5-1994

A Comparison of Amplification Efficacy and Toleration of Background Noise in Hearing Impaired Elderly Persons

Susan Ruth Lytle
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Susan Ruth Lytle entitled "A Comparison of Amplification Efficacy and Toleration of Background Noise in Hearing Impaired Elderly Persons." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech and Hearing Science.

Samuel B. Burchfield, Major Professor

We have read this thesis and recommend its acceptance:

Jim Thelin, Anna Nabelek

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Susan Ruth Lytle entitled "A Comparison of Amplification Efficacy and Toleration of Background Noise in Hearing Impaired Elderly Persons." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Audiology.

Samuel B. Burchfield, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master of Arts degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of the source is made.

Requests for permission for extensive quotation from or reproduction of this thesis in whole or in part may be granted by the copyright holder.

Signature ______________________

Date ______________________

A COMPARISON OF AMPLIFICATION EFFICACY AND TOLERATION OF BACKGROUND NOISE IN HEARING IMPAIRED ELDERLY PERSONS

A Thesis Presented for the Master of Arts Degree
The University of Tennessee, Knoxville

Susan Ruth Lytle
May, 1994

DEDICATION

This thesis is dedicated to my parents, Charles and Carol Lytle, and to the Audiology Graduate Class of 1993.

ACKNOWLEDGMENTS

The author would like to take this opportunity to express appreciation to the many people who have aided in the completion of this project. I am extremely thankful to Dr. Samuel Burchfield who continually offered his guidance and support as well as his friendship. Special thanks is extended to Dr. Anna Nabelek who can be given credit for providing the structure from which this thesis was built, to Dr. Jim Thelin whose input was always insightful, and to Dr. Patrick Carney for stepping in when needed.

I would also like to express appreciation to Bob Muenchen for his statistical assistance and to Max Dawson for his mechanical expertise. Special thanks are extended to Sasha Ochinnikov for her assistance with spectral analysis. I would also like to thank Lisa Wyrick and Linda Reed for their assistance.

I personally want to thank my classmates for their support and friendship. My deepest gratitude is extended to my parents for their unconditional love and unending devotion. And to my heavenly Father through whom all things are possible.

ABSTRACT

Toleration of background noise and amplification efficacy were compared in hearing impaired older persons. Twenty subjects were divided into two matched groups that differed only in their ability to successfully utilize amplification. The successful group utilized their hearing aids full time while the unsuccessful group rarely or never used their hearing aids. The ability to tolerate background noise was assessed by having the subjects select the loudest tolerable level for speech spectrum and speech babble noise while listening to a story. All testing was administered via audible field monaurally with and without the use of the subject's own hearing aid. Signal-to-noise relationships between the story and background noises were compared between the two groups of subjects. A Hearing Aid Performance Inventory rating scale (Schum, 1993) was completed by each subject. Satisfaction rating results were compared with the ability to tolerate background noise. Results showed that successful hearing aid wearers tolerated significantly more background noise. This greater tolerance was seen for both speech spectrum and speech babble noise in both aided and unaided listening conditions. On the average, the successful hearing aid wearers rated their amplification as being more helpful than unsuccessful wearers. A weak correlation was found between the toleration of background noise and

satisfaction ratings. There was the tendency for those who could tolerate more noise to find their hearing aids more helpful.

The ability to tolerate background noise seems to be strongly related to success in the use of amplification. It is possible that tolerance measures may have predictive value for hearing aid evaluations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Many hearing impaired persons have the potential to receive significant benefit from amplification. Communicative improvements such as the ability to enjoy television and radio, and the ability to participate in small group discussions have been reported by many hearing aid wearers (Weinstein, 1991). Psychosocial improvements such as greater independence, improved self-esteem and reduced symptoms of depression have also been cited as benefits resulting from amplification (Weinstein, 1991). Despite the possible advantages of amplification, a 1977 Health Interview Survey estimated that only 20% of hearing impaired elderly persons actually use hearing aids (Ries, 1982). Surr, Schuchman and Montgomery (1978) surveyed recent recipients of hearing aids and found that one-forth of those surveyed wore their hearing aids less than half the time. Although some people only require amplification in certain situations, it is likely that many of those surveyed were dissatisfied with the performance of their hearing aids.

The reasons elderly persons reject hearing aids have been studied in a number of investigations. Some of the most commonly cited reasons for rejection of amplification include problems tolerating background noise (Surr et al., 1978) and unpleasantness of loud sounds (Franks & Beckmann, 1985; Kapteyn, 1977). In a study performed by Pollack (1977),

amplification users were asked to respond to the question of what needs to be improved in hearing aids. The most common response was that background noise needs to be reduced.

Despite the recurrent complaints from amplification users regarding background noise and loudness tolerance, very few attempts have been made to investigate relationships between the ability to tolerate background noise and the efficacy of amplification. In a study performed by Nabelek, Tucker and Letowski (1991), the relationship between hearing aid use and background noise toleration was examined. The test procedure involved separating hearing impaired subjects into three groups based on hearing aid usage: full-time users, part-time users, and nonusers. The three groups were then asked to listen to a story through headphones and adjust several noises to a tolerable level. The frequency spectrums of both the story and the noises were shaped to simulate what would be heard through a hearing aid. It was discovered that full-time users tolerated significantly higher levels of certain kinds of noises than part-time users and nonusers.

The main goal of the present study was to further investigate the relationship between hearing aid use, perceived satisfaction and the ability to tolerate background noise. The study divided subjects into a successful group and an unsuccessful group. Tolerance levels were found for multitalker babble and speech-spectrum noise. The present study attempted to make test conditions as realistic as

possible by utilizing soundfield and using the subject's own hearing aid for measurements. Presentations were made monaurally utilizing an attenuating ear plug in the nontest ear for aided and unaided conditions. A questionnaire was completed by each subject to rate their level of satisfaction with amplification. The purpose of the study was to determine if the degree of hearing aid use is related to the ability to tolerate background noise. Signal-to-noise relationships were obtained and comparisons between the two groups were made.

CHAPTER II

REVIEW OF LITERATURE

Differences Among Individuals in the Ability to Tolerate Noise

Daily, we encounter situations which demand that we separate a given message from competing background noise. Pearson, Bennett and Fidell (1976) reported signal-to-noise relationships for conversation, social and environmental situations. In most conversations, the signal is approximately 5 to 8 dB more intense than the background noise. In a "cocktail party" situation, the signal-to-noise relationship is as low as $\pm$ 1 dB. In traffic, the background noise is often 0 dB or poorer. Some people are able to tolerate and easily decipher speech in these situations. Other people, however, have difficulty understanding speech when the message has to be separated from competing sounds.

