To the Graduate Council:

I am submitting herewith a dissertation written by Hilary J. Crowley entitled "Unaided Factors Predicting Client-Assessed Hearing Aid Performance, Usage and Satisfaction." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Speech and Hearing Science.

Igor V. Nabelek, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

UNAIDED FACTORS PREDICTING CLIENT-ASSESSED HEARING AID PERFORMANCE, USAGE AND SATISFACTION

A Dissertation Presented for the Doctor of Philosophy Degree

The University of Tennessee, Knoxville

Hilary J. Crowley

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ABSTRACT

The purpose of this study was to determine if client-assessed hearing aid performance, usage, and satisfaction ratings could be predicted before hearing aids are purchased. Aided performance was represented by the Profile of Hearing Aid Performance, (PHAP, Cox and Gilmore, 1990), subscales. Based upon data from 46 subjects, multiple regression was applied to 16 unaided variables to determine if they could be used to predict the response variables of performance, usage and satisfaction. The 16 unaided variables included pure tone average, slope of hearing loss, the Speech Perception in Noise (SPIN) test (Kalikow, Stevens & Elliott, 1977), dynamic range, comfortable loudness level, tolerated signal-to-noise levels for babble and speech spectrum noise, the difference between actual gain and target gain based upon the National Acoustic Laboratories' prescription formula, age, gender, percentage of employment, years of education, number of medications taken, Personal Adjustment and Communication Strategies scores of the Communication Profile for the Hearing Impaired (Demorest and Erdman, 1986), and motivation for pursuing hearing aid use.

The regression equations obtained for the Familiar Talkers, Background Noise and Reduced Cues subscales resulted in predicted values which matched actual scores within 12% for about 75% of the subjects. The equation for usage estimated hours of daily hearing aid use within three hours for 75% of the subjects. Further testing of these models using other subjects would be needed to determine the clinical applicability of these equations. Estimates of the other subscale scores were not accurate enough to be considered for clinical application. However, the equations identified relationships between the aided and unaided variables which may be useful for counseling new hearing aid users. Scores for most of the PHAP subscales and for hours of hearing aid use were found to be related to age, Personal Adjustment scores and SPIN scores. Comfortable loudness levels, Communication Strategies scores and difference between insertion gain

and NAL target gain were found to be partially predictive of performance but not of usage or satisfaction. Tolerated signal-to-noise levels were partially predictive of hearing aid usage and satisfaction, and percentage of time employed was related to usage.

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CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem and Rationale for the Study

1.1.1. The Need for Increased Hearing Aid Satisfaction

Numerous technological advances have been made since electronic hearing aids first became commercially available in 1903. Hearing aids are manufactured with gain to fit any degree of hearing loss, and with frequency responses to fit a wide variety of audiometric configurations. Hearing aid selection procedures can be applied more precisely than in the past through the use of probe microphone systems for measuring insertion gain. Even greater precision and flexibility in hearing aid fitting can be expected in the future as the use of digitally programmable hearing aids increases. Automatic gain control systems are available to assist clients experiencing loudness discomfort problems. Hearing aids have also become considerably smaller, which would be expected to increase the acceptance of hearing aid use.

Despite the advances that have been made in hearing aid technology, the number of purchased hearing aids returned for credit has changed very little over the past several years. Hearing Industries Association (HIA) figures from 1993 (reported in ASHA's Audiology Update, 1993) showed a 15.5% return rate of custom in-the-ear hearing aids in 1987 and a 14.6% return rate in 1992.

A number of clients, whether they return their hearing aids or not, continue to report dissatisfaction as well as limited hearing aid use. Smedley (1990) conducted a survey of elderly hearing aid, eyeglass and denture wearers. Hearing aid wearers were found to complain about their fittings to a greater extent than wearers of the other prostheses. Surr, Schuchman and Montgomery (1978) surveyed clients who had recently

purchased hearing aids, and found that 25% wore their hearing aids less than half time. Although this figure may have included some clients who appreciated their hearing aids, but only needed them half of the time; it probably also reflects a number of clients who were dissatisfied with their hearing aid purchases. The 1984 HIA market survey (cited by Kochkin, 1990) revealed that 14% of hearing aid owners were not using their hearing aids at all. The results of these surveys show that continued efforts are needed to increase the satisfaction of hearing aid users.

1.1.2. Increasing Hearing Aid Satisfaction through Prediction of Aided Performance

In the field of marketing, buyer satisfaction is described as requiring a close correspondence between a buyer's expectations and his or her perceived performance of the product (LaBarbera and Mazursky, 1983 cited by Kotler, 1988). Applying this concept to hearing aid fitting, the hearing aid dispenser may potentially increase hearing aid user satisfaction by shaping clients' expectations before they try their hearing aid(s). More thorough counseling before the hearing aid fitting may result in a closer match between clients' expectations of hearing aid use and their actual post-fitting experience.

Hearing aid performance is a more complicated issue than the performance of most other products. It involves both the functioning of the instrument from a mechanical and electronic point of view as well as the listener's performance or communication ability when using the device. Some manufacturers may produce hearing aids with fewer repair problems than others, and some hearing aid dispensers are better than others at making ear impressions or making repairs. However, it should be relatively easy to keep these factors from interfering with satisfaction (a match between expectations and experience) if both manufacturers and dispensers are attentive to detail, and if all strive to continually improve upon their knowledge and skills. Counseling of new hearing aid users should also include

preparation for the possibility that repairs will sometimes be necessary and that some return visits and changes in their hearing aid settings may be needed before their fitting is complete.

It is more difficult to achieve and communicate an accurate and specific prediction of a client's perceived performance with amplification before the decision to purchase hearing aids has been made. However, if satisfaction is dependent upon the user having realistic expectations, it would be useful to be able to predict the client's performance with amplification as accurately and as early in the evaluation process as possible and to communicate these findings to the client in a meaningful way.

Cox and Gilmore (1990) stated that "hearing aid performance" refers to the listener's performance on an absolute scale while wearing their hearing aid(s). A listener's hearing aid performance is represented by either objective or client-assessed measures of aided hearing. "Hearing aid benefit" refers to the difference between aided and unaided performance. Hearing aid benefit can be derived by comparing performance with and without amplification. In this paper, the term "hearing aid benefit" will not be used in general discussions of hearing aid performance, usage, and satisfaction, because it differs from hearing aid performance only in the way it is measured. The term "hearing aid benefit" will be used in the Review of Literature to specify how performance/benefit was measured in a given study.

For the most part, hearing aid performance has been evaluated using objective measures such as speech recognition testing. A variety of materials have been used for assessing speech recognition, including monosyllabic words (Carhart, 1946) and synthetic sentences (Jerger and Hayes, 1976). Because speech recognition testing is such a common part of the hearing aid evaluation process, it can be assumed that most of the subjects who reported dissatisfaction with their hearing aids in the studies cited above

probably obtained satisfactory test results. Thus, clients achieving adequate aided results on objective tests do not necessarily become satisfied hearing aid users. Applying the marketing model of buyer satisfaction that has been described, objective tests of aided performance may not be as directly related to satisfaction as tests of the client's perceived aided performance. Objective tests of aided performance may be useful for making fitting decisions, but tests of client-assessed aided performance may better represent the perceived performance aspect of hearing aid satisfaction.

There are several self-assessment scales of communication or hearing aid performance available which could be used to investigate perceived hearing aid performance. Some examples of self-assessment scales of communication or hearing aid performance are the Hearing Handicap Inventory for the Elderly (Ventry & Weinstein, 1982; Newman & Weinstein, 1988; Malinoff & Weinstein, 1989), the Hearing Problem Inventory (Hutton, 1987), the Communication Profile for the Hearing Impaired (Demorest & Erdman, 1987), the Profile of Hearing Aid Performance (Cox & Gilmore, 1990), the Hearing Aid Performance Inventory (Walden, Demorest & Helper, 1984), and the Hearing Performance Inventory (Lamb, Owens & Schubert, 1983; Dempsey, 1986).

1.1.3. Aims of the Study and Introduction of Variables

The long-range goal of this research is to eventually develop a framework for pre-fitting hearing aid counseling that would provide clients with an accurate estimate of how they will be likely to perceive their aided hearing performance. This could result in a closer agreement between clients' expectations and their perceived aided performance, and ultimately result in greater satisfaction. The purpose of the current study was to determine if unaided information could be used for predicting a client's perceived aided performance. Unaided variables which were considered potentially useful for predicting perceived performance included audiometric information, such as degree of loss and speech

recognition scores; demographic information, such as the client's age and gender; and psychological factors, such as test scores representing a client's attitude toward hearing loss and hearing aid use.

Perceived hearing aid performance was measured utilizing Cox and Gilmore's Profile of Hearing Aid Performance (PHAP). A PHAP questionnaire/response form is shown in Appendix A. It is a 66 item self-assessment scale from which seven subscale scores can be obtained. Subscales include Ease of Communication, Reverberation, Background Noise, Distortion of Sounds, Familiar Talkers, Reduced Cues, and Aversiveness of Sounds. Appendix A also shows the PHAP test questions which are included in each of the seven subscales. The scores obtained for these subscales represent the percentage of difficulty the subject perceives in each area. If clients' results on the PHAP subscales could be predicted or estimated, the subtests could provide a structure for pre-fitting counseling sessions. The areas of communication addressed in each subtest could be discussed in detail with the client, and the client could learn what to expect in each area when he or she tries amplification. The PHAP subscale scores were chosen as response variables in this study because they represent a variety of common listening conditions.

Data were gathered from 46 subjects who were to be fitted with their first hearing aids. Information was obtained regarding 16 unaided variables which were considered potentially predictive of perceived hearing aid performance. After subjects had worn their hearing aids for approximately six weeks, the Profile of Hearing Aid Performance was administered. Multiple regression analyses were then carried out to determine if equations could be obtained for predicting PHAP subscale scores. Multiple regression is a statistical procedure used "to bring more than one predictor variable to bear in predicting scores on a given variable" (Williams, 1986). The relative contribution among a set of variables can

also be described through multiple regression analysis when predicting the response variables; in this case, the PHAP subscale scores.

In addition to predicting perceived hearing aid performance, regression analyses were also performed to determine if the unaided variables could be used to predict hours of daily hearing aid use and subjects' ratings of hearing aid satisfaction. The inclusion of hearing aid usage and satisfaction ratings as response variables makes it possible to compare the results of this study with those of previous studies. In the literature, studies of hearing aid usage and satisfaction have been more common than studies of client-assessed hearing aid performance. In the Review of the Literature, Section 1.2, 12 studies are described which involve hearing aid usage. Eight studies were found which included hearing aid satisfaction ratings, and seven studies were found which included measures of client-assessed aided performance. (Some of the studies included two or all three approaches to measuring the success of hearing aid fittings.)

The following unaided factors or predictive variables were included in the analyses:

1. Pure tone average (PTA).
2. Slope of hearing loss.
3. Speech recognition scores in noise.
4. Dynamic range of hearing (loudness discomfort level for speech minus speech reception threshold).
5. Comfortable loudness level (CLL).
6. Tolerated signal/noise levels when listening to running speech in background multitalker babble.
7. Tolerated signal/noise levels when listening to speech in background speech spectrum noise.
8. The average difference between the National Acoustic Laboratories' (NAL) target and actual insertion gain.

9. Subject's age.

10. Subject's gender.

11. Percentage of time subject is employed.

12. Subject's years of education.

13. Number of medications taken by subject per day.

14. Attitude toward hearing loss as measured by the Personal Adjustment scale of the Communication Profile for the Hearing Impaired (CPHI), (Demorest and Erdman, 1986, shown in Appendix B.).

15. Attitude toward hearing loss as measured by the Communication Strategies scale of the CPHI, shown in Appendix B.

16. Subject's motivation for pursuing hearing aid use (self-motivation versus encouragement from others).

Procedures for measuring all of the variables listed above are described in Chapter 2. Most of these variables were selected based upon the results of studies described in Section 1.2 of this paper. Although multiple regression has not been used with this number of factors in previous studies of hearing aid success, correlations have been tested between many of these factors and hearing aid usage, satisfaction, or performance. With the exception of comfortable loudness level, the variables selected for this study are those for which a relationship has been suggested between the variable and some measure of hearing aid success in a previous study, although in some cases the variable is measured differently in the current study.

Loudness discomfort level was initially considered as a possible factor to include in this study based upon the finding of Kapteyn (1977) that satisfaction ratings were significantly correlated with aversion to loud sounds. (Not all hearing aids are ordered with compression circuitry, and even compression hearing aids can exceed a hearing aid user's loudness discomfort levels if these levels are not measured carefully by the

audiologist or if the automatic gain control on the hearing aid is not set accordingly.) By using dynamic range as a variable in the current study, the subjects' loudness discomfort levels were taken into account because loudness discomfort levels form the upper border of the dynamic range. The dynamic range also represents the subjects' overall range of usable hearing.

Attitude toward hearing aid use was selected as a factor because of the findings of Brooks (1989) and Hosford-Dunn and Baxter (1985). Brooks used an informal questionnaire constructed for his study to obtain information regarding subjects' attitude toward hearing aid use, and Hosford-Dunn and Baxter used The Feasibility Scale for Predicting Hearing Aid Use (FSPHAU) which was developed by Rupp, Higgins and Maurer (1977). The FSPHAU is also an informal scale which is based upon clinicians' assessments rather than those of the client. Instead of applying these measures in the current study, the "Personal Adjustment" and "Communication Strategies" scales of the Communication Profile for the Hearing Impaired (CPHI) were selected for measuring subjects' adjustment to hearing loss. The CPHI is a test that is familiar to many audiologists, through the literature if not through first-hand experience. Such aspects of the test as norms, retest stability of the scales, scale composition and item analysis have been studied thoroughly and have been described by the test's authors (Demorest and Erdman, 1986, 1987, 1988).

The audiologist performing the hearing aid selection and fitting was considered as a possible variable because individuals vary in their approaches to selection, fitting and counseling. However, it was found to be impractical to include audiologist as a variable because of the large number of student clinicians, supervising audiologists, and supervisor-student combinations working with clients in the University Hearing Clinic.

1.2 Review of the Literature

A number of studies have been conducted surveying hearing aid users at various intervals after purchasing their hearing aids, usually one month to two years. The purpose of these studies has been to determine the success of hearing aid fittings and to understand some of the problems encountered by new hearing aid clients. There have been three general approaches to measuring the success of hearing aid fittings from the client's perspective.

1- The extent of hearing aid usage has been determined, usually by asking for the average number of hours the hearing aid is worn per day.

2- Satisfaction with amplification has been rated on a scale usually ranging from 3 to 10 points. Points on the scale are often given labels such as "very satisfactory" or "not satisfactory" at least at the end points.

3- Self-assessment tests or questionnaires have been administered, asking clients about aided communication in a variety of listening situations. Responses may reflect either aided performance or aided benefit, depending upon the wording of the questions. Some of the self-assessment tests or questionnaires have received a great deal of study and others appear to be rather informal, designed for a particular study and not intended for widespread application.

