST telephones with ***NO*** amplifier or loudspeaker? (If you hear well on the telephone *without* hearing aids, check here ☐)	A B C D E F G
12.	How competent was the person who provided you with your hearing aids?	A B C D E F G

(Continued)

SADL, Page 2

A **Not At All**
B **A Little**
C **Somewhat**
D **Medium**
E **Considerably**
F **Greatly**
G **Tremendously**

13. Do you think wearing your hearing aids makes you seem less capable?	A B C D E F G
14. Does the cost of your hearing aids seem reasonable to you?	A B C D E F G
15. How pleased are you with the dependability (how often they need repairs) of your hearing aids?	A B C D E F G

Please respond to these additional items.

EXPERIENCE WITH CURRENT HEARING AIDS	LIFETIME HEARING AID EXPERIENCE (includes all old and current hearing aids)	DAILY HEARING AID USE	DEGREE OF HEARING DIFFICULTY (without wearing a hearing aid)
☐ Less than 6 weeks ☐ 6 weeks to 11 months ☐ 1 to 10 years ☐ Over 10 years	☐ Less than 6 weeks ☐ 6 weeks to 11 months ☐ 1 to 10 years ☐ Over 10 years	☐ None ☐ Less than 1 hour per day ☐ 1 to 4 hours per day ☐ 4 to 8 hours per day ☐ 8 to 16 hours per day	☐ None ☐ Mild ☐ Moderate ☐ Severe

FOR AUDIOLOGISTS USE ONLY

HEARING AID FITTING:

Right Ear	**Left Ear**
Make ____________	Make ____________
Model ____________	Model ____________
Ser. No. ____________	Ser. No. ____________
Fitting Date ____________	Fitting Date ____________
Style CIC ITC ITE BTE	Style CIC ITC ITE BTE

HEARING AID FEATURES (check all that apply)

☐ Directional Microphone	☐ Peak Clipping	☐ Other ____________
☐ Multiple Microphones	☐ Compression Limiting	____________
☐ Multi-channel	☐ TILL	____________
☐ Remote Control	☐ WDRC	
☐ Multi-program	☐ BILL	
☐ No Volume Control	☐ T-Coil	

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Appendix G

Final Questionnaire

1. Which hearing aid program did you prefer, your original or the one that was created for this study?

2. Please list some reasons for your preference.

Appendix H

Raw Data

Subject Data

Patient Initials	Date	Audiogram Configuration	Hearing Aid
JB	7/18/2009	R: mild at 2kHz, sloping to severe in low and high frequencies L: mild sloping to severe	L: Widex VITA - CAM R: Widex Flash ITE
CL	7/18/2009	moderate rising to mild	Widex Aikia BTEs
SS	8/8/2009	mild gently sloping to moderate	Widex Bravissimo ITEs
JE	8/8/2009	R: mild sloping to profound L: moderate sloping to profound	Widex Aikia ITEs
BB	8/22/2009	mild sloping to severe	Widex Bravissimo ITCs
KM	8/26/2009	R: flat, moderate to severe L: flat, mild to moderate	Widex Flash ITE Full shells
NW	1/15/2010	mild sloping to moderately-severe	Widex B2 BTEs
CT	1/29/2010	mild sloping to severe	Widex Inteo CICs

Audiometric Data

Right Ear	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
JB	70	65	55	40	55	60	65	80
CL	55	60	60	55	60	40	30	45
SS	25	35	45	50	40	50	40	45
JE	30	40	50	65	75	100	100	95
BB	30	40	50	50	55	60	65	70
KM	65	65	60	50	55	60	50	75
NW	20	30	35	35	45	55	65	75
CT	35	45	55	75	70	75	75	70
Average	41.25	47.50	51.25	52.50	56.88	62.50	61.25	69.38
St. Dev.	19.226	13.887	8.3452	12.817	11.63	18.127	21.671	16.995