A large variation exists among normal hearing listeners in their ability to tolerate noise. Thomas and Jones (1982) reported that some individuals were intensely annoyed by very low levels of noise while others were able to tolerate extremely high levels of noise with no signs of annoyance. A study performed by Weinstein (1978) demonstrated that the reactions to noise among individuals is correlated with their reactions to other nonrelated judgements. A survey, taken from people living in the same area, found that those who expressed a negative reaction to noise also expressed negative

reactions to air quality and in general to their neighborhood.

Studies have been performed in an attempt to determine what causes individual differences in the ability to tolerate noise. Thomas and Jones (1982) found greater annoyance to noise in older persons and that males generally tolerate more noise than females. Langdon (1985) found that individuals with low incomes are more tolerant of noise.

Although there seems to be some disparity in the ability of normal hearing listeners to tolerate noise, their ability to understand speech in the presence of background noise is remarkably similar (Plomp & Mimpen, 1979). However, it was found that subjects with similar hearing losses have different capabilities of understanding speech in noise. Even though the subjects had the same speech discrimination abilities in quiet, they differed considerably when tested with sentences in noise. Plomp and Mimpen also found that the ability to discriminate speech in the presence of competing speech babble differed for age groups under 44 and over 65 years of age.

A decreased signal-to-noise ratio will effect both normal and impaired listeners' ability to understand, but the two groups are not affected proportionately. Nabelek and Mason (1981) found that some hearing impaired listeners were adversely affected by relatively low levels of noise while normal listeners were not. A study performed by Rowland, Dirks, Dubno and Bell (1985) found that a more favorable signal-to-babble relationship was required for hearing

impaired persons to repeat 50% of the given words regardless of the presentation level when they were compared to normal listeners. It was concluded that hearing impaired individuals experience significantly greater difficulty in noise than those with normal hearing (Rowland et al., 1985).

Noise Tolerance and Use of Amplification

The benefits of amplification can be measured in several ways. One of the most common and most reliable procedures for measuring benefit is to calculate the number of hours per day the amplification is worn. Hutton and Canahl (1985) found this procedure to be a extremely reliable.

Nabelek et al. (1991) examined the tolerable signal-to-noise ratios for five groups of people. The study assessed the ability to tolerate background noise in young and old persons with normal hearing and in hearing impaired elderly persons who had been fitted with amplification. Hearing impaired elderly persons were divided into three groups based on the amount of time they utilized amplification: full time users, part time users and nonusers. The listeners were asked to adjust the background noise to a level which was tolerable without interfering with speech understanding while listening to a story. The speech and noise signals were presented monaurally through earphones after being filtered to approximate the signals produced by amplification appropriate for the individual. Several types of noise were used

including babble, speech-spectrum noise, traffic noise, music and noise from a drill. The results of the study revealed that full-time hearing aid users were able to tolerate significantly higher levels of music and speech-spectrum background noise than part-time users and nonusers. For traffic noise, the signal-to-noise ratios for the full-time hearing aid users were smaller than for the group of young normal listeners and those who rejected their hearing aids. For speech babble and the drill noise, the full-time user group could tolerate higher noise levels than the group of young normal listeners.

A study performed by Surr et al. (1978) examined the various factors influencing the use of hearing aids. A questionnaire was mailed to 430 new hearing aid users. The questionnaire provided six possible usage categories for the subjects ranging from "never use" amplification to "always use" amplification. If the subject reported using hearing aids less than 50% of the time, they were asked to state the reasons for limited use. A detailed checklist was provided which listed several possible reasons for nonuse. When the reasons for limited use or nonuse were tabulated, it was found that 63% of the reasons given were related to excessive background noise or the lack of need. Factors such as speech reception thresholds, audiometric slope, and word recognition scores were not correlated with hearing aid usage.

Noise Tolerance and User Satisfaction

The benefits of amplification have been measured using self-assessment scaling procedures. One of the major limitations of scaling procedures is that the attempts to define the scale are limited by the fact that each user is influenced by his or her own criteria for satisfaction (Hutton and Canahl, 1985). Kapteyn (1977b) could find no consistent relationships between hearing aid satisfaction and variables such as age, amount of hearing age use, speech discrimination scores, or personality characteristics. Studies have also compared hearing aid satisfaction to audiometric configuration, but no strong correlations have been found (Hayes, Jerger, Taff and Barber, 1983).

Kapetyn (1977b) used a scaling procedure to assess 165 amplification users and determine which factors correlate with hearing aid benefit. He found that a majority of the dissatisfied wearers complained of poorly fitting molds, excessive feedback and unpleasantness of loud sounds. Only weak relationships were found between the degree of hearing loss, discrimination loss and user satisfaction.

Pollack (1977) polled hearing aid users to see what they felt needed to be improved regarding amplification. The most common answer was background noise reduction. Franks and Beckmann (1985) examined the reasons for rejection of amplification among those who no longer used amplification. They found that too much amplified noise was ranked third as

a reason for rejection of amplification. Reasons which ranked higher than amplified noise included high cost of amplification and aggressive hearing aid dealers.

Even though background noise is often a major complaint among amplification users, only a weak relationship was found between self-assessed satisfaction ratings and speech understanding performance in noise in a study performed by Rowland et al. (1985). However, a study performed by Hayes et al. (1983) revealed a strong relationship between user satisfaction and aided synthetic speech identification. It was found that those who considered themselves satisfied with their amplification performed thirty percent better on a synthetic sentence identification task performed with a signal-to-noise ratio of -10 dB than those who considered themselves dissatisfied.

Gerber and Fisher (1979) investigated the ability of hearing aid evaluation methods to predict user satisfaction. They used five different signal-to-noise ratios with two hearing aid evaluation methods. Comparisons were made between the method developed by Carhart (1946) which utilized CID W22 word lists and the method developed by Jerger and Hayes (1976) utilizing sentences to test discrimination ability. They examined both hearing aid usage and subjective satisfaction ratings. They found that the best single indicator of satisfaction was the 0 dB signal-to-noise condition used with the Synthetic Sentence Identification (SSI) Test. The -10 dB

signal-to-noise condition with either the SSI or the Carhart method (using CID-W22 word lists) was the best predictor of the subject's willingness to use their hearing aids. Both the Carhart and the SSI methods were more capable of predicting use than satisfaction.

Conclusion

The presence of noise deteriorates a hearing impaired person's ability to perceive more dramatically than a nonimpaired listener. If amplification hinders performance in noisy situations, it is reasonable to believe that failure to receive benefit from hearing aids in such situations could lead to total rejection of amplification. Performance on speech discrimination tasks in noise has proven to be related to both hearing aid use and hearing aid satisfaction.

The present study will examine tolerable noise levels while performing a listening task. The listeners will be asked to set a comfortable noise level while listening to and understanding a story. This method was developed to simulate real life situations in a manner that provides different information than is obtained with speech discrimination tasks. The proposed listening task is a direct measure of background noise tolerance which may or may not be related to speech discrimination ability.