In addition to reporting hours or category of hearing aid usage, satisfaction ratings, or performance/benefit scores; many studies have attempted to identify relationships between these measures of hearing aid success and other factors or characteristics. In most cases the factors investigated have been audiometric, such as pure tone average or speech reception threshold; or demographic, such as age or gender. Correlations have been tested between individual factors and hours of use, satisfaction ratings, and self-assessed performance/benefit scores. In other studies, numbers or percentages have been presented without statistical analyses.

1.2.1. Factors Related to Client-Assessed Aided Performance/Benefit

Scherr, Schwartz, and Montgomery (1985) administered a hearing aid questionnaire developed by the Walter Reed Medical Center staff to 377 hearing aid patients. Subjects were asked to rate their aided performance on a four point scale (excellent, satisfactory, somewhat helpful, or little to no use) for seven listening situations. The performance ratings were found to vary depending upon the patients' aided improvement in word recognition scores in noise. Among the subjects rating aided performance as "excellent", the largest number demonstrated a 10-20% improvement in word recognition scores with amplification. (These did not happen to be the subjects with the highest percentage of improvement in word discrimination.) There was no difference in hearing aid performance ratings based upon pure tone averages or speech reception thresholds. A statistical analysis of their results was not carried out.

Gerber and Fisher (1979) measured perceived aided benefit (although they called it satisfaction) using a questionnaire regarding aided communication ability in a variety of situations to determine if client-assessed performance could be predicted using scores on Speaks and Jerger's (1965) Synthetic Sentence Identification sentences in various signal-to-noise conditions. Client-assessed aided performance and speech recognition in difficult signal-to-noise conditions were found to be correlated, whether using synthetic sentence or monosyllabic word materials. There was no correlation between perceived aided performance and speech recognition in quiet conditions.

Berger et al. (1982) asked subjects how much help they received from their hearing aids. Categories included "a lot", "some", "very little" and "none". Correlations were not tested. However, there appeared to be differences in perceived hearing aid benefit depending upon the subject's gender and speech discrimination ability tested in quiet conditions. Perceived aided benefit appeared to be similar for young versus old

subjects and for subjects with low versus high pure tone averages. In a similar survey, Berger and Hagberg (1982) found no significant correlation between help received from hearing aids and respondents' ages, pure tone averages or speech recognition scores tested in quiet conditions.

Hutton (1980) investigated the effects of hearing loss, experience using hearing aids and age on subjects' scores on his Hearing Problem Inventory self-assessment scale. The scores of subjects with moderate and severe hearing loss showed more post-fitting improvement than those of subjects with mild hearing loss for new, but not for experienced hearing aid users. Age effects were small, with self-reported problems gradually increasing with age. There were no statistical analyses on these factors.

Kapteyn (1977a) used a 38 item questionnaire to investigate client-assessed aided performance. The questionnaire included three subtests: Hearing Index, Aural Perception Index and Social Index. Results on these subtests were not found to be correlated with pure tone averages or with speech discrimination scores.

Mulrow, Tuley and Aguilar (1992) found that baseline (unaided) Hearing Handicap Inventory for the Elderly (HHIE) scores and years of education were significant predictors of aided HHIE scores, their measure of aided performance. It is logical that there might be some correlation between results of the same test given before and after hearing aid fitting, particularly because some of the questions relate to the subjects' attitudes, which may not change quickly with hearing aid use. They did not find the other variables they tested to be predictive of client-assessed performance: age, locus of control, comorbid diseases, medications, visual acuity, or manual dexterity. Summarizing the conclusions of Mulrow et al., although some of their factors were significantly associated with hearing aid performance, the authors did not feel that specificity was high enough to reliably predict which hearing aid fittings would be unsuccessful using their best regression equations.

Table 1 summarizes the factors which appear to be related to client-assessed hearing aid performance or benefit based upon the studies cited above. Client-assessed performance was most consistently related to speech recognition in noise. Other factors which could be useful for predicting perceived performance based upon these studies include the client's gender, years of education, and previous hearing aid use.

When examining only the studies in which statistical tests were carried out, and excluding the HHIE as a predictor because it was also the response variable representing performance in the Mulrow et al. study, only speech perception in noise and years of education were related to perceived aided performance.

1.2.2. Factors Related to Hearing Aid Usage

Studies have shown average hearing aid usage ranging from one or two hours to 11 hours per day for subjects with moderate hearing loss (Hutton, 1982 cited by Oja and Schow, 1984). Gerber and Fisher (1979) used hearing aid usage categories of "almost always", "often", "occasionally" and "never" rather than hours of use per day to represent successful hearing aid fitting. The possibility of predicting subjects' hearing aid usage was examined using word recognition testing with monosyllabic words (Carhart, 1946) and with Speaks and Jerger's (1965, described in Jerger and Hayes, 1976) Synthetic Sentence Identification (SSI) sentences, presenting both words and sentences at five different signal-to-noise levels. The two speech material types differed very little in their usefulness for predicting hearing aid usage. The more difficult listening conditions, 0 dB signal-to-noise or lower, using either type of speech material were significantly correlated with hearing aid usage, although the tests in quiet were not.

Berger et al. (1982) reported results of a hearing aid use survey involving 244 respondents. Percentages of subjects falling into five different usage categories (1-2 hours, 3-4 hours, 5-6 hours, 7-8 hours and 8+ hours) were reported in relation to categories of gender, age, pure tone average, and speech discrimination scores. A

Table 1. Number of studies suggesting a relationship and no relationship between unaided factors and client-assessed aided performance/benefit.

Unaided Factors	Relationship	No Relationship
Pure Tone Average/Degree of Loss	1	4
Speech Reception Threshold	0	1
Speech Recognition in Quiet	1	3
Speech Recognition in Noise (one involved aided testing)	2	0
Age	1	3
Gender	1	0
Previous Use	1	0
Hearing Handicap Inventory for the Elderly	1*	0
Years of Education	1	0
Locus of Control	0	1
Comorbid Diseases	0	1
Medications	0	1
Visual Acuity	0	1
Manual Dexterity	0	1

* The HHIE was also the measure of aided performance in this study

statistical analysis was not applied. However, the hearing aid wearer's gender did not appear to be a factor related to hearing aid usage, although it appeared that age and pure tone average could be. Younger subjects wore their hearing aids slightly longer than older subjects, and those with greater hearing loss wore their hearing aids more hours per day than subjects with milder hearing loss. No difference in hearing aid usage was seen based upon speech discrimination scores in quiet. In another study involving 257 respondents, the same investigators (Berger and Hagberg, 1982) found no correlation between hours of hearing aid use and the factors of age, speech discrimination ability in quiet or pure tone average.

Ovegard and Ramstrom (1992) carried out follow-up interview sessions to obtain information regarding new hearing aid users approximately one year after their fittings. A large percentage (about 30%) of their clients were using their hearing aids less than one hour per day. A significant correlation was found between hours of hearing aid use and the slope of hearing loss (the difference between thresholds at 1000 Hz and 4000 Hz). Subjects with low usage had steeper hearing losses. A relationship was not found between speech recognition and hearing aid usage.

Nabelek, Letowski and Tucker (1991) examined differences between elderly full-time users, part-time users and nonusers of hearing aids in their willingness to tolerate background competing noise while listening to ongoing speech. Full-time hearing aid users tolerated significantly higher levels of background music and speech spectrum noise than part-time and nonusers did when listening to the speech at a comfortable volume. These findings suggested that a subject's ability to tolerate competing noise could be predictive of hearing aid usage.

Surr et al. (1978) examined the usage of hearing aids by having subjects report whether they used their hearing aids "always", "often", "occasionally" or "never". Percentages in each category were reported according to subjects' ages and speech

reception threshold ranges. No statistical analyses were performed, so it is difficult to judge the significance of their findings. However, they found an age difference of about 20 years between subjects always wearing their hearing aids and subjects never wearing their hearing aids, with the older subjects showing less hearing aid use. Little difference in unaided speech reception thresholds was observed between the usage categories. Unaided speech recognition scores using monosyllables in quiet and noise both showed differences greater than 10% between hearing aid usage categories. Subjects wearing their hearing aids "often" or "occasionally" had speech recognition scores more than 10% better than subjects reporting that they "never" wore their hearing aids. There was a smaller difference between speech recognition scores of subjects in the categories of "always" or "never" using their hearing aids, apparently because subjects in these two groups were experiencing a greater degree of hearing loss than subjects in the "often" or "occasionally" categories. Although a 10% difference in word recognition scores is often not statistically significant (Thornton and Raffin, 1978), for the purposes of this summary the findings of Surr et al. will be classified as supporting a possible relationship between word recognition scores and hours of hearing aid use. Hearing loss slopes did not seem to influence hearing aid usage.

Ewertsen (1974) asked both clients and professionals to categorize clients' hearing aid usage as "always", "often", "rarely" or "never". Again, no statistical analyses were performed. Contradicting the results of Berger et al., which did not suggest a relationship between speech reception threshold and hearing aid usage, Ewertsen's data showed greater hearing aid usage among subjects with poorer speech reception thresholds. Hearing aid usage did not seem to depend upon age.

Hutton (1980) examined the effects of experience with hearing aid use (initial versus replacement fitting), degree of hearing loss based upon pure tone average of the better ear, age, and employment on hours of hearing aid use. Experienced users wore

their hearing aids a significantly greater number of hours per day than new hearing aid users. A relationship was also found between hearing aid usage and the pure tone average of the better ear. Subjects with a moderate degree of hearing loss wore their hearing aids more hours per day than subjects in other hearing loss categories. Also, employed subjects wore their hearing aids longer than unemployed subjects, and older subjects seemed to wear their hearing aids slightly less than younger subjects. The data for employment and age were not analyzed statistically.

As in the Hutton study, Hutton and Canahl (1985) found a significant correlation between hours of daily hearing aid use and the pure tone average of the better ear for subjects who were employed. Hearing aid usage did not vary significantly with degree of hearing loss for unemployed subjects. These findings suggests that both degree of hearing loss and employment status are variables which may be predictive of hearing aid usage. Kapteyn (1977a) did not find hours of hearing aid use to be correlated with pure tone average or with maximum speech discrimination scores.

Brooks (1989) examined the relationship between a subject's attitude and hearing aid usage. Before subjects were fitted with hearing aids a questionnaire was administered regarding motivation for using hearing aids and attitude toward hearing loss. Four months later data were obtained regarding hours of daily hearing aid use. Subjects with more realistic attitudes toward hearing loss and greater motivation for trying amplification were found to be likely to wear their hearing aids for more than four hours per day than were subjects with poorer acceptance of hearing loss.

Mulrow et al. (1992) used multiple regression to identify factors predictive of the number of hours subjects wore their hearing aids per week (as well as satisfaction and performance). A number of factors were proposed as possible predictors of hearing aid success which were primarily relevant for an elderly client population, but also included pure tone average, education and age. Of the factors studied, only the clients' number of

medications used was partially predictive of weekly hours of hearing aid use. The specific medications taken by their subjects were not identified. This variable was selected to reflect the burden of concurrent illnesses experienced by the subjects rather than an effect of the drugs themselves.

Table 2 provides a summary of the unaided factors or characteristics to which, based upon the studies described above, hearing aid usage seems to be related. Hearing aid usage was found most consistently to be related to the unaided factors of speech recognition in noise and employment. (Studies involving speech recognition are being grouped together regardless of test material because the relationships between speech recognition and hearing aid use appear to be the same for all speech materials studied.) Factors which have received little attention in the literature up to this point, but for which there is evidence of a relationship to hearing aid use, are toleration of background noise, previous experience using amplification, and number of medications taken by the client.

All of the studies cited in this review have involved large numbers of subjects. However, because correlation or other statistical tests were not applied to the data in many of these studies, the significance of the findings is uncertain in many cases. When examining the results of only those studies in which statistical analyses were carried out, evidence has pointed to few potentially predictive factors. Only speech recognition in noise, pure tone average (in two out of the four studies in which correlations have been performed), tolerated signal-to-noise levels, number of medications taken, and experience using hearing aids have been shown to be related to amount of hearing aid use. The findings of these studies in which significant relationships have been found have not been replicated or have not been replicated consistently.

Although studies expressing hearing aid usage in hours per day or by category such as "always", "sometimes" or "never" have been popular, it is possible that results expressed in this way may be misleading. Satisfied clients with successful hearing aid

Table 2. Number of studies suggesting a relationship and no relationship between unaided factors and hearing aid usage.

Unaided Factors	Relationship	No Relationship
Pure Tone Average	3	3
Slope of Hearing Loss	1	1
Speech Reception Threshold	1	1
Speech Recognition in Quiet	1	5
Speech Recognition in Noise	2	0
Tolerated Signal-to-Noise Level	1	0
Age	3	3
Gender	0	1
Employment	2	0
Previous Use	1	0
Hearing Handicap Inventory for the Elderly	0	1
Attitude Toward Hearing Loss	1	0
Years of Education	0	1
Locus of Control	0	1
Comorbid Diseases	0	1
Medications	1	0
Visual Acuity	0	1
Manual Dexterity	0	1

fittings may not wish to wear their hearing aids full-time for a variety of reasons. For example, clients with health problems may sleep more and wear their hearing aids less each day, and clients working in loud conditions are often advised not to wear their hearing aids at work. Oja and Schow (1984) proposed a partial solution to this problem. Full-time hearing aid use is assumed to ordinarily involve wearing a hearing aid for 16 hours each day. An adjusted percentage of hearing aid use can be obtained by dividing a subject's actual hours of daily hearing aid use by their hours of possible use. The hours of possible daily hearing aid use for an individual client is obtained by subtracting the average amount of time each day in which the client is working in noise, taking a nap, or exercising from the 16 waking hours representing maximum use.

1.2.3. Factors Related to Hearing Aid Satisfaction Ratings

Kapteyn (1977a), in addition to measuring hours of hearing aid use, also asked subjects to rate their "appreciation" of their hearing aids on a scale of 1 to 10. A rating of 1 indicated that their hearing aid was of "no use" and 10 represented excellent appreciation of the hearing aid. The satisfaction ratings were not correlated with pure tone averages or with speech recognition scores. Kapteyn reported responses to the same question in his 1977b publication, stating that no correlation was found between hearing aid ratings and subject age. There was a significant correlation between satisfaction ratings and aversion to loud sounds. Berger and Hagberg (1982) found no significant correlations between subjects' satisfaction with their hearing aid(s) and their ages, pure tone averages or speech recognition scores.

Cunningham et al. (1978) surveyed hearing aid users two years after their fittings. Satisfaction ratings were obtained on a three point scale: very satisfied, satisfied, and not satisfied. Of 71 respondents, 40% were very satisfied, 48% were satisfied and 12% were not satisfied. Cunningham et al. attributed the high degree of satisfaction they observed to

the fact that the subjects returned to the clinic for follow-up visits. (Of their dissatisfied hearing aid users, 75% did not return for their post-fitting appointment.) The finding that only 12% of the subjects were dissatisfied with their hearing aids is similar to the results of Berger et al. (1982), who found that only 7% of respondents reported little or no help from their hearing aids. Cunningham et al. tested correlations between satisfaction ratings and speech reception thresholds, speech discrimination in quiet conditions, and age. None were found to be significant.