Left Ear	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
JB	40	50	50	45	60	65	65	70
CL	60	65	60	60	60	50	35	45
SS	35	45	50	50	55	60	60	50
JE	45	45	40	55	70	85	80	90
BB	25	35	45	45	50	60	60	70
KM	35	45	45	50	50	60	55	60
NW	25	30	35	40	50	55	65	70
CT	45	60	60	70	70	70	65	70
Average	38.75	46.88	48.13	51.88	58.13	63.13	60.63	65.63
St Dev.	11.573	11.63	8.8388	9.613	8.4251	10.67	12.66	13.999

REIG Data

AIDED ORIGINAL

Target = 50		**500 Hz**			**1000 Hz**			**2000 Hz**	
Patient Initials	Target	Actual	Difference	Target	Actual	Difference	Target	Actual	Difference
SS Left	18	9	9	32	15	17	31	21	10
SS Right	14	13	1	29	20	9	29	23	6
JE Left	13	-1	14	25	12	13	27	27	0
JE Right	18	8	10	28	21	7	31	13	18
CL Left	0	12	-12	40	18	22	39	17	22
CL Right	0	4	-4	38	17	21	36	20	16
BB Left	13	10	3	28	26	2	28	17	11
BB Right	16	7	9	31	27	4	30	16	14
NW Left	0	2	-2	15	9	6	19	11	8
NW Right	10	5	5	22	16	6	22	15	7
CT Left	29	10	19	40	19	21	40	19	21
CT Right	22	9	13	37	21	16	38	17	21
JB Left	11	12	-1	24	13	11	21	11	10
JB Right	15	10	5	22	21	1	22	17	5
KM Left	11	4	7	24	17	7	25	21	4
KM Right	12	13	-1	29	18	11	28	14	14
Average	12.625	7.9375	4.6875	29	18.125	10.875	29.125	17.438	11.6875
St. Dev.	8	4	8	7	5	7	7	4	7

Target = 65		**500 Hz**			**1000 Hz**			**2000 Hz**	
Patient Initials	Target	Actual	Difference	Target	Actual	Difference	Target	Actual	Difference
SS Left	12	7	5	24	10	14	24	17	7
SS Right	8	7	1	21	14	7	24	17	7
JE Left	11	-1	12	20	9	11	26	22	4
JE Right	11	5	6	25	19	6	31	9	22
CL Left	21	5	16	31	16	15	31	16	15
CL Right	19	3	16	30	11	19	28	16	12
BB Left	8	6	2	21	25	-4	22	21	1
BB Right	10	4	6	24	25	-1	24	10	14
NW Left	0	2	-2	10	5	5	12	8	4
NW Right	6	2	4	16	10	6	18	11	7
CT Left	20	10	10	32	19	13	35	19	16
CT Right	15	3	12	29	18	11	36	12	24
JB Left	8	9	-1	18	7	11	26	5	21
JB Right	10	3	7	18	17	1	17	19	-2
KM Left	17	3	14	18	20	2	20	19	1
KM Right	7	12	5	20	19	1	19	17	2
Average	11.438	5	7.0625	22.313	15.25	7.3125	24.563	14.875	9.6875
St. Dev.	6	3	6	6	6	6	7	5	8

AIDED WITH REAL-EAR

Target = 50		**500 Hz**			**1000 Hz**			**2000 Hz**	
Patient Initials	Target	Actual	Difference	Target	Actual	Difference	Target	Actual	Difference
SS Left	18	6	12	32	18	14	31	23	8
SS Right	14	7	7	29	19	10	29	28	1
JE Left	18	13	5	28	27	1	31	35	-4
JE Right	18	4	14	33	32	1	34	21	13
CL Left	0	16	-16	40	30	10	39	34	5
CL Right	0	8	-8	38	29	9	36	32	4
BB Left	13	4	9	28	18	10	28	29	-1
BB Right	16	11	5	31	22	9	30	27	3
NW Left	0	4	-4	15	11	4	19	12	7
NW Right	10	8	2	22	22	0	22	19	3
CT Left	29	6	23	40	21	19	40	18	22
CT Right	22	10	12	37	27	10	38	28	10
JB Left	11	11	0	24	15	9	21	16	5
JB Right	15	11	4	22	18	4	22	21	1
KM Left	11	16	-5	24	20	4	25	22	3
KM Right	12	9	3	29	25	4	28	24	4
Average	12.94	9.00	3.94	29.50	22.13	7.38	29.56	24.31	5.25
St. Dev.	8	4	9	7	6	5	7	7	6