CHAPTER III

METHOD

This study explored the relationship between toleration of background noise and amplification efficacy in hearing impaired elderly persons. The ability to tolerate background noise was assessed by having the subjects select the loudest tolerable level for speech spectrum and speech babble noise while listening to a story. All testing was administered via minimal audible field with and without the subjects using their own hearing aid. Signal-to-noise relationships between the story and background noises were compared between two groups of subjects. The subjects completed a Hearing Aid Performance Inventory (Schum, 1993) which rated their satisfaction with their hearing aid(s). The results of the questionnaire were compared to the subject's ability to tolerate background noise.

Subjects

Twenty subjects between the ages of 60 and 80 were involved in this study. The subjects were selected from a pool of clients who were issued non-compression in-the-ear hearing aids through the University of Tennessee Hearing and Speech Center. All subjects were considered to be socially active.

Subjects were divided into two groups of ten based on the

amount of time they wore their hearing aids. If they wore their hearing aids whenever needed, they were considered successful users, and if they rarely or never wore their hearing aids, they were classified as unsuccessful users. Subjects not wearing their hearing aids due to cost, inconvenience, or aesthetic reasons were omitted from the study.

The experimental groups were matched as closely as possible for gender, age, hearing loss, and speech discrimination ability. Because of limited availability of subjects, the groups had unequal numbers of male and female subjects. The successful group contained one female and nine males and the unsuccessful group contained three females and seven males. Table 1 shows a comparison of gender between the subject groups.

The ages of participants in this study ranged from 63 to 80 years (see Table 1). The mean age for the successful group was 69.3 years and the mean age for the unsuccessful group was 71.3 years. No significant age differences between the two groups were shown, $t(18)=.95$, $p>.05$.

The subjects had acquired high frequency sensorineural hearing losses (ranging from mild to moderately-severe) with puretone averages not exceeding 55 dB HL. To assess the equivalence of hearing levels of subjects within each group, comparisons were made for pure tone averages (PTA) as well as individual thresholds at 250, 500, 1000, 2000, 4000 and 8000

Table 1. Comparisons of gender, age and speech discrimination scores between successful (S) and unsuccessful (U) groups.

Group		Number of females	Age (years)	Speech discrimination score (% correct)
	M		69.30	87.60
S	Range	1	63-78	80-96
	SD		5.08	4.79
	M		71.30	85.60
U	Range	3	63-80	76-92
	SD		4.35	5.72

Hz (see Table 2). A t-test revealed no significant difference between the groups with PTAs as a measure of threshold, $t(18)=.45$, $p > .05$. Additionally, no significant differences were found at any of the individual frequencies examined, 250 Hz [$t(18)=.54$]; 500 Hz [$t(18)=1.59$], 1000 Hz [$t(18)=.37$], 2000 Hz [$t(18)=.70$], 4000 Hz [$t(18)=.00$], 8000 Hz [$t(18)=1.24$].

Unaided speech discrimination scores for the subjects were acquired from their audiological files. Discrimination scores were compared to determine if a statistically significant difference existed between the groups (see Table 1). The average score for the successful group was 87.6% words correct and the average score for the unsuccessful group was 85.6% words correct. No significant differences were noted in speech discrimination scores, $t(18)=.85$, $p >.05$.

Subjects who had not been evaluated within the last six months received a puretone air conduction test through earphones to ensure changes had not occurred since their hearing aid(s) were issued. Real Ear probe-tube microphone measures were performed to determine if the subjects' hearing aids conformed to the National Acoustic Laboratory's target gain (Byrne and Cotton, 1988) within +/- 15 dB.

Apparatus and Test Materials

Speech and noise stimuli were delivered from two tape recorders (Technics M205 and a Marantz SD162) through an

Table 2. Comparison of puretone averages (average threshold at 500, 1000 & 2000 Hz) and individual thresholds for 250 through 8000 Hz for successful (S) and unsuccessful (U) hearing aid users.

			kHz					
Group		PTA	.25	.50	1	2	4	8
	M	31.6	21.5	26.0	28.5	39.5	57.5	61.5
S	Range	8-53	10-45	5-50	0-55	20-55	50-60	30-85
	SD	15.9	11.1	15.1	19.4	15.1	4.3	14.9
	M	29.1	18.5	17.0	26.0	43.5	57.5	70.0
U	Range	20-45	0-50	5-35	15-45	25-55	50-70	50-90
	SD	7.5	13.6	9.8	9.1	9.7	7.9	15.8

audiometer (Madsen OB802 or Grayson Stradler 16) to a loudspeaker (Beovox S45) located at a 0 degree azimuth one meter from the subject. An Auditec recording of running speech (female voice) was presented as the primary stimulus. An Auditec tape of multitalker babble and speech-spectrum noise were used as competing stimuli. The frequency spectrum of each stimuli are shown in Figures 1, 2 and 3. The LEQ longterm average intensity of the speech spectrum noise was 3 dB louder than the babble tape; thus, intensity corrections were made for this difference. Both the primary stimulus and the competing stimuli were delivered through the loudspeaker located directly in front of the subject. Subjects were given two hand held buttons with which to adjust the volume of the story and the competing noise. The buttons were connected to the audiometer and signaled the examiner to manipulate the volume up or down by 2 dB steps. Subjects were tested with and without the use of their hearing aid. For subjects that utilized binaural hearing aids, the ear evaluated for the study was the one judged as the most helpful by the subject. If no preference was given, the hearing aid which best matched the NAL target was used. Participation of the opposite ear was minimized by having the subject wear an attenuating ear plug (E-A-R corporation) in the nontest ear.

Calibration of the audiometer was performed before the experiment began and at three other times at three week intervals during the study. The soundfield was calibrated to

Figure 1. Frequency spectrum for story.

Figure 2. Frequency spectrum for babble noise.