Hayes, Jerger, Taff and Barber (1983) asked subjects to rate their hearing aids as very helpful, satisfactory, sometimes helpful or unsatisfactory. Subjects in the "very helpful" or "satisfactory" categories obtained significantly better scores on the aided Synthetic Sentence Identification (SSI) test in noise at a -10 dB signal-to-noise level when compared with subjects in the lower satisfaction categories. They found no systematic relationship between rating category and the length of time subjects had used their hearing aids. The wording of their categories is somewhat confusing in that both the words "help" and "satisfaction" are included. The word "help" would seem to be addressing perceived benefit rather than overall satisfaction. Because the word "satisfaction" appears more often than the word "help" in the rating system of Hayes et al., it is being included here among studies rating hearing aid satisfaction.

Jerger and Hayes (1976) also used both the words "help" and "satisfaction" in a rating scale for hearing aid users. Subjects were asked to rate their hearing aid satisfaction on a three point scale. Categories included "satisfactory", "sometimes helpful", and "unsatisfactory". Of 65 respondents, 87.2% found their hearing aids to be satisfactory or sometimes helpful, which is similar to the findings of Berger et al. and Cunningham et al. No relationship was found between hearing aid satisfaction and pure tone averages or speech recognition scores. It was found that satisfaction declined as the age of the subjects increased. Satisfaction ratings also seemed to be related to the slope of the

subjects' hearing losses. Slope of the audiogram was defined as the difference between hearing thresholds at 1000 Hz and 4000 Hz. Subjects describing their hearing aids as "satisfactory" had a mean slope of 26.9 dB and subjects reporting their hearing aids to be "unsatisfactory" had a slope of 17.2 dB. As in the Hayes et al. (1983) study, satisfaction also seemed to be related to SSI scores in a -10 dB S/N condition. A statistical analysis was not applied to these data.

In their multiple regression study of factors which may be predictive of hearing aid success in the elderly, Mulrow et al. (1992) found that age and baseline Hearing Handicap Inventory for the Elderly (HHIE) scores were most predictive of hearing aid satisfaction. Satisfaction was measured using an 11 item questionnaire proposed by Lazenby, Logan, Ahlstrom & Bess (1986). The HHIE includes two subtests, Emotional and Social. Mulrow et al. did not analyze the results for Emotional and Social scores separately, so it is not known if the emotional aspects, such as attitude toward hearing loss, or the social/ performance aspects of the test are more predictive of satisfaction. In addition, the tool used to represent satisfaction is a questionnaire in which the subject rates how helpful his or her hearing aid is in various listening situations. Thus, it may have been measuring perceived performance more than general satisfaction.

Hosford-Dunn and Baxter (1985) used multiple regression to test the usefulness of several variables in predicting hearing aid satisfaction ratings. Variables included the Feasibility Scale for Predicting Hearing Aid Use which was developed by Rupp, Higgins and Maurer (1977), age, hearing loss, word recognition in quiet, and the Hearing Performance Inventory (Lamb, Owens, and Schubert, 1983). Of these unaided variables, the only one found to be significantly related to satisfaction was a portion of the FSPHAU involving a rating made by the clinician of the client's motivation regarding hearing aid use.

Table 3 summarizes the factors which appear to be related to hearing aid satisfaction ratings based upon the studies described above. Although they have not been

Table 3. Number of studies suggesting a relationship and no relationship between unaided factors and ratings of hearing aid satisfaction.

Unaided Factors	Relationship	No Relationship
Pure Tone Average	0	3
Slope of Hearing Loss	1	0
Speech Reception Threshold	0	1
Speech Recognition in Quiet	0	4
Speech Recognition in Noise	2	0
Loudness Discomfort Level	1	0
Age	2	3
Previous Use	0	1
Hearing Handicap Inventory for the Elderly	1	0
Years of Education	0	1
Locus of Control	0	1
Comorbid Diseases	0	1
Medications	0	1
Visual Acuity	0	1
Manual Dexterity	0	1
Clinician's Judgment of Motivation	1	0

studied thoroughly, the factors which appear to possibly relate to hearing aid satisfaction are speech recognition in noise, audiogram slope, aversion to loud sounds (loudness discomfort level), and the Hearing Handicap Inventory for the Elderly. When examining only those studies in which statistical analyses were conducted, but excluding the Mulrow et al. (1992) study in which direct satisfaction ratings were not obtained; speech recognition in noise, age, and aversion to loud sounds seem to have potential predictive value.

1.2.4. Relationships Between Hearing Aid Performance/Benefit, Usage and Satisfaction

Several studies have reported testing for correlations among hearing aid performance/benefit, usage, and satisfaction. Some correlation would be expected if they all reflect the success of a hearing aid fitting. However, correlations should not be high if they are measuring different aspects of hearing aid success, as is assumed in this paper. Gerber and Fisher (1979) found a moderate correlation (.67) between hearing aid satisfaction ratings and category of hearing aid usage. Hutton and Canahl (1985) found a slightly weaker correlation (.47) between hours of hearing aid use and perceived benefit as measured by their Hearing Problem Inventory, and between satisfaction ratings and perceived benefit (.40). The correlation between satisfaction and benefit of .40, although close to that of use and benefit, was not considered significant.

Walden, Demorest and Helper (1984) found a significant, but weak correlation between hearing aid use and client-assessed aided benefit. Kapteyn (1977b) found a correlation between satisfaction and perceived performance. Oja and Schow (1984) did not find a significant correlation between any of the three measures. In summary, most of the correlations obtained in these studies, although statistically significant, were not high.

The most frequently occurring correlation was between perceived performance/ benefit and hearing aid usage.

1.2.5. Summary of the Literature Review

The composite results from the studies cited in this review indicate that the same factors may not always be predictive of all three measures of hearing aid success addressed in this study: client-assessed performance/benefit, hours of use, and satisfaction ratings. For example, it appears that hearing aid usage may be more strongly related to a subject's age than are satisfaction ratings or perceived performance. Slope of the hearing loss, however, may be more useful for predicting hearing aid satisfaction than for predicting hours of hearing aid use. Speech recognition in noise is the only factor which seems to be correlated with all three measurement approaches. Speech recognition in quiet appears not to be useful for predicting hours of use, satisfaction rating, or perceived performance with hearing aids. There are several factors which appear to be related to at least one of the three client-reported measures of hearing aid success, but possible relationships to the others have not yet been investigated. There has only been one study (Mulrow et al., 1992) which has applied multiple regression analysis to a number of factors in order to obtain equations for predicting hearing aid usage, satisfaction or perceived performance. The Mulrow et al. (1992) study focused on determining when hearing aids should be recommended for elderly clients with medical problems, so the set of factors they included differed from those in the current study. (Variables used by Mulrow et al. which were not included in the current study are the Hearing Handicap Inventory for the Elderly, locus of control, comorbid diseases, vision, manual dexterity, and speech reception threshold.) The studies which have been discussed provided some guidance as to variables which should be included in the present study.

1.3. Hypotheses

Research Hypothesis 1. For subjects who are purchasing their first binaural hearing aids there are combinations of unaided factors which, when used as variables in multiple regression equations, are predictive of perceived aided performance as measured by Profile of Hearing Aid Performance (PHAP) subscale scores. The PHAP subscales include Aversiveness of Sounds, Background Noise, Distortion of Sounds, Ease of Communication, Familiar Talkers, Reduced Cues and Reverberation. Unaided factors to be considered include pure tone average, slope of hearing loss, speech recognition in noise, dynamic range, comfortable loudness level, tolerated signal-to-noise level when listening to speech in background noise (multitalker babble and speech spectrum noise), the difference between measured insertion gain and target gain using the National Acoustic Laboratories' formula, age, gender, percentage of time employed, years of education, number of medications used, Personal Adjustment and Communication Strategies scores from the Communication Profile for the Hearing Impaired, and motivation for pursuing hearing aid use (whether subjects were self-motivated or encouraged by family members or others). The regression equations for the seven different PHAP subscales may contain some of the same predictor variables, but will not be exactly the same.

Research Hypothesis 2. For the same subjects there are also combinations of unaided factors which, when used as predictive variables in multiple regression equations, are predictive of hours of daily hearing aid use and of hearing aid satisfaction ratings. The same group of unaided variables is included in the regression analyses for hearing aid usage and satisfaction as listed above for the study of perceived performance.

Research Hypothesis 3. The sets of predictive variables which will be obtained in the equations for hearing aid usage and satisfaction will differ from one another as well as

from the equations for the seven PHAP subscales, although some of the same variables may overlap.

CHAPTER 2

METHOD

2.1. Subjects

Data obtained from forty-six adult subjects, ages 52-86 years, who were purchasing hearing aids for the first time were included in this study. Because results could differ for binaural versus monaural fittings, only subjects using binaural hearing aids were included. All subjects had acquired, predominantly sensorineural hearing loss. The largest difference between air and bone conduction thresholds for any subject was an average of 6.25 dB for the frequencies of .5, 1, 2 and 4 KHz, with the mean for all subjects being 2.58 dB. Pure tone averages (the average of thresholds for 500, 1000 and 2000 Hz from both ears) ranged from 10 dB to 50.5 dB, with a mean of 31.8 dB. All subjects had symmetrical hearing, with the greatest interear difference being 20 dB for the average of .5, 1, 2, and 4 KHz. The average interear difference for all 46 subjects was 6.68 dB.

Clients purchasing binaural hearing aids were identified from a list of hearing aid orders in the University of Tennessee Hearing Clinic. Those clients meeting the criteria of having an acquired, symmetrical sensorineural hearing loss who were purchasing hearing aids for the first time were sent a letter describing the research project (a copy of the letter is shown in Appendix C). Complete audiometric testing and hearing aid counseling regarding the clients' decision to purchase amplification were carried out through the hearing clinic before the clients were contacted for this study. About one week after the letters were sent to prospective subjects, they were contacted by telephone to determine if they were interested in taking part in the study. Of the clients contacted, 82% were able to participate in the study. The Communication Profile for the Hearing Impaired (Demorest and Erdman, 1986, shown in Appendix B) was mailed to the subjects to be

completed and returned when they returned to the Hearing Clinic. Subjects were generally seen for one hour of testing as part of this study on the same day they were fitted with their hearing aids; before their fittings, if possible. Consent forms were signed during the testing session. A copy of the consent form is shown in Appendix C. Hearing aid fittings were conducted by the Clinic audiologists. In the consent form, the subjects agreed to allow the investigator to have access to information regarding their hearing loss and hearing aid fittings from their clinic files. Subjects were given the Profile of Hearing Aid Performance (Cox and Gilmore, 1990, shown in Appendix A) questionnaires during their testing sessions, and they were asked to complete and return them by mail within six weeks after their hearing aid fittings. Subjects were paid $15.00 for participating in the study.

2.2. Procedures

2.2.1. Measurement of Hearing Aid Performance, Usage and Satisfaction

Subjects' perceived hearing aid performance was assessed using the Profile of Hearing Aid Performance, PHAP, (Cox and Gilmore, 1990). The authors describe it as a "66-item self-administered inventory that quantifies performance with a hearing aid in everyday life". Subjects were given a copy of the PHAP on the day they were fitted with their hearing aids, and were asked to complete and return the questionnaires after wearing the hearing aids for six weeks. Although subjects were asked to complete the questionnaires after wearing their hearing aids for six weeks, questionnaires were accepted and included in the study if they were completed and returned earlier or later than six weeks. Six weeks was selected as a realistic time period for adjustment to hearing aids for the purposes of this study. (See Results Section 3.1.)

Results of the PHAP can be divided into seven subtest scores: Familiar Talkers, Ease of Communication, Communication in Reverberation, Communication in

Background Noise, Communication with Reduced Cues, Aversiveness of Sounds, and Distortion of Sounds. When responding to the PHAP questions the subject is asked to select the percentage of time they experience difficulty in a specific listening condition. Thus, when the questions are sorted according to subscale category and responses for each category are averaged, the scores represent the percentage of difficulty the client believes he or she is experiencing in each of the subscale areas. Questions making up the Familiar Talkers and Ease of Communication subscales involve listening in quiet conditions. Questions regarding "Ease of Communication" include wording such as "I have to strain" or "I have difficulty". "Reduced Cues" situations are generally those in which a speaker's face is not visible and only auditory information is available, such as talking on the telephone or listening to the radio. Regression equations were obtained for each of the seven subscales in order to determine if the unaided data would be useful in predicting clients' perceived performance in any or all of these communication situations.

An additional page (shown in Appendix A) was included with the PHAP questionnaire asking subjects to report the average number of hours they had been wearing their hearing aids each day. They were also asked to indicate the average number of hours each day in which they were not wearing their hearing aids due to sleeping, working in noise or exercising. This additional information regarding hearing aid use was obtained in order to calculate a percentage of hearing aid use as proposed by Oja and Schow (1984). This approach is described in section 1.2. In addition to completing the Profile of Hearing Aid Performance questionnaire and reporting their hours of hearing aid use, subjects were asked to rate their overall satisfaction with their hearing aids. A seven point rating scale borrowed from Oja and Schow (1984) was used, in which 1= highly satisfied, 2= moderately satisfied, 3= slightly satisfied, 4= neutral, 5= slightly dissatisfied, 6= moderately dissatisfied and 7= highly dissatisfied.

2.2.2. Measurement of Unaided Variables

Sixteen unaided variables were investigated to determine their usefulness in predicting perceived hearing aid performance, satisfaction and usage. All of the variables were unaided in that they can be obtained before a client makes a definite decision regarding hearing aid use. One of the variables, the difference between NAL target gain and actual insertion gain did involve measurements with hearing aids. Data involving auditory measurements were obtained for both ears. The values from the two ears were averaged, and this single value was entered into the analyses for each variable. Procedures for collecting data for each of the unaided variables are as follows.

Demographic Factors

Information was obtained from the subjects regarding age, gender, employment and education. When the subjects came to the University for their hearing aid fittings and for the additional testing required for this study, the investigator obtained background information from each subject using the subject information form shown in Appendix C. Age and gender were noted on the information form, as well as the subjects' percentage of employment (full-time, 50%, etc.) and years of education. Subjects were asked to include volunteer work when reporting their time spent working. Very few subjects reported their percentage of work time to be anything other than full-time, half-time or none at all; so employment was included in the analysis as a categorical variable. If a subject reported working about 30% of a full work week, for example, his percentage of employment was rounded up to 50%. Subjects were asked how many years of education they had completed. If they responded that they finished high school, or college, they were considered to have completed the typical number of years required for these degrees, 12 years of education for high school and 16 years of education for college.

Pure Tone Average and Comfortable Loudness Level

Copies of the subjects' audiograms were obtained from their Hearing Clinic files. In the consent form for this study, subjects' gave permission for information to be obtained from their hearing clinic files. Audiologic information contained on the audiograms included pure tone air and bone conduction thresholds, speech reception thresholds, word recognition scores, and comfortable loudness levels. Pure tone averages, which represent the subjects' degree of hearing loss were calculated from pure tone hearing thresholds. Pure tone average, for the purpose of this study, was defined as the average of eight thresholds: .5, 1, 2, and 4 KHz from each ear. Four thousand Hz was included because of the importance of higher audiometric frequencies for maximum intelligibility of speech (French and Steinberg, 1947). The comfortable loudness levels analyzed in this study were copied from the clients' audiograms and the values for the two ears were averaged.