Target = 65		**500 Hz**			**1000 Hz**			**2000 Hz**	
Patient Initials	Target	Actual	Difference	Target	Actual	Difference	Target	Actual	Difference
SS Left	12	6	6	24	16	8	24	22	2
SS Right	8	5	3	21	14	7	24	21	3
JE Left	11	6	5	20	24	-4	26	25	1
JE Right	11	2	9	25	30	-5	31	21	10
CL Left	21	9		31	25	6	31	32	-1
CL Right	19	2	16	30	20	10	28	26	2
BB Left	8	-4	12	21	14	7	22	24	-2
BB Right	10	3	7	24	19	5	24	21	3
NW Left	0	3	-3	10	9	1	12	10	2
NW Right	6	5	1	16	16	0	18	15	3
CT Left	20	8	12	32	25	7	35	22	13
CT Right	15	10	5	29	27	2	36	26	10
JB Left	8	9	-1	18	11	7	26	11	15
JB Right	10	2	8	18	10	8	17	14	3
KM Left	17	13	4	18	17	1	20	18	2
KM Right	7	6	1	20	20	0	19	19	0
Average	11.44	5.31	5.67	22.31	18.56	3.75	24.56	20.44	4.13
St. Dev.	6	4	5	6	6	5	7	6	5

HINT Data

AIDED ORIGINAL

		HINT Quiet		***HINT 0 Degrees***		***HINT 90 Degrees***	
Patient Initials	**Date**	Aided	Unaided	Aided	Unaided	Aided	Unaided
JB	7/18/2009	36.2	57.0	-1.3	0.3	-4.8	-2.0
CL	7/18/2009	47.5	53.7	-1.3	0.9	-7.5	-3.9
SS	8/8/2009	40.5	47.4	0.9	2.0	-4.4	-2.6
JE	8/8/2009	36.9	63.6	3.7	4.5	0.5	1.0
BB	8/22/2009	41.7	58.4	-1.2	2.0	-3.8	-1.2
KM	8/28/2009	40.5	54.9	-1.1	-1.5	-3.3	-3.3
NW	1/15/2010	37.3	41.8	0.1	0.3	-2.3	1.8
CT	1/29/2010	51.8	68.5	-2.7	3.5	-1.3	7.6
Average		41.6	55.7	-0.4	1.5	-3.4	-0.3
St. Dev.		5.4903	8.4658	1.9559	1.9176	2.413	3.7693

AIDED WITH REAL-EAR

		HINT Quiet	***HINT 0 Degrees***	***HINT 90 Degrees***
Patient Initials	**Date**	Aided	Aided	Aided
JB	2/5/2010	40.2	0.5	-2.5
CL	3/12/2010	42.3	-1.8	-4.4
SS	2/20/2010	29.3	-0.6	-4.5
JE	2/20/2010	26.3	3.4	-0.4
BB	2/5/2010	42.7	-0.3	-3.7
KM	2/5/2010	37.8	0.5	-4.5
NW	1/29/2010	31.7	-0.8	-5.5
CT	2/19/2010	37.8	1.5	-3.2
Average		36.0	0.3	-3.6
St. Dev.		6.16636904	1.6	1.580630525