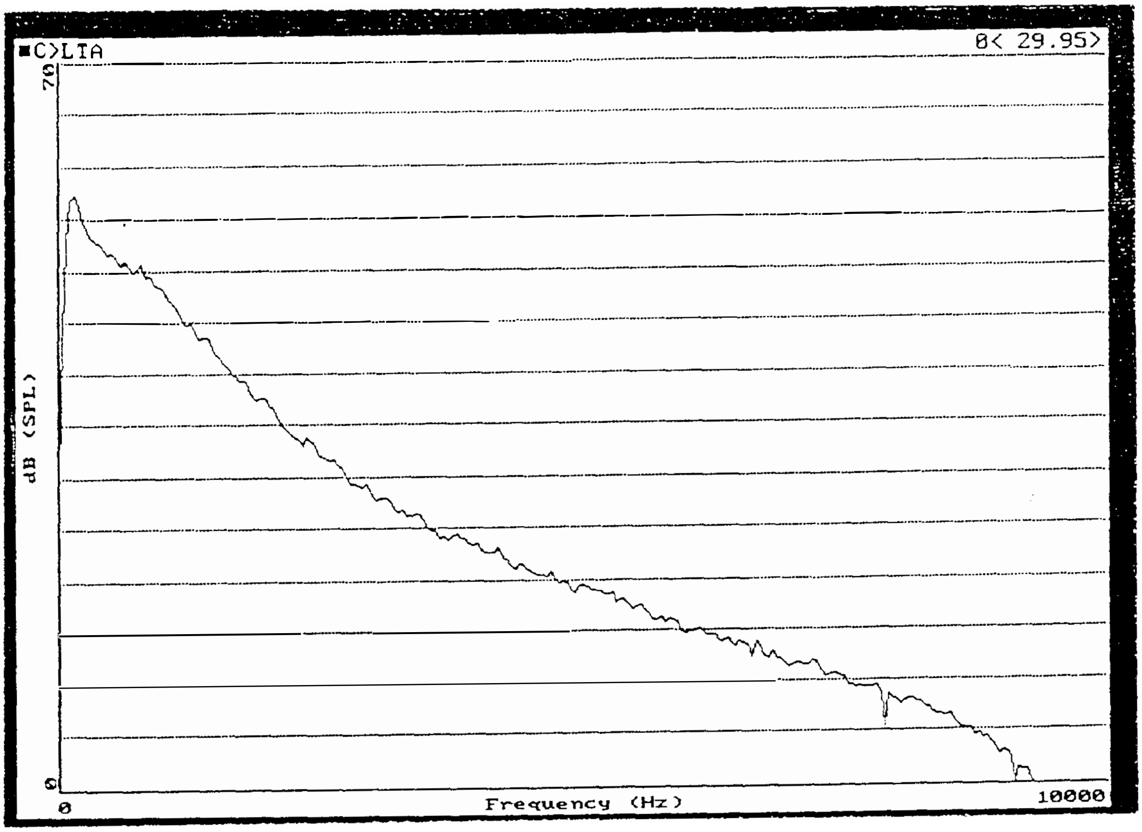

Figure 3. Frequency spectrum for speech-spectrum noise.

ensure the output through the two tape decks was equal before each test session. This was accomplished with speech spectrum noise delivered from each tape deck through the loudspeaker with the audiometer level set at 70 dB HL and the volume unit meter set to zero. Each tape deck was always used with a specific channel and the two channels agreed within 2 dB or less. All values were within the acceptable limits stated in the current audiometric standards (ANSI S3.6-1972b, ANSI S3.6-1989). In addition to periodic electroacoustical calibration checks, biological listening checks were performed daily.

Procedures

All testing was performed at the University of Tennessee Hearing and Speech Center. Prior to testing, subjects were given verbal and written instructions describing the experiment and their task (see appendix B). It was emphasized that the goal of the experiment was to determine the highest possible level of noise which the subject would be willing to tolerate without becoming tense or tired when listening to a story.

Each subject first adjusted the story to their most comfortable loudness level using a modified method of limits. The background noise was then introduced and the subjects adjusted the speech spectrum noise and speech babble noise to a tolerable background level. The subjects performed the tasks both with and without their hearing aid. The order of

tasks both with and without their hearing aid. The order of the listening conditions (aided and unaided) and the order in which the two background noises were introduced were randomized.

A modified method of adjustments was used to determine the comfortable levels. The subjects were instructed to turn the stimuli up until it was too loud, then down until it was too soft, and then choose their most comfortable loudness level. The noises were then introduced and adjusted to a tolerable background level relative to the story. The subjects were given two hand held buttons which were marked "up" and "down". They were able to adjust the volume of the stimuli by pushing the appropriate buttons. The buttons were connected to the audiometer and the examiner manipulated the volume as desired by the subject in 2 dB increments. Subjects generally took one to three minutes to adjust the noise levels, but no time limit was given.

Following the testing procedures, the subjects were asked to fill out a 38 item questionnaire which rated the level of satisfaction they receive from their hearing aids. A shortened version of the Hearing Aid Performance Inventory (HAPI) was used to rate their level of satisfaction (see appendix C). The original HAPI was revised and shortened so it would be more appropriate for elderly persons. The revised thirty-eight item questionnaire has been proven to have good test-retest reliability (Schum, 1993).

Test Reliability

Test reliability was determined by measuring the tolerated signal-to-noise relationships between the story and the two background noises for both the aided and unaided conditions twice. An average of the two trials was taken as the tolerated signal-to-noise ratio. If the first and second signal-to-noise relationships disagreed by greater than 4 dB, a third trial was performed and an average of the three trials was taken. Twenty-five percent of the trials were repeated a third time.

CHAPTER IV.

RESULTS

Comparison of MCLs

MCLs were established during the noise tolerance portion of the study for each subject with and without amplification. A two factor repeated measures analysis of variance was used to evaluate the effect of group and condition on MCLs. The main effect for group was statistically significant, $F(1,18)=25.22$; $p < .05$. The successful group (M=62.1 dB) set MCLs at a greater intensity level than the unsuccessful group (M=52.6). There was also a significant main effect for condition, $F(1,18)=29.4$, $p < .05$. The average MCLs were 55.4 dB in the aided condition and 59.3 dB in the unaided condition. There were no significant interactions between group and condition, $F(1,18)=.34$; $p > .05$.

Tolerated Signal-to-Noise Ratios for Speech-spectrum versus Babble Noise in Aided and Unaided Conditions

Means, ranges and standard deviations of the two groups for both background noises with and without amplification are displayed in Table 3. Figure 4 displays the average group differences for each type of noise in each condition.

A three factor repeated measures analysis of variance was used to evaluate the effects of group (G), type of noise (N), and condition (C). The main effect for group was

Table 3. Comparisons of most comfortable loudness levels and signal-to-noise ratios with speech-spectrum noise and speech babble noise as competing signals for successful (S) and unsuccessful (U) hearing aid users with and without amplification.

	Aided			Unaided				
Group	MCL	Speech Noise	Babble Noise	MCL	Speech Noise	Babble Noise	Grand mean (MCL)	Grand mean (S/N)
S M	59.2	9.0	8.0	64.9	9.6	7.8	62.1	8.6
S Range	49-67	1-17	1-13	56-74	1-17	-1-15	49-74	-1-17
S SD	5.2	4.7	4.4	4.5	4.9	5.2	5.8	4.8
U M	51.6	15.1	14.5	53.6	13.7	14.5	52.6	14.5
U Range	46-56	4-22	4-22	39-62	7-26	4-25	39-62	4-26
U SD	2.5	5.9	5.02	6.0	5.6	6.4	4.8	5.8