Slope of Hearing Loss

The slopes of subjects' hearing loss were calculated based on the audiometric thresholds obtained from the Hearing Clinic records. For each ear, slopes were determined using the equation : Slope= $(L_{0.5\ kHz} + L_{1\ kHz})/2 - (L_{2kHz} + L_{4kHz})/2$. L represents the hearing threshold level for each of the frequencies indicated. The slopes from each ear were averaged to obtain a single value representing slope which could be entered into the regression analyses.

Dynamic Range

According to Hemeyer (1980), dynamic range can be defined as the usable range of hearing with respect to intensity. When applied to the understanding of speech, he suggested as an operational definition of dynamic range, the intensity range between a person's spondee threshold and his or her tolerance level (loudness discomfort level) for speech. Thus, in this study the dynamic range was obtained by subtracting speech

reception thresholds from loudness discomfort levels for speech for each ear. In the statistical analyses, dynamic range is represented by an average of both ears.

Testing was carried out using the Madsen OB 802 audiometer. Speech reception threshold (SRT) values for each ear were obtained through earphones using taped CID W-1 spondaic words (List A). Subjects were familiarized with the test items at a comfortable volume, then the Tillman and Olsen (1973) procedure was used to obtain a threshold to the nearest 2 dB. The Tillman-Olsen procedure for SRTs is a descending procedure which begins in 10 dB steps. When no response is obtained, the level is increased by 10 dB and testing continues, changing the step size to 2 dB.

Loudness discomfort levels (LDLs) for speech were measured for each ear through earphones using the same spondee tape described above. The investigator read the LDL test instructions (see Appendix C) to the subjects and they were provided with a list of categories (also shown in Appendix C) for labeling loudness levels. It was the list used by Hawkins, Walden, Montgomery and Prosek (1987) which includes:

Painfully Loud

Extremely Uncomfortable

Uncomfortably Loud

Loud, but O.K.

Comfortable, but Slightly Loud

Comfortable

Comfortable, but Slightly Soft.

Soft

Very Soft

All stimuli were located near the middle of this scale. The categories of "painfully loud" and "very soft" were provided to help subjects label the sounds they heard in relation to the full range of sounds potentially available through their hearing aids. The subjects were

instructed to point to the loudness category which best described each of the stimuli. The level of interest was "Uncomfortably Loud". An ascending method of limits procedure was used with a 2 dB step size. Testing began 6 dB above the level at which word recognition testing was carried out for each ear during the subject's audiologic evaluation. The procedure was repeated until the "Uncomfortably Loud" category was reached twice at the same intensity level.

Speech Recognition in Noise

Speech recognition in noise was tested using the Revised Speech Perception in Noise (SPIN) Test (Kalikow, Stevens and Elliott, 1977; Bilger, Neutzel, Rabinowitz and Rzeczkowski, 1984) Form 1. This test was selected because sentence material is more representative of everyday communication than words or syllables, which are used in most tests of speech recognition or perception. The SPIN test includes "high predictability" and "low predictability" sentences which also simulates everyday communication situations, in which the available contextual information varies. In addition, the SPIN test only requires scoring of the final/key word, making it easier to score than most other sentence tests.

Testing was carried out in an IAC audiometric test booth, in a sound field to simulate conversational situations in which background noise is present. A reel-to-reel tape recording of the Revised SPIN Test Form 1 was played through one channel of a Madsen OB 802 audiometer, through an amplifier and through a loudspeaker at 0 degrees azimuth. The competing 12 speaker babble from the SPIN test recording was played through the other channel of the audiometer as well as a second channel of the amplifier, and was presented through additional loudspeakers at 90 and 270 degrees.

Bilger et al. (1984) recommend presenting the SPIN sentences at 50 dB above a subject's reception threshold for the multispeaker babble. Initially a threshold for the babble was obtained for each subject to the nearest 2 dB, presenting the babble through the loudspeaker positioned at 0 degrees azimuth. The procedure used for obtaining these

thresholds was the same as is typically used for pure tone testing (ANSI S3.211978). The first subjects tested for the study found that sentences presented at 50 dB above their threshold for the babble were louder than they preferred to listen to. Therefore, sentences were instead presented at a comfortable level for each subject, which was generally 30 to 40 dB above his or her threshold for the babble. The level of the sentences was initially set by the investigator at 40 dB SL. After two sentences were presented, the tape was stopped and the subject was asked to comment on the volume. An adjustment to 30 or 35 dB SL was made at that time, if necessary. As recommended by Bilger et al., the competing multispeaker babble was presented at a signal-to-noise level of 8 dB. They cite Pearsons, Bennett and Fidell (1977) as suggesting an 8 dB signal-to-noise level as the median value encountered in real-life situations. Subjects were asked to repeat the final word of each test sentence. Scores represent the percentage of key words identified correctly out of a 50 sentence test.

Tolerated Signal-to-Noise Levels

The highest comfortable level of competing background noise was determined for 12-speaker babble and for speech spectrum noise using the procedures of Nabelek et al. (1991). An Auditec tape of Multitalker Noise was used for the babble, and speech spectrum noise was recorded from the Madsen OB 802 audiometer. The speech signal was an Auditec recording of Connected Discourse, which was a story read by a female talker. Power spectra of a 600 msec. section of each of the speech and noise stimuli are shown in Figure 1.[1]

Testing was carried out in a sound treated room. The speech stimulus and the competing noise were played through two different cassette tape recorders. The output from each tape recorder was fed through one of two separate channels of an equalizer, then through the two separate channels of the audiometer. The two channels of the

[1]All figures may be found in Appendices F through I.

audiometer were then mixed and played through the same earphone. The frequency response of the stimuli was modified by adjusting the equalizer to produce a response similar to that which would be expected with a hearing aid. The equalizer corrections used for setting frequency response were based upon the National Acoustic Laboratories' (NAL) procedure for selecting hearing aid frequency response and gain (Byrne & Dillon, 1986). The worksheet used for calculating frequency response is shown in Appendix C. Because the NAL formulas are for the purpose of determining desired hearing aid insertion gain, a correction was applied to these values to convert desired levels at the eardrum to the desired levels through an earphone or 6cc coupler (Bentler & Pavlovic, 1989).

Instructions (see Appendix C) were read to the subjects. Initially subjects were asked to adjust the audiometer dial to the most comfortable listening level on one channel for the connected speech stimulus using an up-down procedure in 2 dB steps. Then, competing noise, either the multitalker babble or the speech spectrum noise, was added at a 0 dB S/N level through the other channel. (The dial for adjusting the speech was on the right side of the audiometer and the dial for adjusting noise was on the left.) Subjects were asked to set the highest possible level of the noise which they would be willing to tolerate without becoming tired while listening to the words of the story. As with the connected speech, subjects were asked to use an up-down procedure when setting the highest comfortable level for the noise. The step size for the noise dial was also set at 2 dB. This procedure was repeated for each of the two noise types for each ear. Results from both ears were averaged to obtain one value for multitalker babble and one value for speech spectrum noise from each subject to enter into the statistical analysis.

Psychological Aspects of Hearing Loss

Psychological aspects of hearing loss and hearing aid use were assessed using the "Personal Adjustment" and "Communication Strategies" scales of the Communication

Profile for the Hearing Impaired (Demorest & Erdman, 1986, 1989). The Personal Adjustment component of the CPHI includes 8 scales: self-acceptance, acceptance of loss, anger, displacement of responsibility, exaggeration of responsibility, discouragement, stress, and withdrawal. The Communication Strategies scales include maladaptive behaviors, verbal strategies and nonverbal strategies. Overall, the Personal Adjustment and Communication Strategies scales of the CPHI made up an 88 item self-assessment test (shown in Appendix B). The scores range from 1 to 5, with lower scores representing greater difficulty. A score for Personal Adjustment and one for Communication Strategies from each subject were entered into the statistical analysis.

In addition to obtaining Personal Adjustment and Communication Strategies scores from each subject, subjects' were asked about their motivation for pursuing hearing aid use. As part of the history-taking (see the subject information form in Appendix C), subjects were asked if they were purchasing hearing aids as the result of self-motivation, family encouragement, or encouragement by a professional, such as their physician. Their responses were coded as 1 for self-motivation, 2 for family encouragement or 3 for professional encouragement. Only one subject reported pursuing hearing aid use because of professional encouragement, so that data point was combined with category "2" and only the two motivation categories were used for the purposes of data analysis, one representing self-motivation and the second representing encouragement from others.

Difference Between NAL Target and Insertion Gain

Selection and fitting of hearing aids was carried out by the University Hearing Clinic staff. The clinic audiologists and students generally determined target hearing aid gain using the National Acoustic Laboratories' (NAL) prescription method (Byrne and Dillon, 1986). Because the same hearing aid selection procedure was used for all of the hearing aid fittings in this study, it was not necessary to include hearing aid selection procedure as another variable which could influence hearing aid performance, satisfaction

or usage in this study. However, this fact limits the applicability of this study only to hearing aid fitting situations in which the NAL selection procedure is used. Fortunately, this procedure is one of the more popular prescription methods currently in use. In the Hearing Clinic the program for applying the NAL procedure is available on the Virtual M340 probe microphone system which is used for calculating target gain for each client and for determining if hearing aid insertion gain is a close match to the target. A computer print out showing target gain and insertion gain was available in each subject's clinic file.

Printouts of the probe microphone test results were examined to determine the difference between target gain and insertion gain at the frequencies of 500, 1000, 2000 and 4000 Hz for each ear. These values were recorded on the data sheet (see Appendix C). The average difference between target gain and insertion gain at these frequencies for both ears was determined and this value was entered into the statistical analysis.

2.2.3. Instrumentation and Calibration

Pure Tone Thresholds, Comfortable Loudness Levels and Insertion Gain Measures.

Pure tone thresholds, comfortable loudness levels and insertion gain were tested by audiologists and graduate student clinicians in the University Hearing Clinic. Audiometers used in the Hearing Clinic include a Virtual M320 and a Grason Statler GSI 16. These audiometers are calibrated quarterly according to current ANSI standards (ANSI S3.6-1989, ANSI S3.26-1981). A Virtual M340 probe microphone instrument was used for insertion gain measures. It is completely calibrated annually by a Virtual Corporation representative as recommended in the equipment manual.

Speech Reception Thresholds and Loudness Discomfort Levels.

Speech reception thresholds and loudness discomfort levels were determined in an IAC test booth using a Madsen OB802 audiometer with TDH-39 earphones. Speech stimuli were played through a ReVox PR99 reel-to-reel tape recorder. The audiometer

was calibrated quarterly according to ANSI standards. Calibration included the measurement of output when a taped calibration tone was played through the audiometer to be sure it was within 5 dB of the reference Sound Pressure Level for speech according to ANSI S3.6-1989. Ambient noise levels in the IAC test booth were adequate for threshold testing via earphones according to ANSI S3.1-1977. A listening check of the taped spondee stimuli through the earphones was completed each day before a subject was tested.

Speech Recognition in Noise.

Sound field testing was conducted out in an IAC audiometric booth. The reel-to-reel tape recording of the Revised SPIN Test Form 1 was played on a ReVox PR99 tape recorder. The test sentences were presented through one channel of a Madsen OB 802 audiometer, through a McIntosh amplifier (type 043-667/668), and through a Bang and Olufsen Beovox S45 loudspeaker at 0 degrees azimuth. The competing babble was presented through the other channel of the audiometer as well as a second channel of the amplifier, and was presented through additional Bang and Olufsen loudspeakers at 90 and 270 degrees. Ambient noise levels in the sound field were checked at one-third octave frequencies and were found to be adequate for speech recognition testing in sound field (based upon ANSI S3.1-1977). Uniformity of the sound field was checked and a position in the center of the booth was selected as the location in which the subject would be seated. At this location the intensity of speech spectrum noise played through the loudspeakers was uniform (+/- 1 dB) within 15 cm to the front, back, left, right, above and below the center (a procedure similar to that described by Walker, Dillon and Byrne, 1984).

Loudspeaker output was calibrated by presenting speech spectrum noise (recorded from the Madsen audiometer) through the same ReVox tape recorder used for playing the SPIN test. The noise was delivered through the left channel and the McIntosh amplifier to

the speaker at zero degrees azimuth, and through the right channel to the amplifier and the speakers at both 90 and 270 degrees. A sound field microphone connected to a B & K 2203 sound level meter was positioned at the selected location in which the subjects were to be seated. Applying sound field equivalent sound pressure levels (relating sound field to earphone measures) from Dirks, Stream and Wilson (1972) for loudspeakers at zero and 90 degrees azimuth; the amplifier was adjusted until loudspeakers were in calibration within 3 dB when the speech spectrum signal was presented at 70 dB. The audiometer dials were also found to be linear when presenting the speech spectrum noise through the loudspeakers between 50 and 90 dB (i.e., down to the noise floor), which was adequate for the suprathreshold soundfield testing of hearing-impaired subjects performed in this study. Calibration of the loudspeakers was checked monthly, and listening checks took place each day that the equipment was to be used.

Tolerated Signal-to-Noise Levels.

Testing was conducted in a sound treated room. The connected discourse stimulus was played through a JVC TD-W303 tape recorder and the competing babble or noise was played through a Technics M205 tape recorder. The output from each tape recorder was delivered through one of two separate channels of a Soundcraftsman TG3044-R one-third octave equalizer, then through the two separate channels of the audiometer. The two channels of the audiometer were mixed and played through the same TDH-39 earphone. The frequency response of the stimuli was modified by adjusting the equalizer to produce a response similar to that which would be expected with a hearing aid.

Like the other audiometers used in this study, the Madsen OB802 audiometer used for testing tolerated signal-to-noise levels was calibrated quarterly. However, only the levels of taped stimuli were measured because the audiometer was not used for other testing. The levels of a 1000 Hz calibration tone played through the JVC tape recorder

and the audiometer "Tape 1" and through the Technics tape recorder and the audiometer "Tape 2" fell within 5 dB of the reference Sound Pressure Level for speech according to the ANSI S3.6-1989 standard. Attenuator linearity also met the standard. During calibration the audiometer VU meters and the equalizer were set at 0 dB. Each day that a subject was tested, the equalizer was reset to zero. The taped calibration tones were played and the audiometer VU meters were reset to zero. A listening check of the taped stimuli was also performed daily.

After resetting the levels of the taped calibration tones, the equalizer was adjusted to fit the hearing loss of the next subject based upon their NAL target gain. Target gain was calculated using the worksheet shown in Appendix C. The correct equalizer settings were obtained by playing pure tones (.25, .5, 1, 2 and 4 KHz) generated by a B & K Beat Frequency Oscillator Type 1022 through the equalizer and reading the output on the audiometer VU meter. Adjustments were made on the equalizer, until the desired frequency response was achieved as closely as possible.

CHAPTER 3

RESULTS

3.1 Mean Values for Predictive and Response Variables

The mean values obtained for the 16 predictive variables are shown in Table 4. Also shown are the minimum and maximum values for each variable. Overall, the subjects in this study represent listeners with normal or borderline normal hearing for low frequencies, gradually sloping to a high frequency hearing loss. Two thirds of the subjects were male and one third were female. On average, hearing aid fittings matched NAL target gain within about 3 dB. Subjects had an average of 13.8 years of education, with a range of four to 21 years. Subjects were fairly evenly divided between working full-time, half-time and not working/retired. The mean percentage of time employed was 40%. Most of the subjects were pursuing hearing aid use because of their own motivation rather than influence from family members or others. Scores for the Personal Adjustment and Communication Strategies scales of the Communication Profile for the Hearing Impaired reflect some room for improvement, although the group as a whole was not demonstrating unusual difficulty in these areas. The mean scores fell within the norms obtained by Demorest and Erdman (1987). Average tolerated signal-to-noise levels were similar to those obtained by Nabelek et al. (1991) for their group of full-time hearing aid users. The average dynamic range and SPIN scores also appeared to be typical of a hearing impaired group.