APHAB Data

AIDED ORIGINAL

		Ease of Communication		Background Noise		Reverberation		Aversiveness to Sound	
Patient Initials	**Date**	With HA	Without HA	With HA	Without HA	With HA	Without HA	With HA	Without HA
JB	7/18/2009	29.00%	62%	49.70%	85%	28.80%	62.20%	51.80%	24.70%
CL	7/18/2009	18.50%	50%	39.50%	78.80%	37.50%	62.50%	45.80%	18.70%
SS	8/8/2009	24.80%	68.50%	27%	78.70%	50%	93%	70.50%	80.70%
JE	8/8/2009	26.80%	62.30%	33%	39.50%	24.80%	64.30%	47.50%	58.20%
BB	8/22/2009	18.30%	48%	45.70%	68.50%	33.20%	62.50%	53.80%	27%
KM	8/26/2009	26.70%	64.50%	31%	41.50%	45.70%	37.30%	35.30%	35.30%
NW	1/15/2010	17%	74.50%	33.30%	97%	31.30%	68.30%	76.70%	54%
CT	2/9/2010	2.80%	41.70%	14.20%	74.70%	10.50%	58%	45.70%	11%
Average		20.45%	58.93%	34.18%	70.46%	32.73%	63.51%	53.39%	38.70%
St. Dev.		0.084972	0.11274592	0.11116	0.20256423	0.12329	0.1518603	0.13719	0.23573835

AIDED WITH REAL-EAR

		Ease of Communication		Background Noise		Reverberation		Aversiveness to Sound	
Patient Initials	**Date**	With HA	Without HA	With HA	Without HA	With HA	Without HA	With HA	Without HA
JB	2/5/2010	37.30%		66.30%		33%		27.20%	
CL	3/12/2010	18.50%		51.80%		40%		29.30%	
SS	2/20/2010	14.20%		31.20%		24.70%		51.80%	
JE	2/20/2010	24.80%		35.30%		45.80%		82.80%	
BB	2/5/2010	47.80%		50%		52%		66.50%	
KM	2/5/2010	8.30%		14.20%		18.30%		12.30%	
NW	1/29/2010	27.20%		33.20%		29.20%		45.70%	
CT	2/19/2010	5%		19%		8.30%		99%	
Average		22.89%		37.63%		31.35%		51.83%	

SADL Data

AIDED ORIGINAL

Patient Initials	Date	Positive Effect	Service and Cost	Negative Features	Personal Image	Global
JB	7/18/2009	6.20	3.00	5.00	5.30	5.10
CL	7/18/2009	5.70	4.70	4.70	5.30	5.20
SS	8/8/2009	6.70	5.30	4.70	5.70	5.80
JE	8/8/2009	4.30	5.70	4.00	6.00	4.90
BB	8/22/2009	4.70	4.00	1.00	6.30	4.40
KM	8/26/2009	5.30	5.30	6.50	6.30	5.70
NW	1/15/2010	4.80	5.30	4.00	7.00	5.27
CT		6.7	6	5.7	5.7	6.1
Average		5.55	4.91	4.45	5.95	5.31
St. Dev.		0.93	0.98	1.63	0.58	0.54

AIDED WITH REAL-EAR

Patient Initials	Date	Positive Effect	Service and Cost	Negative Features	Personal Image	Global
JB	2/5/2010	6.50	5.00	3.50	6.00	~~5.60~~
CL	3/12/2010	6.20	5.30	5.70	6.30	5.90
SS	2/20/2010	6.80	6.00	3.70	3.30	5.30
JE	2/20/2010	6.20	6.70	2.70	6.30	5.60
BB	2/5/2010	4.00	2.30	2.00	5.00	3.60
KM	2/5/2010	5.50	5.30	5.00	7.00	5.70
NW	1/29/2010	6.30	5.70	4.70	6.70	5.90
CT	2/19/2010	6.30	6.00	3.70	5.00	5.50
Average		5.98	5.29	3.88	5.70	5.39
St. Dev.		0.88	1.32	1.22	1.21	0.75

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