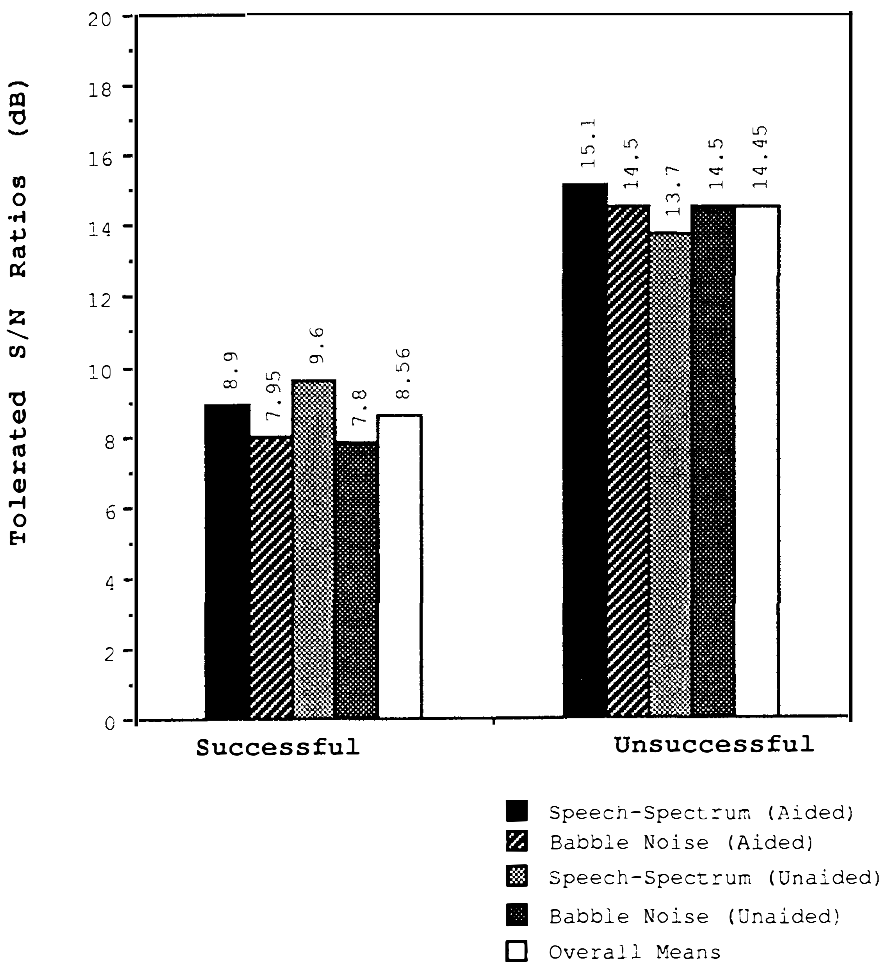

Figure 4. Comparison of mean tolerated signal-to-noise ratios for successful and unsuccessful groups.

statistically significant: G [F (1,18)=6.82; p < .05]. The successful group (M= 8.56 dB) was able to tolerate significantly more noise than the unsuccessful group (M=14.45). There were no significant main effects found for noise nor condition, nor their interaction: N [F (1,18)=1.41; p > .05] and C [F (1,18)=.07; p = > .05], N X C [F (1,18)=.08; p > .05].

A stepwise discriminant analysis was used to determine the ability of the speech-spectrum and babble noises in aided and unaided conditions to classify cases into one of the two groups. It was found that babble noise in the aided condition had the strongest predictive value for group, F (1,18)= 8.923; p<.05. Babble in the aided condition was able to correctly classify 80% of the cases appropriately as successful versus unsuccessful users. Babble in the unaided condition was able to classify 75% of the cases, F (1,18)= 5.976; p < .05. Speech-spectrum noise was able to classify 75% of the cases in the aided condition [F (1,18)= 6.05; p < .05], and 65% of the cases in the unaided condition [F (1,18)= 2.73; p>.05].

Satisfaction Ratings

Nineteen subjects completed a thirty-eight item Hearing Aid Performance Inventory (HAPI) and the average response was calculated. Average values determined a level of satisfaction based on a five point scale which ranged from 1, "very helpful" to 5, "hinders performance". Table 4 lists the

Table 4. Satisfaction ratings and overall tolerance levels per subject.

Group	Subject	Mean tolerated S/N levels	Satisfaction Rating (HAPI)
Successful	1	1.13	1.60
	2	10.00	1.40
	3	8.00	1.80
	4	15.00	2.42
	5	4.75	3.39
	6	8.75	1.80
	7	1.50	2.31
	8	12.00	2.24
	9	11.25	1.73
	10	13.25	2.06
	means:	8.56	2.08
Unsuccessful	11	17.50	
	12	16.50	3.76
	13	19.00	2.26
	14	18.50	2.82
	15	14.25	3.05
	16	5.50	2.39
	17	6.75	1.91
	18	13.00	3.09
	19	11.75	2.41
	20	21.75	3.45
	means:	14.45	2.79

satisfaction ratings along with the average tolerated signal-to-noise ratios for each subject.

A t-test for independent samples was performed to determine if there was a significant difference between HAPI scores for the two groups. It was found that the HAPI ratings were significantly better in the successful group (M=2.08) versus the unsuccessful group (M=2.79), $t(19)=2.67$, $p < .05$.

A correlation analysis was performed which compared HAPI ratings for each subject to overall signal-to-noise tolerance levels. A Pearson product-moment correlation coefficient of .4596 was obtained, p=.048. Therefore, a weak but statistically significant relation was found for high satisfaction ratings with high tolerance of noise and for low satisfaction ratings with low tolerance of noise. Further statistical analysis was performed to determine if babble noise in the aided condition was a good predictor of satisfaction. There was no significant relationship between HAPI scores and signal-to-noise ratios obtained with babble noise in the aided condition ($p > .05$).

CHAPTER V.

DISCUSSION

Previous studies have attempted to determine the efficacy of amplification in background noise by measuring the influence of various types and various levels of background noises on speech understanding. In the present study, performance in noise was measured by determining how much background noise was tolerable for successful and unsuccessful hearing aid users. If systematic and significant differences in toleration of background noise are seen between subject groups, a simple background noise toleration test might be useful in predicting success in using hearing aids.

The present study was conducted to determine if toleration of background noise is related to the level of satisfaction and usage of amplification. This study was based upon a previous study performed by Nabelek, Tucker and Letowski (1991). Nabelek et al. found significant differences between full-time hearing aid users and other groups (including normals, part-time users and nonusers) in their ability to tolerate various types of background noise delivered monaurally under earphones. The overall average preferred signal-to-noise ratio was 7.5 dB for full-time users and greater than 10 dB for all other groups. Significant differences were found between full-time users and part-time users and nonusers in their ability to tolerate speech-

spectrum noise. For babble noise, the only significant difference between S/N ratios for groups was found between full-time amplification users versus young normal hearing subjects.

Tolerated Signal to Noise Relationships

The present study assessed toleration for background noise via minimal auditory field. Background noises included speech-spectrum noise and speech babble noise. The speech-spectrum noise was included because of the significant differences found by Nabelek et al. (1991). Speech babble noise was included because of its simulation to a realistic listening environment.