The means, standard deviations and ranges of the response variables are shown in Table 5. They were obtained from questionnaires that were returned between two and 16 weeks after subjects' hearing aid fittings, with an average of seven weeks. The mean scores for the PHAP subscales showed a similar percentage of difficulty (see Section 2.2.1) for Reverberation, Background Noise, Reduced Cues, Aversiveness of Sounds and

Table 4. Means, Standard Deviations and Ranges of Predictive Variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
Pure Tone Average (dB)	31.8	10.4	10.0	50.5
Slope (dB)	-29.2	16.4	-66.2	6.2
Comfortable Loudness Level (dB)	65.0	7.8	50.0	82.5
Difference from National Acoustic Labs.' target gain (dB)	3.3	2.4	0.5	13.5
Age (years)	68.7	7.7	52.0	86.0
Gender	30% Female	-	-	-
Employment (%)	42.4	44.7	0.0	100.0
Medications (#)	2.0	1.8	0.0	7.0
Motivation for Hearing Aid Use (Self or other)	59% self-motivated	-	-	-
CPHI Communication Strategies	3.6	0.5	2.4	4.8
CPHI Personal Adjustment	3.4	0.5	2.1	4.6
Dynamic Range (dB)	64.6	15.3	31.0	93.0
Speech Perception in Noise Test Score (%)	68.3	16.3	36.0	96.0

Table 4, Continued.

Variable	Mean	Standard Deviation	Minimum	Maximum
Tolerated Signal-to-Noise Level for Babble (dB)	7.6	6.5	-0.5	26.0
Tolerated Signal-to-Noise Level for Speech Spectrum Noise (dB)	6.9	7.3	-4.5	28.0
Education (yrs.)	13.8	3.4	4.0	21.0

* Communication Profile for the Hearing Impaired

Table 5. Means, Standard Deviations and Ranges for Profile of Hearing Aid Performance (PHAP) Subscale Scores, Hearing Aid Usage, and Hearing Aid Satisfaction Ratings.

Variable	Mean	Standard Deviation	Minimum	Maximum
PHAP-Familiar Talkers Score (%)	10.4	8.2	1.0	32.3
PHAP-Ease of Communication Score (%)	23.1	17.1	1.0	71.4
PHAP- Reverberation Score (%)	31.3	15.2	5.4	60.8
PHAP- Background Noise Score (%)	31.2	14.0	3.2	64.6
PHAP- Reduced Cues Score (%)	34.7	13.6	6.5	65.2
PHAP-Aversiveness of Sounds Score (%)	37.5	23.0	3.9	90.8
PHAP-Distortion of Sounds Score (%)	31.6	18.6	1.0	74.8
Total PHAP Score (%)	28.4	12.1	6.9	59.4
Usage (hrs./day)	7.0	4.2	1.0	17.0
Satisfaction rating (best=1)	2.8	1.7	1.0	7.0

Distortion of Sounds; with all falling between 30 and 40 percent. Less difficulty was apparent for the Familiar Talkers (10%) and Ease of Communication (23%) subscales. These scores were better than those obtained by Cox and Gilmore (1990). However, their norms included subjects who had worn hearing aids for a number of years as well as new hearing aid users. Therefore, it can be assumed that some of their subjects experienced a greater degree of hearing loss than those represented in the current study.

On average, the subjects wore their hearing aids seven hours per day during the first seven weeks with their new hearing aids. Information was obtained regarding how many hours per day subjects would like to be able to wear their hearing aids and how many hours a day they did not wear their hearing aids because of noise exposure, exercising, or napping for the purpose of calculating a percentage of hearing aid usage as proposed by Oja and Schow. However, these calculations could not be made because many of the subjects did not respond to these questions or seemed to misunderstand them. The average satisfaction rating was 2.8, which most closely represents the category of "slightly satisfied" on a scale of one to seven in which one was the highest rating. The distribution of results for each of the response variables is shown in Figures 2 through 10 located in Appendix F. Although the mean satisfaction rating was close to three, the largest number of subjects responded with a satisfaction rating of "two" which represents "moderately satisfied", followed by "one" representing "highly satisfied". Although mean hearing aid use was 7 hours per day, the largest number of subjects reported wearing hearing aids for four to six hours per day. The majority of subjects responded better (about 10%) than the means for the PHAP subscales of Familiar Talkers, Ease of Communication, Reverberation and Background Noise. The scores for Reduced Cues, Aversiveness of Sounds, and Distortion of Sounds showed a wide distribution, with a number of subjects reporting little difficulty and a number reporting a great deal of difficulty in these areas.

3.2. Rejection of Hearing Aids and Comments Regarding Hearing Aids

Five of the 46 subjects in this study returned one or both of their hearing aids. One of the subjects returned only one of his hearing aids because he was finding no advantage to wearing two hearing aids over one. One subject who initially rejected his behind-the-ear hearing aids was eventually, outside the time frame of this study, fitted with in-the-ear hearing aids that he found to be more satisfactory. The reasons reported by the other three subjects for returning their hearing aids included that they were uncomfortable and produced a "stopped up" feeling, that they made little difference in the situations where the subject had difficulty hearing, and that the subject found it necessary to remove his hearing aids while operating machinery. Most of these reasons for returning hearing aids were similar to those described in other studies. Hall, Jacobs and Swerdfeger (1993) reported that the primary reasons for rejection of hearing aids in their practice include inadequate hearing benefit, complaints related to occlusion of the subjects' ears, manual dexterity problems, one hearing aid returned in a binaural fitting, and subjects simply changing their minds about wanting to purchase hearing aids.

Smedley and Schow (1990) reported the results of a hearing aid survey in which they asked subjects for "other comments I wish to make about my hearing aids". They found that 63% of the comments made by their subjects were negative, 19% were positive, and 17% were neutral. In the current study subjects were asked if their experience using hearing aids has met their expectations (see Appendix A.) Very few of the subjects addressed the issue of expectations in their responses. However, they did make comments about their experience wearing hearing aids. Fifty-three percent of the comments made by subjects about their hearings aids were positive, 37.5% were negative and 9.5% were neutral. Although the finding of 37.5% negative comments suggests some dissatisfaction with the hearing aid fittings these subjects received, these results were more encouraging than those of the earlier study by Smedley and Schow (1990).

3.3. Correlations

3.3.1. Correlations Between Predictive Variables

Correlations between predictive variables were of interest to determine the risk of multicollinearity, or the presence of nearly linear relationships among the predictive variables. When predictive variables are correlated it is more difficult to determine the contribution of each variable in a regression model. By calculating correlations between the predictive variables some interesting relationships could also be found which might help describe first time hearing aid users. Pearson correlation coefficients were obtained using SAS (Sas Institute, Version 6, 1989).

Matrices showing correlations between the sixteen predictive variables appear in Table 6. The relationships between some of these variables were also plotted and are shown in Appendix G. As shown in Table 6, the tolerated signal-to-noise levels for babble and speech spectrum noise were the most highly correlated of the variables tested in this study (.85). This was expected because they involved the same task using different types of competing background noise. It was not initially intended for both noise types to be included in the same regression analyses. Testing using both types was carried out to determine which might be most clinically applicable, if a difference between the two noise types was found to exist. Tolerated signal-to-noise levels using both babble and speech spectrum noise were also slightly correlated with the audiometric variables of pure tone average and dynamic range, and with the Personal Adjustment scale of the Communication Profile for the Hearing Impaired. Some subjects with better hearing sensitivity and with larger dynamic ranges tolerated greater amounts of background noise. Subjects with greater difficulty tolerating background noise appeared to be having more difficulty coping with their hearing loss based on the Personal Adjustment scale. Subjects with greater hearing loss in general (variables of PTA, slope, CLL and dynamic range)

Table 6. Correlations Between Predictive Variables.

	Sp. Spect.	SPIN	Slope	Rea-son	PTA	PA	NAL	Med.	Gen-der	Emp.	Educ.	DR	CS	CLL	Bab-ble
Age	-.07	-.25	.13	.16	.22	.17	.09	.21	.13	-.46*	-.01	-.18	-.32*	.13	-.06
Babble	.85*	-.05	.12	.23	.31*	-.39*	-.05	.18	.11	.08	-.42*	-.38*	.16	.18	-
CLL	.14	-.32*	-.01	.11	.43*	-.40*	.04	.16	.06	-.27	-.23	-.22	.21	-	-
CS	.07	-.09	-.08	-.30*	.18	-.18	-.05	.22	.08	.07	.05	-.23	-	-	-
DR	-.30*	-.13	-.56*	.09	-.75*	.40*	.08	.00	-.32*	.17	.35*	-	-	-	-
Education	-.24	.02	-.24	-.07	-.35*	.32*	.23	.01	-.15	.21	-	-	-	-	-
Employment	.16	.10	.00	-.28	-.21	-.07	.10	-.22	-.14	-	-	-	-	-	-
Gender	.21	.24	.58	-.15	.35*	-.17	.26	.05	-	-	-	-	-	-	-
Medications	.01	-.02	.01	-.20	-.07	-.26	.21	-	-	-	-	-	-	-	-
NAL Target	-.02	.10	-.01	-.24	.05	-.16	-	-	-	-	-	-	-	-	-
PA	.31*	-.25	-.37*	.15	-.32*	-	-	-	-	-	-	-	-	-	-
PTA	.30*	-.10	.28	.03	-	-	-	-	-	-	-	-	-	-	-
Motivation	.20	-.08	-.20	-	-	-	-	-	-	-	-	-	-	-	-
Slope	.08	.51*	-	-	-	-	-	-	-	-	-	-	-	-	-
SPIN	-.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes. *= $p < 0.05$, CLL= Comfortable Loudness Level, CS=Communication Strategies, DR=Dynamic Range, NAL=National Acoustic Laboratories Target, PA=Personal Adjustment, PTA=Pure Tone Average, SPIN=Speech Perception in Noise, Sp. Spect.= Tolerated Signal- to-Noise Level for Speech Spectrum Noise

also scored more poorly on the Personal Adjustment Scale. Subjects with more education obtained better scores on the Personal Adjustment Scale. The variables of pure tone average, tolerated signal-to-noise level with babble and dynamic range were also slightly correlated with education.

Slight correlations were found between pure tone average and both comfortable loudness level and dynamic range, as well as between dynamic range and slope. As shown in Table 6, one of the strongest correlations (.58) was observed between gender and slope of hearing loss. Male subjects had more sharply sloping hearing losses with poorer hearing in the high frequencies, probably because of their greater history of exposure to loud noise. They also had slightly poorer pure tone averages and slightly greater dynamic ranges than the female subjects. There were correlations between speech recognition in noise (SPIN test) results and both slope and comfortable loudness level. Subjects with more sloping hearing losses performed more poorly on the SPIN test. Although some of the subjects with high comfortable loudness levels scored well on the SPIN test, there was also a trend among a number of subjects of scoring better when CLLs were lower. The correlation between the Communication Strategies Scale of the CPHI and the subject's motivation for purchasing a hearing aid (self-motivation or other) indicates that subjects who are self-motivated to purchase amplification may also be more motivated to apply good communication strategies to compensate for their hearing loss. Obviously, the correlation between age and employment reflects the fact that the older subjects were less likely to be employed than the younger subjects.

3.3.2. Correlations Between Predictive and Response Variables

Correlations were computed between the predictive and response variables because they are the relationships of primary interest in this study and to allow for comparisons to be made between the current results and those of previous studies. These

correlations (shown in Table 7) also gave an indication of the variables which were likely to appear in the regression equations for the nine response variables. Number of medications taken, Personal Adjustment scores and tolerated S/N levels using babble were correlated with perceived hearing performance listening to Familiar Talkers. Personal Adjustment scores and comfortable loudness levels were correlated with perceived Ease of Communication. Comfortable loudness level, Personal Adjustment scores, and SPIN scores were correlated with perceived performance in Reverberation. The same predictive variables were correlated with perceived performance in Background Noise, with the addition of Communication Strategies scores. Personal Adjustment scores, SPIN scores and tolerated S/N levels using babble were correlated with the PHAP Reduced Cues subscale scores. Comfortable loudness level, number of medications taken, SPIN scores, and years of education were correlated with perceived Distortion of Sounds. Communication Strategies scores were correlated with perceived Aversiveness of Sounds. None of the predictive variables was significantly correlated with satisfaction. Age and number of medications were correlated with hours of hearing aid use. The relationships between predictive and response variables were also plotted for those predictive variables appearing in the regression equations for each response variable (shown in Appendix H).

3.3.3. Correlations Between Response Variables

Correlations between response variables were obtained in an attempt to better understand the relationships between hearing aid performance, usage and satisfaction. These results are shown in Table 8. Relationships between the seven PHAP subscales, hours of use and satisfaction ratings were also plotted and are shown in Appendix I.

All of the subscales of the PHAP were correlated with each other with the exception of Familiar Talkers and Aversiveness of Sounds. The performance subscales representing listening in adverse conditions: Reverberation (.43), Background Noise (.35)

Table 7. Correlations Between Predictive and Response Variables

	Aversiveness of Sound	Background Noise	Distortion of Sound	Ease of Communication	Familiar Talkers	Reduced Cues	Reverberation	Satisfaction	Use
Age	.27	.14	.15	.05	-.20	-.01	.28	.13	-.45*
Babble	.17	.29	.28	.17	.34*	.30*	.25*	-.03	.18
CLL	.15	.49*	.52*	.38*	.26	.24	.50*	.17	-.15
CS	.31*	.34*	.22	.12	.01	.34*	.26	.01	.08
DR	.02	-.11	-.04	.12	-.03	-.15	-.21	.03	.12
Education	-.14	-.20	-.40*	-.10	-.19	-.24	-.11	.15	.15
Employment	-.06	-.15	-.13	.11	.13	-.06	-.21	.10	.26
Gender	.14	.16	-.04	-.07	.09	.06	.07	-.01	-.06
Medication	.03	.33*	.34*	.38*	. 30*	.21	.28	.13	-.36*
NAL	-.04	-.06	-.21	-.15	.11	-.11	.05	.15	-.16
PA	-.18	-.38*	-.26	-.32*	-.34*	-.33*	-.34*	-.03	.00
PTA	.10	.10	.09	-.09	.12	.13	.26	.11	-.02
Motivation	-.04	.06	.05	.03	.13	.01	.14	.13	-.11
Slope	.10	.07	-.01	.03	.04	.01	-.03	-.20	.08
SPIN	-.28	-.22	-.39*	-.07	-.03	-.30*	-.31*	-.20	.20
Sp.Spect	.18	.20	.07	.08	.15	.19	.21	.08	.14

Notes: *= $p < 0.05$, CLL=Comfortable Loudness Level, CS=Communication Strategies, DR=Dynamic Range, NAL=National Acoustic Laboratories' Target Gain, PA=Personal Adjustment, PTA=Pure Tone Average, SPIN=Speech Perception in Noise Test, Sp. Spect.=Tolerated Signal-to-Noise Level for Speech Spectrum Noise

Table 8. Correlations Between Response Variables.