MCL's and tolerated signal-to-noise relationships were examined with and without the subjects wearing their hearing aids to see if the results of Nabelek et al.'s (1991) study could be generalized to aided and unaided conditions in soundfield.

In the present study, it was found that despite the similarities in hearing sensitivity, the MCL's for the successful group differed significantly from those of the unsuccessful group. Nabelek et al. (1991) did not find significant differences in MCLs between the groups. However, a significant correlation was found between the full-time users' hearing threshold levels and MCLs. It was hypothesized that this might indicate full-time users are better able to

select listening levels which are appropriate for their hearing losses. The data collected in this study indicates that the successful wearers chose louder listening levels (M= 62 dB) than the unsuccessful wearers (M= 53 dB). It is conceivable that unsuccessful hearing aid users are afraid of amplified noise and select lower MCLs to guard against loud sounds.

Comparisons of means, ranges and standard deviations were made between the present study and the study performed by Nabelek et al. (1991) and are shown in Table 5. Means obtained for each noise were very similar despite the differences in the procedures used in the two studies. The signal-to-noise ratios obtained in the present study varied by less than 2 dB from the results obtained by Nabelek et al. for both speech-spectrum and babble noises. Thus, the simulation of amplified stimuli through earphones which was used in Nabelek et al.'s study yielded similar results to the present study which utilized the subject's own amplification devices in soundfield. Two minor differences between results of the two studies were found. Nabelek et al. found a more significant difference between speech-spectrum noise and babble than did the present study. Also, the ranges for the unsuccessful group were greater for the present study versus the previous one.

Statistical analysis revealed no significant difference between the aided and unaided conditions. Therefore, it can

Table 5. Comparison between Nabelek et al. (1991) results and present study.

		Nabelek et al.		Present Study	
		Speech Spectrum	Speech Babble	Speech Spectrum	Speech Babble
S	M	7.67	7.40	8.90	7.95
	Range	2-18	2-17	1-17	1-13
	SD	5.70	5.10	4.74	4.43
U	M	15.93	14.00	15.10	14.50
	Range	7-27	7-22	4-22	4-22
	SD	5.61	4.68	5.89	5.02
S-U		8.26	6.60	6.20	6.55

Note: S=Successful users, U= unsuccessful users. Present study used aided condition for comparison.

be assumed that one can expect similar results whether the subject is tested with or without their hearing aids. However, it cannot be assumed that tolerated signal-to-noise levels do not change over time. Silverman (1947) found that tolerance thresholds could be changed over time with exposure to high-intensity stimuli. He suggested directing clinical practice towards elevating the tolerance thresholds of amplification users.

Based on the results of this study, no significant differences were found between the types of noises used. However, Nabelek et al. (1991) found speech-spectrum noise to differ more significantly than babble. However, this study found babble noise was more capable of classifying subjects as successful versus unsuccessful users. Therefore, some discrepancies exist as to which noise would be the most effective tool in predicting the use of amplification.

Satisfaction Ratings

Rowland et al. (1985) attempted to compare performance on speech recognition in noise tasks with self-assessment ratings from the Hearing Performance Inventory Scale. Only weak correlations were found between the two measures. They concluded that the Hearing Performance Inventory Scale has limited predictive value in hearing aid evaluations and is a poor predictor of performance in noise.

Hayes et al. (1983) were more successful in their

endeavors to relate performance in noise to hearing aid satisfaction. They found that those who rated themselves as satisfied users performed an average of 30% better on an aided synthetic speech test with a -10 dB message-to-competing ratio. These investigators determined satisfaction with amplification by asking subjects to choose one of four degrees of satisfaction ranging from "very helpful" to "unsatisfactory" to describe how they felt about their hearing aid's performance.

Gerber and Fisher (1979) were also successful in relating hearing aid use and satisfaction to performance in noise. They examined monosyllabic words and sentences with various signal-to-noise ratios. Sentences presented at poorer signal-to-noise ratios proved to be the best predictor of use of amplification. These investigators concluded that hearing aid use could be more accurately predicted, despite the method used, than satisfaction.

Speech recognition tasks can be contaminated by variables such as the speaker's voice, the examiner's interpretation of the responses, or dialectal differences found between the examiner and client. The method which was used in the present study avoids such contamination. It also gives the examiner information concerning the level at which the patient begins to react negatively to background noise. The examiner might then use this information to predict the patient's reaction to various listening environments.

Successful amplification users tolerated more noise than unsuccessful users; however, some overlap existed between individual subjects in the two experimental groups. Ratios were found to range from -1 to 17 dB in the successful group and from 4 to 26 dB in the unsuccessful group. Standard deviations of 4.818 and 5.783 were found for successful and unsuccessful groups respectively. Although the measure may be clinically useful, the overlap between the groups limits the value of tolerable levels as a predictor of hearing aid use. However, discriminative analysis has revealed that babble noise in the aided condition was able to correctly classify 80% of the subjects tested as full-time users versus nonusers. Therefore, the measure has the potential to provide clinical insight for many patients during hearing aid evaluations.

When satisfaction ratings were compared with overall tolerated signal-to-noise relationships, a weak correlation was found. Although there was a significant difference between the satisfaction ratings of the two groups, the scores overlapped. A direct relationship between use and satisfaction was not seen. The relationship between noise tolerance and use was found to be much stronger than the relationship between noise tolerance and satisfaction.

Conclusion

The procedures for deriving tolerance levels utilized in this study may have some clinical value. Because there is no

statistically significant effect of aided versus unaided conditions, this procedure could possibly be used as an additional clinical tool to aid in hearing aid evaluations. However, the predictive value of this procedure has not yet been fully assessed and several limitations exist. One major concern is that considerable overlap exists between the two groups in their ability to tolerate noise. Therefore, the relationship between noise tolerance and amplification efficacy is not always predictable.

Also, because the subjects tested in this study were experienced hearing aids users, one cannot assume that their ability to tolerate noise has remained the same since they first began utilizing amplification. If the ability to tolerate noise changes significantly over time, it would be difficult to predict success with hearing aids before dispensing amplification.

Because of subject availability, the groups in this study were unequal in relation to gender. The first group had only one female and the second had three. Thomas and Jones (1985) found males more tolerant of noise than females. This factor may have effected the outcome of this study.

Monaural amplification was used to provide more control in testing. The procedure used does not account for the binaural advantage which is received when two hearing aids are worn. The exact same results may have not been obtained had binaural amplification been used.

Future Research

Additional research needs to be performed regarding toleration of background noise before and after amplification to see if any changes take place over time. Subject groups need to be balanced in terms of gender and a larger sample size may yield different results.

Future research could examine different age groups and various degrees and configurations of hearing losses to see if results differ. Those with flat hearing losses may react differently to noise than those with normal hearing in the low frequency regions. The correlations found between tolerated noise levels and satisfaction levels were weak. Different scales for rating satisfaction may correlate better with toleration of background noise.