	Usage	Satis-faction	Total PHAP	Rev-erber-ation	Re-duced Cues	Familiar Talkers	Ease of Comm-unica-tion	Distor-tion of Sound	Back-ground Noise
Aversive-ness of Sounds	-.19	.24	.67*	.42*	.42*	-.05	.37*	.46*	.46*
Back-ground Noise	-.08	.35*	.88*	.76*	.73*	.48*	.67*	.69*	-
Distor-tion of Sounds	.01	.15	.84*	.55*	.64*	.36*	.63*	-	-
Ease of Comm-unication	.13	.17	.76*	.46*	.57*	.35*	-	-	-
Familiar Talkers	.02	.18	.44*	.41*	.35*	-	-	-	-
Reduced Cues	.07	.44*	.83*	.69*	-	-	-	-	-
Rever-beration	-.07	.43*	.78*	-	-	-	-	-	-
Total PHAP	-.04	.36*	-	-	-	-	-	-	-
Satis-faction	-.30*	-	-	-	-	-	-	-	-

Notes:*= $p < 0.05$, PHAP=Profile of Hearing Aid Performance

and Reduced Cues (.44) were significantly correlated with satisfaction ratings. Hearing aid usage was not correlated with any of the performance subscales. There was a low, but significant (-.30, negative because lower ratings represented greater satisfaction) correlation between hearing aid satisfaction and usage. These results will be discussed further in Chapter 4.

3.4. Regression Analyses

Regression analyses were performed using SAS (SAS Institute, Version 6, 1989) to obtain equations which could be used to predict hearing aid performance, usage, and satisfaction. Although the tolerated signal-to-noise levels with babble and speech spectrum noise were originally not intended to be included in the same equations, it was found that in some cases the relationships became stronger when both were included in a model. Thus, there were 16 predictive variables which could potentially be included in models for each of the response variables. Initially the five "best" models were obtained for every possible number of predictive variables, one through 16. This was performed by the SAS program based upon the coefficients of determination (R^2) values. R^2 measures the fit of a regression line and represents the proportion of variation in the response variables which is explained by the model. An example of the computer printout of R^2 and mean squared error (MSE) values for the "best" five models is shown in Appendix E for models containing one through eight predictive variables. The example is for only one of the response variables, the hours of hearing aid usage.

From the list of the five best models for one through 16 predictive variables, the model with the lowest mean squared error was identified and selected as the best combination of factors available from the data for predicting the response variables. After the predictive variables were identified for each model, their coefficients for the regression equations were determined by the SAS program. The overall equations were

tested for significance using an F statistic. T- tests on the individual variables were also computed to determine if the extra variation explained by a coefficient in the presence of the other variables is more than can be attributed to chance. As mentioned above, multicollinearity, or linear relationships among the predictive variables, can interfere with determining the contribution of each variable individually. Variance inflation factors were obtained to examine the extent to which multicollinearity was occurring in the selected equations. (If the variance of an individual coefficient is high, there is a chance that it has a strong linear association with the remaining regressors.) Although, the tolerated signal-to-noise scores with speech spectrum noise and multitalker babble were highly correlated, as shown in Table 6, inflation of the coefficients was not found to be excessive for any of the selected equations due to multicollinearity. The maximum variance inflation factor from the group of predictive variables for each of the selected regression equations is shown in Table 9. It is generally not considered necessary to delete a predictive variable because of multicollinearity unless the variance inflation factor value for that variable exceeds 10 (Myers, 1986).

Regression equation values for each of the PHAP subscales, total PHAP scores, hearing aid usage, and satisfaction ratings are shown in Table 9. For each response variable, the corresponding intercepts and coefficients for each of the predictor variables are provided. The regression equations take the form:

$$Y= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

(Y represents the response variable, β_0 represents the intercept, β_1, $_2$, etc. represent the coefficients of the predictive variables, and X_1, $_2$, etc. represent the predictive variables.) Thus, for example, the regression equation for the average PHAP scores would be:

$$PHAP= 9.81 + .34\ age + .35\ babble + .23\ CLL + 4.57\ CS + .31\ DR - 0.87\ NAL$$
$$-9.82\ PA + 0.18\ slope - 0.27\ SPIN.$$

Table 9. Regression Coefficients, Coefficients of Determination (R^2), P-values, and Maximum Variance Inflation Factors (VIF) for the Best Models for each Response Variable.

	PHAP	AV	BN	DS	EC	FT	RC	RV	Use	Sat.
Inter-cept	9.81	39.72	23.58	-23.50	-11.66	3.68	98.72*	14.47	13.66	0.90
Age	0.34	1.02*	0.36	-	-	-0.25	-	0.56*	-0.16*	-
Babble	0.35	-	-	1.06	-	0.93*	-	-	0.43*	-0.19*
CLL	0.23	-0.77	0.42	1.05*	0.64	0.31*	-	0.29	-	-
CS	4.57	17.93*	6.83	-	-	-3.13	-	4.36	-	-
DR	0.31*	0.84*	-	0.38*	0.43*	-	-	-	-	-
Educa-tion	-	-	-	-1.18	-	-	-	-	-	-
Empl-oyment	-	-.09	-	-	-	0.07*	-	-	-	0.01
Gen-der	-	-	8.35	-	-	4.53	3.69	-	-	-
Medi-cation	-	-3.41	-	2.61*	2.77*	1.48*	-	-	-0.92*	0.37*
NAL	-0.87	-	-1.00	-1.57	-1.61	-	-0.95	-	-	-
PA	-9.82*	-20.70*	-12.32*	-	-8.61	-	-11.03*	-11.28*	1.32	-
PTA	-	-	-0.48*	-	-	-	-	-	-	0.04
Moti-vation	-	-	3.37	-	-	4.03	-	-	-2.02	1.23*
Slope	0.18	0.58*	-	0.17	0.20	-	-	-	-	-
SPIN	-0.27*	-0.69*	-0.23	-0.28	-	-	-0.36*	0.26	0.04	-0.02
Sp. Spect.	-	0.64	-	-0.74	-	-0.77*	-	-	-0.19	0.12
R^2	0.52	0.50	0.49	0.63	0.36	0.47	0.30	0.41	0.41	0.25
p	.0007*	.0030*	.0015*	.0001*	.0053*	.0033*	.0047*	.0005*	.0031*	.1159
VIF	2.30	2.45	1.79	5.42	1.69	4.65	1.14	1.59	4.73	4.47

Notes: * indicates significance with alpha=.05, CLL= comfortable loudness level, CS=Communication Strategies, DR=dynamic range, NAL=difference between insertion gain and National Acoustic Laboratories' target gain, PA=Personal Adjustment, PTA=pure tone average, SPIN=Speech Perception in Noise test., Sp. Spect.= tolerated signal-to-noise level for speech spectrum noise, PHAP=Profile of Hearing Aid Performance, AV=Aversiveness of Sounds, BN=Background Noise, DS=Distortion of Sounds, EC=Ease of Communication, FT=Familiar Talkers, RC=Reduced Cues, RV=Reverberation, Sat.=Satisfaction rating

Coefficients of determination (R^2 values) are also shown in Table 9 for each equation, and significant p-values are indicated for the equations and for individual predictive variables.

As shown in Table 9, the number of variables appearing in the regression equations ranged from four for the Reduced Cues subscale of the PHAP to 10 for the Aversiveness of Sounds subscale. The variables which were most predictive of total PHAP scores were age, comfortable loudness levels, Communication Strategies and Personal Adjustment scores from the CPHI, dynamic range, difference between actual gain and NAL target gain, slope of hearing loss, SPIN scores, and tolerated signal-to-noise levels with babble. Unaided variables partially predicting Aversiveness of Sounds included age, comfortable loudness levels, Communication Strategies and Personal Adjustment CPHI scores, dynamic range, employment, number of medications taken, slope of hearing loss, SPIN scores, and tolerated signal-to-noise levels with speech spectrum noise. Variables in the equation predicting background noise were age, comfortable loudness levels, Communication Strategies and Personal Adjustment CPHI scores, gender, difference from NAL target gain, pure tone average, motivation for pursuing hearing aid use, and SPIN scores.

Variables in the equation for Distortion of Sounds included comfortable loudness level, dynamic range, years of education, number of medications taken, difference between actual gain and NAL target, slope of the hearing loss, SPIN scores, and tolerated signal-to-noise levels with both babble and speech spectrum noise. Variables partially predicting Ease of Communication scores were comfortable loudness levels, dynamic range, number of medications taken, difference between actual gain and NAL target gain, Personal Adjustment scores of the CPHI, and slope of the hearing loss. The regression equation for Familiar Talkers scores included the variables of age, comfortable loudness levels, Communication Strategies scores of the CPHI, gender, percent of time employed, number

of medications taken, motivation for pursuing hearing aid use, and tolerated signal-to-noise levels for babble and speech spectrum noise.

Variables partially predicting Reduced Cues scores were gender, difference between actual gain and NAL target gain, Personal Adjustment scores of the CPHI, and SPIN scores. Reverberation scores were best predicted by age, comfortable loudness levels, Communication Strategies and Personal Adjustment scores of the CPHI, and SPIN scores. Hearing aid usage was best predicted by age, number of medications taken, Personal Adjustment scores, motivation for pursuing hearing aid use, and tolerated signal-to-noise levels for speech spectrum noise and babble. Hearing aid satisfaction was best predicted by percent of time employed, number of medications used, pure tone average, motivation for pursuing hearing aid use, SPIN test scores, and tolerated signal-to-noise levels using babble and speech spectrum noise.

Age, Personal Adjustment scores from the CPHI and the SPIN test, appeared in the greatest number of equations for partially predicting performance subscale scores (five or six) as well as hearing aid usage. Variables which appeared in many of the equations for performance subscales (5 to 7 subscale scores), but not usage or satisfaction included comfortable loudness levels, the Communication Strategies scale of the CPHI and the difference between actual gain and NAL target gain. Tolerated signal-to-noise levels and number of medications taken were found to be partially predictive of hearing aid usage and satisfaction, but not predictive of many performance subscale scores. The percentage of time a subject was employed was partially predictive of hearing aid usage, but not of performance or satisfaction. Years of education, gender, and pure tone average were not found to be very useful for predicting performance, usage or satisfaction.

F values for each of the ten models were found to be significant with alpha set at .05, with the exception of the model for satisfaction ratings. Although a meaningful regression model could not be obtained for satisfaction ratings using the variables available

in this study, significant t-test results were obtained for two of the variables in the satisfaction model, the number of medications taken and tolerated signal-to-noise level using babble.

The R^2 values show the percentage of variation in the response variables which is explained by the models. The highest R^2 value was obtained for the model describing the Distortion of Sounds subscale of the PHAP. In this case the model explains 63% of the variation in subjects' perceived distortion of sounds. The other models explain 30 to 50% of the variation in the response variables they represent. These R^2 values seem to suggest that the models may not explain enough of the variation in hearing aid performance, usage and satisfaction to be used for making precise predictions of the response variables for individual clients. To further investigate the possibility that some of the equations could be applied clinically, 95% prediction intervals were obtained for the responses from each subject for each regression equation. Table 10 shows the average length of the 95% prediction intervals along with the mean squared error value for each of the response variables. The average lengths of the prediction intervals show that, with the exception of the Aversiveness of Sounds subscale, the PHAP subscale scores were, on average, predicted within about +/- 15%. The 95% prediction intervals for a number of the individual subjects were much greater than these averages. Residual values, or the difference between predicted and actual responses were also obtained for each of the individual subjects.

Narrow 95% prediction intervals would not necessarily be needed in order for these equations to be clinically useful. The ability to predict the performance scores of 75% of new hearing aid users within about 10 or 12% could be very useful for the purposes of counseling potential hearing aid users. Among the equations obtained in this study, 75% or more of the data points were predicted within 12% for the PHAP subscales of Background Noise, Reduced Cues and Familiar Talkers. The equation for the total

Table 10. Mean Squared Error and Average Length of Prediction Intervals for the Equations Predicting each Response Variable.

Response Variable	Mean Squared Error of Model	Average Length of Prediction Interval
Total PHAP	87.61	20.71 %
Aversiveness of Sounds	348.73	42.07 %
Background Noise	128.20	25.28 %
Distortion of Sounds	155.50	27.59 %
Ease of Communication	220.33	32.07 %
Familiar Talkers	46.00	15.14 %
Reduced Cues	142.20	25.28 %
Reverberation	160.08	27.09 %
Hours of Use	12.20	7.61 hours
Satisfaction Rating	2.61	3.51

Notes: The average length of the prediction interval was obtained using the equation : $\hat{y} = t_{.025}\,(RMSE)\,\frac{\Sigma\,(1 + h_i)}{n}^{1/2}$.

h_i represents the leverage of each observation which was obtained using SAS.

PHAP subscale score prediction intervals are in % difficulty.

PHAP score also predicted more than 75% of the data points correctly. However, the total PHAP score would not be as useful as the subscale scores for counseling clients about their expectations of hearing aid use. The equation for hours of daily hearing aid use predicted hours of usage correctly within three hours for 74% of the subjects. Even the equations which are less successful at describing the aided performance, usage and satisfaction ratings for individual subjects provide some insight into unaided tests and demographic information which may be useful for counseling new hearing aid users regarding their expectations of hearing aid use. They also suggest that some of the unaided information frequently gathered in hearing aid evaluations may be of little use in predicting a client's self-assessed aided performance, usage and satisfaction.

CHAPTER 4

DISCUSSION

4.1. Summary of Results in Relation to Hypotheses

In Chapter 1 it was hypothesized that regression models would be identified which could be used to predict an individual subject's aided scores on the Profile of Hearing Aid Performance subscales. The regression equations obtained accounted for a significant portion of the PHAP scores, but in most cases did not explain enough of the variation in the scores to be used for making precise predictions for individual clients. It is possible that the equations for predicting difficulty hearing Familiar Talkers, in Background Noise and with Reduced Cues could be applied clinically. Their applicability could be determined through further testing with a different group of subjects. For all of the equations, it is possible that additional variables which were not considered in the current study could be added to increase their accuracy in predicting client-assessed performance scores. Some other variables which could be considered for future studies will be suggested later in this chapter. It is also possible that the addition of other variables may not greatly improve the predictive ability of these equations. Differences between subjects may make it impossible to identify more precise models of the variables contributing to aided performance scores.

It was assumed that the seven subscales of the Profile of Hearing Aid Performance generally represent seven different aspects of hearing performance. Thus, the regression equations obtained for the seven subscale scores were expected to be different, although they might contain some of the same predictive variables. This was found to be the case. The equations for Reduced Cues and Reverberation differed the most from those of the other subscales in that they contained only four and five variables respectively, while the others contained six to ten variables. Correlations between the PHAP subscale scores

showed that all pairs were correlated with the exception of Familiar Talkers and Aversiveness of Sounds, although the regression equations for these two response variables were similar. In general it can be said that the regression equations show that different combinations of variables predict a subject's scores on each of the aspects of aided performance addressed by the PHAP. The correlation results show that, although a different set of variables partially predict subjects' scores for each subscale, the PHAP scores obtained from a group of subjects may actually be similar for all of the subscales except Familiar Talkers and Aversiveness of Sounds.