Further research could be devoted to assessing comprehension of material at preferred signal-to-noise levels. The procedure used in this study could also be modified to require the subjects to listen to the story and background noise over a longer period of time.

Research also needs to be performed to determine why these differences in the ability to tolerate noise exist among individuals. It has not yet been determined whether the phenomenon is cochlear or central. In addition to defining the origin of the problem, research needs to focus on efficacy of teaching people to tolerate background noise. Further research also needs to be devoted to determining if the

solutions we offer with automatic signal procession circuits and other amplification circuits really help individuals better tolerate noisy situations.

This study has shown that two groups matched closely in terms of lifestyle, hearing loss, speech discrimination ability and prescriptive fitting differ significantly in their ability to tolerate background noise. Tolerated signal-to-noise relationships with babble or speech-spectrum noise has proven to be significantly different between groups of users and nonusers. The procedure utilized in this study has some predictive value and may aid the clinician in classifying potential users and nonusers before amplification is given. Such clinical insight may be of substantial benefit during hearing aid evaluations.

REFERENCES

American National Standards Institute. (1972b). Specifications for Audiometers, ANSI S3.6-1969. American National Standards Institute, New York.

American National Standards Institute. (1989). Specification for Audiometers, ANSI S3.6-1989. American National Standards Institute, New York.

Byrne, D., & Cotton, S. (1988). Evaluation of the National Acoustic Laboratories' new hearing aid selection procedure. Journal of Speech and Hearing Research, 31, 178-186.

Carhart, R. (1946). Tests for selection of hearing aids. Laryngoscope, 56, 780-794.

Cunningham, D.R., Merle, K.S., & Drakem J. (1978). Users' satisfaction with hearing aids. Journal of the American Audiological Society, 4, 81-85.

Dirks, D., Morgan, D. & Dubno, J. (1982). A procedure for quantifying the effects of noise on speech recognition. Journal of Speech and Hearing Disorders, 47, 114-123.

Dubno, J., Dirks, D., & Morgan, D. (1984). Effects of age and mild hearing loss on speech recognition in noise. Acoustical Society of America, 76(1) 87-96.

Franks, R., & Beckmann, N. (1985). Rejection of hearing aids: Attitudes of a geriatric sample. Ear and Hearing, 6(3), 161-166.

Gerber, S.E. & Fisher, L.B. (1979). Prediction of hearing aid users' satisfaction. Journal of American Auditory Society,5(1), 35-40.

Hayes, D., Jerger, J., Taff, J., & Barber, B. (1983). Relation between aided synthetic sentence identification scores and hearing aid user satisfaction. Ear and Hearing, 4(3), 158-161.

Hutton, C.L. & Canahl, J.A. (1985). Scaling patient reports of hearing aid benefit. The Journal of Auditory Research, 25, 255-269.

Jerger, J. & Hayes, D. (1976). Hearing aid evaluation: clinical experience with a new philosophy. Archives of Otolaryngology, 102, 214-225.

Jones, D.M. & Davies, D.R. (1984). Individual and group differences in the response to noise. In Noise and

Society (pp. 125-155). New York: John Wiley & Sons.

Kalikow, D.N. & Stevens, K.N., Elliot, L.L. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. Journal of Acoustical Society of America, 61 (5) 1337-1351.

Kapteyn, T.S. (1977). Satisfaction with fitted hearing aids. Scandinavian Audiology, 6, 147-156.

Kapteyn, T.S. (1977b). Satisfaction with fitted hearing aids II. An investigation into the influence of psycho-social factors. Scandinavian Audiology, 6, 171-177.

Langdon, F.J. (1985). Noise annoyance. In The Noise Handbook (pp. 162-167) Orlando: Academic Press Inc.

Nabelek, A.K., Tucker, F.M., Letowski, T.R. (1991). Toleration of background noises: Relationship with patterns of hearing aid use by elderly persons. Journal of Speech and Hearing Research, 34, 679-685.

Nabelek, A.K. & Mason, D. (1981). Effects of noise and reverberation on binaural and monaural word identification by subjects with various audiograms. Journal of Speech and Hearing Research, 24, 375-383.

Newman, C.W., Weinstein, B.E., Jacobson, G.P., Hug, G.A. (1990). The hearing handicap inventory for adults: Psychometric adequacy and audiometric correlates. Ear and Hearing, 11 (6) 430-433.

Pearson, K., Bennett, R.S., & Fidell, S. Speech levels in various environments, Bolt, Beranek and Newman, Inc., Report No. 3281. Prepared for Office of Resources and Development, Environmental Protection Agency, 1976.

Pollack, M.C. (1977). Hearing aids: needs and developments, part I. Hearing Aid Journal, 30 (10) 29-31.

Plomp, R. & Mimpen, A.M. (1979). Speech reception threshold for sentences as a function of age and noise level. Acoustical Society of America, 66 (5) 1333-1342.

Ries, P.W. (1982). Hearing ability of persons by sociodemographic and health characteristics: United States. Series 10, Number 140, DHS Publication No. (PHS) 82-1568. Washington, DC: U.S. Department of Health and Human Services.

Rowland, J.P., Dirks, D.D., Dubno, J.R., & Bell, T.S. (1985). Comparison of speech recognition-in-noise and subjective communication assessment. Ear and Hearing, 6, (6) 291-296.

Schum, D.J. (1993). Test-retest reliability of a shortened version of the hearing aid performance inventory. American Academy of Audiology, 4, 18-21.

Silverman, S.R. (1947). Tolerance for pure tones and speech in normal and defective hearing. Annals of Otology, Rhinology, and Laryngology, 56, (3) 658-677.

Surr, R.K., Schuchman, G.I., Montgomery, A.A. (1978). Factors influencing use of hearing aids. Archives of Otolaryngology, 104, 732-736.

Thomas, J.R., & Jones, D.M. (1982). Individual differences in noise annoyance and the uncomfortable loudness level, Journal of Sound and Vibration, 83, 289-304.

Weinstein, B. (1991). Hearing aids at my age: Why bother? ASHA, December: 38-40.

Weinstein, N.D. (1978). Individual differences in critical tendencies and noise annoyance, Journal of Sound and Vibration, 68, 241-248.

APPENDICES

APPENDIX A
SUBJECT CONSENT FORM

INFORMED CONSENT DOCUMENT

You are asked to participate in a research study which will investigate the relationship between the ability to tolerate background noise and the amount of benefit a person derives from amplification. All research information will be gathered in one session lasting approximately one and one-half hours.

During this session, you will be given a free hearing re-evaluation. Your hearing aid(s) will also be analyzed to determine if they fit your hearing loss appropriately. Following these routine procedures, a brief test will be performed. You will be asked to adjust a given noise to a level which you feel is tolerable while listening to a story read by a female voice. This test will be repeated under four different conditions (aided and unaided with two types of noise). You will then be asked to fill out a brief self-assessment questionnaire which asks you to rate the helpfulness of your hearing aid(s) in various listening situations.