It was also hypothesized that, using the same pool of predictive variables, regression equations could be obtained which could be used to predict hearing aid usage and satisfaction ratings. A regression equation was obtained which accounted for the variation in hours of daily hearing aid use to a significant extent. Using this equation, the number of hours of daily hearing aid use could be estimated within three hours for almost 75% of the subjects in this study. Further testing would be needed to determine if this is also possible with another group of subjects.

A significant portion of the variation in satisfaction ratings could not be explained by the best regression equation obtained using the unaided variables. To further examine hearing aid user satisfaction, a regression model for satisfaction was obtained using both the original unaided variables as well as the aided PHAP scores as predictive variables. The result was a model containing the following 14 predictive variables: tolerated S/N level for babble, comfortable loudness level, Communication Strategies and Personal Adjustment scores from the CPHI, percent employment, number of medications taken, pure tone average, motivation for using hearing aids, slope of hearing loss, SPIN test scores and PHAP subscale scores of Aversiveness of Sounds, Distortion of Sounds, Ease of Communication and Reduced Cues. This model accounted for 62% of the variation in satisfaction ratings. In Section 1.1.2. a marketing definition of buyer satisfaction was

described which states that satisfaction requires a close correspondence between the buyer's expectations and his or her perceived performance of the product. Considering this definition, it is logical that measures of perceived aided performance would be needed in a model predicting satisfaction ratings. In the current study there was not a way to quantify and include a measure of the hearing aid user's expectations of hearing aid use to test in a model of hearing aid satisfaction. As hypothesized, the combination of unaided variables contained in the regression equations for usage and satisfaction differed from one another as well as from those obtained for the performance scores, with some overlap.

4.2. Comparison of Results with those of Previous Studies

4.2.1. Client-Assessed Aided Performance

Variables predicting client-assessed aided performance in this study will be compared with the results of previous studies primarily based upon the regression equation obtained for average PHAP scores. The variables appearing in equations for the majority of the PHAP subscales generally appear in the equation for the average PHAP scores.

The most promising variable for predicting client-assessed aided performance based upon earlier studies was speech recognition in noise. Other factors which have been examined in only one earlier study which appeared to be related to perceived performance include: gender, education, employment and HHIE scores (although the HHIE was also used to represent perceived performance in that study).

The current results are in agreement with the previous studies (those of Scherr et al., 1985 and Gerber and Fisher, 1979) which showed a relationship between unaided speech recognition in noise and subjects' perceived aided performance. In the current study the variables of gender, education and employment were not generally found to be

predictive of perceived performance, although they did appear in equations for one to three of the seven PHAP subscales. The Hearing Handicap Inventory for the Elderly was not included as a variable in this study. It could be considered as a variable in future studies, although the usefulness of including a measure of client-assessed hearing performance as both a predictive and response variable in a study is questionable. It is possible that a relationship between results of the same test given before and after a hearing aid fitting could simply represent a certain amount of test-retest reliability. In contrast with earlier studies (Berger et al., 1982 and Berger and Hagberg, 1982), age was also found to be partially predictive of perceived performance, appearing in equations for the total PHAP and for the majority of PHAP subscales.

Variables which were not tested before which appeared in the equations for PHAP scores or for the majority of subscales were comfortable loudness level, difference between actual gain and NAL target gain, and the Personal Adjustment and Communication Strategies scales of the Communication Profile for the Hearing Impaired. Dynamic range, slope of the hearing loss, and tolerated S/N level for babble may also be useful for predicting general client-assessed performance with hearing aids. They appear in the total PHAP equation, but not in equations for the majority of subscales.

4.2.2. Hearing Aid Usage

Based upon the results of previous studies (see Table 2), the most promising factors for predicting hours of daily hearing aid usage appeared to be speech recognition in noise, tolerated signal-to-noise levels, employment and number of medications taken per day. The results of the current study were in agreement with previous studies in that speech recognition in noise (in agreement with Gerber and Fisher, 1979), tolerated S/N levels (in agreement with Nabelek et al., 1991) and number of medications taken (in agreement with Mulrow et al., 1992) appeared in the best equations for predicting daily

hearing aid use. Although the findings of Hutton (1980), in which employed subjects wore their hearing aids longer than subjects who were unemployed, would have suggested that employment might be partially predictive of hearing aid use, it did not appear in the best model for hours of hearing aid use in this study.

Results of previous studies were split regarding the relationship between hearing aid usage and the ages and pure tone averages of the subjects. The current results were in agreement with the three studies showing a relationship between age and hearing aid usage: Berger et al. (1982), Surr et al. (1978) and Hutton (1980). Pure tone average did not appear in the best regression equations in this study. This finding was consistent with the results of Berger et al. (1982), Hutton (1980) and Hutton and Canahl (1985).

Two variables which had not previously been studied in relation to hearing aid use appeared in the regression equations in the current study: the Personal Adjustment Scale from the Communication Profile for the Hearing Impaired and the subjects' motivation for pursuing hearing aid use. These factors are both related to a subject's degree of motivation toward coping with hearing loss and using hearing aids. Although these specific variables have not been studied in relation to hearing aid usage in the past, the importance of the hearing aid user's motivation is not a new concept. As mentioned in Section 1.2.2., Brooks (1989) found that subjects with more realistic attitudes and greater motivation and acceptance of hearing loss were more likely to wear their hearing aids for more than four hours per day than were subjects with poorer acceptance of hearing loss.

4.2.3. Satisfaction Ratings

As shown in Table 3, previous studies have suggested aversion to loud sounds, slope of hearing loss, speech recognition in noise, the Hearing Handicap Inventory for the Elderly, and clinician judgments of client's motivation as factors which might be predictive of hearing aid satisfaction. The results of the current study are similar to those of earlier

studies in that the Speech Perception in Noise test, a measure of speech recognition in noise, appeared in the best regression equation for satisfaction using unaided variables. The subjects' motivation for purchasing hearing aids, self-motivation versus encouragement from others, also appeared in the best equation for satisfaction, which is in agreement with the finding of Hosford-Dunn and Baxter (1985) that clinicians' judgments of subjects' motivation appeared to partially predict hearing aid satisfaction. In the present study, subjects' percentage of employment and subjects' tolerated S/N level for both speech spectrum noise and multitalker babble appeared in the best equation. These variables had not previously been studied in relation to hearing aid satisfaction ratings. Pure tone average also appeared in the equation for hearing aid satisfaction in the current study, which contradicted the results of three earlier studies: Kapteyn (1977a), Berger and Hagberg (1982) and Mulrow et al. (1992). The inclusion of medications in the regression equation for satisfaction in the current study also contradicted the findings of Mulrow et al., although satisfaction was measured by Mulrow et al. using a questionnaire regarding aided performance in various listening conditions which have been more comparable to perceived performance in the current study.

It is important to keep in mind that the best regression equation for predicting hearing aid satisfaction ratings using unaided variables in the current study was found not to be statistically significant. Of the individual t-tests on the variables, only those for medications taken and for tolerated S/N level for babble were found to be significant. Thus, the variables in the regression equation for satisfaction represent only the best among the unaided variables available in this study.

4.3. The Relationship Between Perceived Hearing Aid Performance, Hearing Aid Usage, and Satisfaction Ratings

In Chapter 1 it was theorized that a better match between expectations of hearing aid use and perceived performance with hearing aids leads to greater hearing aid satisfaction. It was also hypothesized and found to be the case that there would be some overlap in the predictive variables contained in the regression equations for hearing aid performance, usage and satisfaction ratings. As explained in Chapter 1, measures of hearing aid performance, usage and satisfaction have been used interchangeably in previous studies to evaluate the success of hearing aid fittings. Thus, it might be suspected that there should be some correlation between measures hearing aid performance, usage and satisfaction ratings. In the current study, there was a small but significant correlation (.30) between satisfaction ratings and hours of use. This suggests some relationship, but also that they must to some extent be measuring different aspects of hearing aid success. This finding was in agreement with the results of Rosedale, Ossakow, Berger, Landenberger and Everett (1992) who found a correlation of .29 between hearing aid usage and satisfaction. Some earlier studies had found higher correlations between usage and satisfaction. Gerber and Fisher (1979) found a correlation of .66 and Brooks (1989) reported a correlation between .67 and .72.

Hearing aid performance and satisfaction were also significantly correlated, particularly for the PHAP subscales of Reverberation (.43), Background Noise (.35) and Reduced Cues (.44). The correlation between average PHAP scores and satisfaction ratings was .36. This supports the concept that hearing aid satisfaction could be increased if aided performance could be predicted in advance and clients could be counseled regarding their expectations. There was not a significant correlation between satisfaction ratings and perceived aided performance in situations with familiar talkers or involving loudness discomfort (Aversiveness of Sounds) or distortion of sounds.

There was also not a significant correlation between hours of hearing aid use and subjects' perceived aided performance. It would seem that the number of hours a hearing aid user wears his or her hearing aids would be greater if they perceived an improvement in their hearing performance with the hearing aids. To understand the lack of correlation between these two measures, the predictive variables from the regression equations for hearing aid usage and perceived performance were examined. The two equations contained several of the same variables. The only two variables which were much more important for predicting hearing aid usage than perceived aided performance were the subjects' motivation for pursuing hearing aid use and their tolerated signal-to-noise levels. Subjects who were self-motivated to use hearing aids wore their hearing aids a greater number of hours per day than those who were not. Possibly, subjects who purchased hearing aids primarily because of encouragement by their families would admit that their hearing performance was improved with hearing aids, but would not necessarily wear the hearing aids as much as the self-motivated subjects. The relationship between average PHAP scores and hours of hearing aid use is plotted in Figure 11. The data points are coded according to the subject's motivation category, self-motivation versus encouragement from others. There appears to be a stronger relationship between performance and usage among the self-motivated subjects.

The lack of correlation between hours of use and perceived performance are more difficult to explain based upon results of the tolerated S/N levels. Subjects with the greatest difficulty tolerating background noise (those preferring signal-to-noise conditions of +20 dB or better) tended to wear their hearing aids a greater number of hours per day. This was an unexpected finding, because subjects who had rejected their hearing aids in the Nabelek et al. study also had greater difficulty tolerating poorer signal-to-noise conditions. It is possible that the subjects with the highest tolerated signal-to-noise levels in the current study recognized their need for amplification more because of their difficulty

tolerating background noise, although their actual aided performance in adverse listening conditions may have been no different from that of other subjects. This is supported by the fact that there was not a significant correlation in this study between results of the SPIN test and tolerated S/N levels with babble or speech spectrum noise. The finding that hearing aid usage and perceived performance were not correlated contradicted previous studies. Hutton and Canahl (1985) and Walden et al. (1984) found slight but significant correlations between hearing aid usage and perceived benefit.

4.4. Clinical Implications

Based upon the residuals, or differences between predicted and actual values, obtained using the regression equations in this study, it appears that the equations for predicting the difficulty new hearing aid users will have hearing in background noise, hearing with reduced cues and hearing familiar talkers may estimate scores accurately enough to be applied in pre-hearing aid counseling. These findings must be confirmed by testing the equations on a group of new hearing aid users other than the one used for obtaining the equations. If performance on these PHAP subscales can be predicted within about 10-12% for a majority of subjects, it would be useful to apply these equations clinically to describe to clients the difficulty they might be expected to experience in these listening conditions with amplification. This would help the clients establish realistic expectations of hearing aid use, which should increase their overall satisfaction with amplification.

It may also be possible to estimate hours of hearing aid use per day for the majority of clients. However, clients should not be discouraged from purchasing hearing aids if they are considered likely to only wear them for a small number of hours per day. The correlation between hearing aid usage and satisfaction in this study was significant, but not high. There are a number of hearing aid clients who wear their hearing aids a

small number of hours per day, yet report satisfaction. These clients may only require the use of amplification in certain situations which may be important to them.

The results of this study indicated that some of the information which is commonly gathered about new hearing aid users has a strong relationship to client-assessed aided performance, while other information does not. The most useful variables tested in this study for partially predicting client-assessed aided performance were age, comfortable loudness level, the Communication Strategies and Personal Adjustment scales of the Communication Profile for the Hearing Impaired, the difference between actual hearing aid gain and NAL target gain, and SPIN test scores. It is always important to explain to clients that they will most likely continue to experience some difficulty hearing in adverse listening situations. The finding of age as a predictor of aided performance indicates that it is particularly important to warn elderly clients to expect continued difficulty hearing in conditions of background noise and reverberation, and to expect to be bothered at times by loud sounds.

Subjects obtaining high scores on the Communication Strategies scale and low scores on the Personal Adjustment scale of the CPHI before their hearing aid fittings reported poorer aided performance than other subjects. Thus, these CPHI scales seem to provide useful information for counseling subjects about how they may expect to hear in the listening situations covered by the PHAP, such as with familiar talkers, in background noise or reverberation, or when exposed to aversive sounds. Subjects obtaining poor speech recognition scores in noise as tested by the SPIN test were also found to report greater aided difficulty in the listening conditions covered by the PHAP. Like the CPHI scales, the SPIN test should be considered for use in hearing aid evaluations to help counsel clients regarding their aided expectations.

The fact that subjects wearing hearing aids with gain farther from the NAL target expressed greater difficulty on the PHAP confirms the usefulness of applying the NAL

procedure for hearing aid selection. However, CLLs were partially predictive of even more PHAP subscales than was the difference in gain from the NAL target. This finding along with the fact that pure tone average was a very poor predictor of the PHAP scores suggests that it may be worthwhile to consider applying a hearing aid selection procedure which incorporates measurements of comfortable loudness level such as, for example, that proposed by Pascoe (1978) , rather than one based purely upon pure tone thresholds.

There was a trend toward a greater amount of hearing aid use per day among subjects tolerating more difficult signal-to-noise conditions using multitalker babble or speech spectrum noise. However, the three subjects with the greatest difficulty tolerating poor signal-to-noise conditions in the current study (preferring signal-to-noise levels of 20 dB or greater) were found to wear their hearing aids eight hours or more per day and to be slightly to highly satisfied with their hearing aids. Because only three subjects fell into this category, further study would be needed to determine if this trend is repeatable. However, it appears that clinical testing of tolerated signal-to-noise levels may be useful as part of the hearing aid evaluation to determine the likelihood that a client will be satisfied with his or her hearing aid(s) and wear them often. Both speech spectrum noise and multitalker babble were included for tolerated signal-to-noise testing in this study because it was not known if one noise type would be more useful than the other for predicting aided performance, use or satisfaction. The results were similar using either noise type, and the scores for the two noise types were highly correlated. Therefore, tolerated signal-to-noise testing could be applied clinically using either noise type.

As discussed in Chapter 3, the subscales of the PHAP were all significantly positively correlated with one another, with the exception of Familiar Talkers and Aversiveness of Sounds. Thus, clients may be expected to report similar perceived performance in situations involving background noise, reverberation, reduced cues or distortion of sounds. This implies that it may be appropriate to divide listening situations

into three categories for the purposes of counseling potential hearing aid users: situations which are quiet or involve familiar talkers, difficult listening situations, and situations involving loud or otherwise aversive sounds.