Procedures which will be used will present no physical or psychological harm to you. The hearing re-evaluation and evaluation of hearing aid performance will be given to you at no charge. If your amplification seems to be inappropriately fit, you will be referred for rehabilitative services.

The information derived from this research will be beneficial to audiologists in assessing and managing older persons with hearing impairments. Your participation in this study is greatly appreciated. You may elect to stop participation in the project at any time without penalty. Questions concerning the project will be answered by contacting:

Samuel B. Burchfield, Ph.D.
974-5453

or

Susan Lytle
974-5453

________________________ ________________________

Subject's signature Witness

APPENDIX B
INSTRUCTIONS FOR SELECTING LOUDNESS TOLERANCE LEVELS

INSTRUCTIONS

Task #1: Finding a comfortable loudness level while listening to a story.

You will be listening through a loud speaker to a story. After you listen for a few moments we will ask you to adjust the loudness as you would like to hear this. You will be given two hand held buttons which will allow you to adjust the story louder and softer in small steps. Please turn the volume up to a level that is too loud and down to a level that is too soft and then zero in on your "favorite" listening level.

Task #2: Finding a comfortable noise level.

We will now add some noise and ask you to adjust the loudness of the noise to a level where it will not spoil your pleasure and comfort as you listen to and follow the words of the woman reading the story. Please indicate the highest acceptable amount of loudness you will that is intolerable and down to a level which is barely noticeable and then zero in on the level you feel you could "put up with" for a long period of time.

APPENDIX C
HEARING AID PERFORMANCE INVENTORY

HEARING AID PERFORMANCE INVENTORY

Rate the performance of your hearing aid(s) in the following situations as being one of the following:

1- Very helpful
2- Helpful
3- Very little help
4- No help
5- Hinders performance
6- Not applicable (I am not faced with this situation or any similar situations)

1) Alone watching TV news.
2) Intimate conversation with spouse.
3) Watching TV with noise.
4) Telephone rings in the other room.
5) Talk to family in the other room.
6) Lecturer speaking with back turned.
7) Horn sounds, busy street.
8) Conversation on city street.
9) Listening to the news on a car radio with the window closed.
10) Talking to a cashier in a crowded grocery store.
11) Doorbell rings while the TV is on.
12) Evening stroll in a quiet park.
13) Listening to the stereo at home.
14) Whisper to spouse in a restaurant.
15) Converse with spouse in the kitchen.
16) Converse with family, face to face.
17) Talk to clerk in a busy store.
18) Listen to sermon, front pew.
19) Listen to speaker from afar
20) Talk to salesman at home, noise
21) Listen to sermon, back pew
22) Talk to a friend on a windy day
23) Talk to your spouse in the car
24) Order food at McDonalds
25) Listening to a conversation between family in another room
26) Talk to a bank teller at a drive-in
27) Converse over the backyard fence
28) Waiting in a crowded reception room
29) Neighbor yelling with mower running
30) Listen to soft speaker in a quiet room
31) Someone talking to you from behind
32) Conversation in the car with the window open
33) Talking to a doctor in an examination room
34) Taking questions from an audience
35) Talking at a large, noisy party
36) Talking to spouse at a family dinner
37) Talking to a teller at a quiet bank
38) Conversing in car with friends

APPENDIX D
RAW DATA FOR MOST COMFORTABLE LOUDNESS LEVELS AND TOLERATED SIGNAL-TO-NOISE RATIOS FOR SUCCESSFUL AND UNSUCCESSFUL USERS

RAW DATA FOR MOST COMFORTABLE LOUDNESS LEVELS AND TOLERATED SIGNAL-TO-NOISE RATIOS FOR SUCCESSFUL AND UNSUCCESSFUL USERS

		Aided			Unaided		
Group	Subject	MCL	Speech Noise	Babble Noise	MCL	Speech Noise	Babble Noise
Successful	1	58	3	1.5	63	1	-1
	2	54	9	9	65	11	11
	3	60	10	8	66	9	5
	4	58	17	12	69	17	14
	5	67	4	3	74	6	6
	6	58	9	10	62	9	7
	7	67	1	1	66	4	0
	8	59	12	13	66	12	11
	9	62	14	11	62	10	10
	10	49	10	11	56	17	15
Unsuccessful	11	52	22	22	51	14	12
	12	52	16	13	57	20	17
	13	50	20	15	51	16	25
	14	53	20	21	57	12	21
	15	46	15	13	57	15	14
	16	39	7	4	52	7	4
	17	52	4	9	56	7	7
	18	50	13	16	50	10	13
	19	53	12	15	56	10	10
	20	56	22	17	62	26	22

APPENDIX E

RAW DATA FOR HEARING THRESHOLDS AND PURETONE AVERAGES
FOR SUCCESSFUL AND UNSUCCESSFUL HEARING AID USERS

COMPARISON OF PURETONE AVERAGES, AND INDIVIDUAL THRESHOLDS FOR SUCCESSFUL AND UNSUCCESSFUL HEARING AID USERS

		kHz					
Group	PTA	.25	.50	1	2	4	8
S	18	30	25	10	20	55	70
	48	25	45	50	50	55	60
	8	10	5	0	20	60	60
	53	45	50	55	55	55	65
	43	20	40	40	50	60	30
	22	10	15	20	30	60	55
	45	25	30	45	50	65	85
	37	25	20	35	55	55	75
	12	10	10	5	20	60	65
	30	15	20	25	45	50	50
U	28	0	5	30	50	55	90
	28	20	15	20	50	50	50
	25	10	10	20	45	55	50
	25	15	20	15	40	50	65
	45	30	35	45	55	65	75
	27	15	15	25	40	50	90
	32	15	15	30	50	70	60
	38	50	30	35	50	65	70
	23	20	20	20	30	50	60
	20	10	5	20	25	65	90

APPENDIX F
GENDER, AGE AND SPEECH DISCRIMINATION SCORES FOR SUCCESSFUL AND UNSUCCESSFUL HEARING AID USERS

GENDER, AGE AND SPEECH DISCRIMINATION SCORES IN SUCCESSFUL AND UNSUCCESSFUL HEARING AID USERS

Group	Gender	Age	Speech Discrimination Score (% correct)
S	M	75	88
	M	74	84
	M	66	92
	F	71	84
	M	68	88
	M	67	96
	M	78	84
	M	68	80
	M	63	88
	M	63	92
U	M	68	76
	M	68	92
	M	64	76
	F	73	88
	F	73	84
	M	70	84
	M	80	88
	M	70	92
	F	73	88
	M	74	88

VITA

Susan Ruth Lytle was born in Atlanta, Georgia on November 13, 1969. She received her Bachelor of Science in Education with a concentration in Hearing and Speech from the University of Tennessee in August of 1992. Future plans include completing a Clinical Fellowship Year in Audiology and pursuing a Doctoral degree in Neuroscience.