4.5. Implications for Future Research

As mentioned above in section 4.4 and in Chapter 3, there were significant correlations between scores for most of the PHAP subscales. These findings are in agreement with the factor analysis and correlation results for the PHAP obtained by Cox and Gilmore (1990). Correlations between the reverberation, background noise and reduced cues subscales were particularly high both in this study and in that of Cox and Gilmore, showing that they are not measuring independent aspects of hearing aid performance. These findings suggest that there may be a better way to represent the different aspects of client-assessed hearing aid performance. The seven PHAP subscales were chosen to represent aided performance in this study because it was felt that they might provide a better framework for counseling hearing aid clients than would a single test score. Because there was no correlation between the Familiar Talkers and Aversiveness of Sounds subscales and the correlation was very high between Reverberation, Background Noise and Reduced Cues; use of the PHAP for future studies of factors predicting client-assessed performance could include only three subtests: Familiar Talkers, Adverse Listening Conditions (combining RV, BN and RC) and Aversiveness of Sounds.

In future studies, it may be more logical to try to predict perceived benefit rather than performance. This would involve obtaining difference scores between results of a hearing performance questionnaire such as the PHAP administered before and after the subjects' hearing aid fittings, or phrasing the questions to ask about performance before and after their fittings and obtaining a difference score as is done in Cox, Gilmore and

Alexander's (1991) Profile of Hearing Aid Benefit. Aided performance scores are actually the sum of subjects' unaided performance and the benefit they are receiving with their hearing aids. By using benefit as a response variable, unaided performance will no longer contaminate results and could even be used as a predictive variable.

The regression equations obtained in this study for Background Noise, Familiar Talkers and Reduced Cues may be useful for estimating client-assessed aided performance. They should be tested with a different group of subjects to determine if these results can be repeated. The accuracy of these equations could also possibly be improved upon by combining the results of the current group of subjects with a new group and recalculating the equations for the Familiar Talkers, Background Noise and Reduced Cues subscales. In a follow-up study additional predictive factors could also be tested to attempt to improve upon the equations for these or for other response variables representing client-assessed aided performance, usage or satisfaction.

The subject's motivation for pursuing hearing aid use (self-motivation versus encouragement from others) was found to be partially predictive of usage and of four of the PHAP subscales. Other approaches to measuring motivation could be considered as variables in future studies; for example, portions of the Feasibility Scale for Predicting Hearing Aid Use (Rupp, Higgins and Maurer; 1977).

Unaided client-assessed performance could also be taken into account as contributing to perceived aided benefit, by including unaided portions of the PHAP or the Hearing Handicap Inventory for the Elderly as variables in future studies. Cox and Rivera (1992) examined the possibility of predicting Profile of Hearing Aid Benefit (PHAB) scores based upon subjects' unaided difficulties measured by three scales from the Communication Profile for the Hearing Impaired (Demorest and Erdman, 1986) and unaided PHAP scores. The PHAB is identical to the PHAP, but asks subjects to respond to questions based on their hearing performance with and without hearing aids , and a

difference score is obtained. For all seven PHAB subscales they found that unaided performance results were partially predictive of benefit scores. For the Aversiveness of Sounds and Distortion of Sounds subscales of the PHAP, the Problem Denial scale from the CPHI, which was not included in the current study, also improved the regression equations. The Problem Denial scale from the CPHI could also be included in future studies of hearing aid performance or benefit in addition to the Communication Strategies and Personal Adjustment scales.

Previous studies of hearing aid success have not always been precise in stating whether they were measuring client-assessed aided performance, usage or satisfaction. Correlations obtained in the current study show that performance results and satisfaction ratings are only slightly correlated and that performance and usage are not significantly correlated at all. Therefore, in future studies, all three measurement types should be used, if possible, to represent different aspects of a successful hearing aid fitting. The measures used to represent the success of hearing aid fittings should also be labelled carefully.

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APPENDICES

APPENDIX A

Profile of Hearing Aid Performance (Cox and Gilmore, 1990)
with additional page showing usage and satisfaction ratings

Scoring of the Profile of Hearing Aid Performance

PROFILE OF HEARING AID PERFORMANCE

Instructions: Please circle the answer that comes 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 the statement is true about 75% of the time, circle C for that item. If you have not experienced a particular situation, imagine how you would respond in a similar situation.

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

WHEN I WEAR MY HEARING AID

1. I can understand others in a small group situation if there is no noise.	A	B	C	D	E	F	G
2. When I am listening to a speaker who is talking to a large group, and I am seated toward the rear of the room, I must make an effort to listen.	A	B	C	D	E	F	G
3. Women's voices sound "shrill".	A	B	C	D	E	F	G
4. I find that most people speak too softly.	A	B	C	D	E	F	G
5. I have trouble comprehending speech when I am in a busy department store talking with the clerk.	A	B	C	D	E	F	G
6. I can understand my family when they speak to me softly.	A	B	C	D	E	F	G
7. I can understand a speaker in a small group even when those around us are speaking softly to each other.	A	B	C	D	E	F	G
8. I can understand conversations even when several people are talking.	A	B	C	D	E	F	G

A=Always, B=Almost Always, C=Generally, D=Half-the-time,
E=Occasionally, F=Seldom, G=Never

9. When the telephone rings, the sound startles me.	A	B	C	D	E	F	G
10. I have to ask people to repeat themselves when there is background noise.	A	B	C	D	E	F	G
11. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.	A	B	C	D	E	F	G
12. When I am having a conversation and people are talking quietly nearby, I have to strain to understand the speaker.	A	B	C	D	E	F	G
13. If a car horn sounds, it makes me jump.	A	B	C	D	E	F	G
14. When I am talking to a group, and someone from the back of the room asks a question, I have to ask someone up front to repeat the question.	A	B	C	D	E	F	G
15. The sounds of construction work are uncomfortably loud.	A	B	C	D	E	F	G
16. When I am in a crowded reception room waiting to be called, I miss hearing my name.	A	B	C	D	E	F	G
17. When I am having a quiet conversation with a companion, I have difficulty understanding.	A	B	C	D	E	F	G
18. 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
19. The sound of screeching tires is uncomfortably loud.	A	B	C	D	E	F	G

A=Always, B=Almost always, C=Generally, D=Half-the-time,
E=Occasionally, F=Seldom, G=Never

20. I can understand conversation when I am walking with a friend through a quiet park.	A	B	C	D	E	F	G
21. 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
22. When I am in a conversation with someone across a large empty room (such as an auditorium), I understand the words.	A	B	C	D	E	F	G
23. When I am on a busy street, asking someone for directions, I have to ask him to repeat them before I really understand.	A	B	C	D	E	F	G
24. The sounds of running water, such as a toilet or shower, are uncomfortably loud.	A	B	C	D	E	F	G
25. 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
26. I have trouble understanding dialogue in a movie or at the theater.	A	B	C	D	E	F	G
27. When I am in a crowd with a friend who doesn't want others to overhear our conversation, I have trouble hearing as well.	A	B	C	D	E	F	G
28. When I am at the dinner table with several people, and I am trying to have a conversation with one person, understanding speech is difficult.	A	B	C	D	E	F	G
29. When I am 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
30. I have trouble understanding others when an air conditioner or fan is on.	A	B	C	D	E	F	G

A=Always, B=Almost always, C=Generally, D=Half-the-time,
E=Occasionally, F=Seldom, G=Never

31. I miss a lot of information when I'm listening to a lecture.	A	B	C	D	E	F	G
32. I can understand my family when they talk to me in a normal voice.	A	B	C	D	E	F	G
33. I have to ask people to repeat themselves in one-to-one conversation in a quiet room.	A	B	C	D	E	F	G
34. I have difficulty hearing a conversation when I'm with one other person at home.	A	B	C	D	E	F	G
35. When I am riding in the back seat of a car, and the driver talks to me from the front, I have to strain to understand.	A	B	C	D	E	F	G
36. Music sounds distorted to me.	A	B	C	D	E	F	G
37. When I'm talking with the teller at the drive-in window of my bank, I understand the speech coming from the loudspeaker.	A	B	C	D	E	F	G
38. When I am in a small office, interviewing or answering questions, I have difficulty following the conversation.	A	B	C	D	E	F	G
39. When a lecturer is giving instructions, I can easily follow along.	A	B	C	D	E	F	G
40. Everyday sounds are too soft for me to hear clearly.	A	B	C	D	E	F	G
41. I avoid using certain appliances (blender, vacuum cleaner, etc.) because their loudness is uncomfortable.	A	B	C	D	E	F	G
42. When I am in a busy restaurant and the waitress is taking my order, I can comprehend her questions.	A	B	C	D	E	F	G

A=Always, B=Almost always, C=Generally, D=Half-the-time,
E=Occasionally, F=Seldom, G=Never

43. I avoid crowds because the noise is uncomfortably loud.	A	B	C	D	E	F	G
44. When I'm at a large, noisy party, conversation is very confusing.	A	B	C	D	E	F	G
45. When I'm at 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
46. When I am in a quiet restaurant, I can understand soft conversation.	A	B	C	D	E	F	G
47. I can't understand the TV news when the volume is set by a normal-hearing person.	A	B	C	D	E	F	G
48. I can understand conversation during a quiet dinner with my family.	A	B	C	D	E	F	G
49. When I am listening to the news on my radio, and the car windows are closed, I can understand the words.	A	B	C	D	E	F	G
50. The sound quality of music isn't very good.	A	B	C	D	E	F	G
51. The ring of a telephone sounds "tinny".	A	B	C	D	E	F	G
52. I understand the newscaster when I am watching the TV news at home alone.	A	B	C	D	E	F	G
53. I can follow the words of a sermon when listening to a religious service.	A	B	C	D	E	F	G
54. When I am at home, talking with someone who is in another room, following the conversation is difficult.	A	B	C	D	E	F	G
55. Unexpected sounds like a smoke detector or alarm bell are uncomfortable.	A	B	C	D	E	F	G

A=Always, B=Almost always, C=Generally, D=Half-the-time,
E=Occasionally, F=Seldom, G=Never

56. When I'm talking with a friend outdoors on a windy day, I miss a lot of the conversation.	A	B	C	D	E	F	G
57. Everyday sounds that don't bother others are too loud for me.	A	B	C	D	E	F	G
58. It's hard for me to understand what is being said at lectures or church services.	A	B	C	D	E	F	G
59. When I am in a room with the door closed and I want to overhear a conversation going on outside the door, I have to strain to listen.	A	B	C	D	E	F	G
60. People's voices sound unnatural.	A	B	C	D	E	F	G
61. When I am in face-to-face conversation with one member of my family, I can easily follow along.	A	B	C	D	E	F	G
62. When I am in a meeting with several other people, I can comprehend speech.	A	B	C	D	E	F	G
63. Traffic noises are too loud.	A	B	C	D	E	F	G
64. The sound of glass breaking is uncomfortably loud.	A	B	C	D	E	F	G
65. I can communicate with others when we are in a crowd.	A	B	C	D	E	F	G
66. I understand speech when I am talking to a bank teller, and I am one of a few customers at the bank.	A	B	C	D	E	F	G

HEARING AID SATISFACTION RATING

Please rate your hearing aid satisfaction on a scale of 1 to 7.

1= highly satisfied
2= moderately satisfied
3= slightly satisfied
4= neutral
5= slightly dissatisfied
6= moderately dissatisfied
7= highly dissatisfied

Your rating _____

HEARING AID USAGE

How many hours per day do you wear your hearing aids on average?_____

How many hours per day would you like to wear your hearing aids?_____

On average, how many hours per day do you not wear your hearing aid because you are taking a nap, working in loud noise, or exercising? _____

HEARING AID EXPECTATIONS

Is your experience using hearing aids what you thought it would be? In what ways do your hearing aids meet your expectations or not meet your expectations?

_____
_____
_____
_____
_____

Profile of Hearing Aid Performance Scoring

Subscale	Item Numbers
Familiar Talkers (FT)	1*, 20*, 32*, 48*, 52*, 61*, 66*
Ease of Communication (RC)	12, 17, 25, 29, 33, 34, 38
Reverberation (RV)	2, 14, 22*, 26, 31, 39*, 45*, 53*, 58
Reduced Cues (RC)	4, 6*, 35, 37*, 46*, 47, 49*, 54, 59
Background Noise (BN)	5, 7*, 8*, 10, 11*, 16, 18, 23, 27, 28, 30, 42*, 44, 56, 62*, 65*
Aversiveness of Sounds (AV)	9, 13, 15, 19, 21, 24, 41, 43, 55, 57, 63
Distortion of Sounds (DS)	3, 36, 40, 50, 51, 60

* indicates that letter values should be reversed for scoring

APPENDIX B

Personal Adjustment and Communication Strategies items from the Communication Profile for the Hearing Impaired (Demorest and Erdman, 1987)

Scoring of the CPHI

Communication Profile for the Hearing Impaired

Part I. In this section of the questionnaire you're asked to describe the kinds of experiences you have when you're communicating with others. What kinds of things happen when you're trying to carry on a conversation? What do you do when you have trouble understanding what someone has said? What kinds of things do other people do that make it harder or easier for you to communicate with them?

Each item below describes a particular behavior or a situation. Think carefully about each one and indicate how often the situation occurs or how frequently you have the experience that's described.

1= Rarely happens or Almost Never True
2= Occasionally or Sometimes
3= About Half the Time
4= Frequently or Often
5= Almost Always

1- The way I get people to repeat what they said is by ignoring them.	1	2	3	4	5
2- If someone repeats what they've said and I still don't understand, I ask them to repeat again.	1	2	3	4	5
3- In difficult listening situations, I try to position myself so that I can hear as well as possible.	1	2	3	4	5
4- I get bothered or upset when I'm unable to follow a conversation.	1	2	3	4	5
5- I try to give the impression of normal hearing.	1	2	3	4	5
6- I interrupt others when listening to them is difficult.	1	2	3	4	5
7- If I hear part of what someone has said, I only ask them to repeat what I didn't hear.	1	2	3	4	5
8- When I have trouble understanding someone, I pay close attention to his or her face.	1	2	3	4	5

1= rarely, 2= occasionally, 3= half-the-time, 4-= often, 5=almost always

9- I feel stupid when I have to ask someone to repeat what they've said.	1	2	3	4	5
10- I try to hide my hearing problem.	1	2	3	4	5
11- I tend to dominate conversations so I won't have to listen to others.	1	2	3	4	5
12- I've asked my family to get my attention before speaking to me.	1	2	3	4	5
13- If I'm sitting where I can't hear, I'll move to another seat.	1	2	3	4	5
14- I feel foolish when I misunderstand what someone has said.	1	2	3	4	5
15- If someone seems irritated at having to repeat, I stop asking them to do so and pretend to understand.	1	2	3	4	5
16- When I don't understand what someone has said, I ask them to repeat it.	1	2	3	4	5
17- At parties or other social gatherings I try to stay in a well-lighted area so I can see the speaker's face.	1	2	3	4	5
18- I get mad at myself when I can't understand what people are saying.	1	2	3	4	5
19- I tend to avoid social situations where I think I'll have problems hearing.	1	2	3	4	5
20- When I'm having trouble understanding friends or family members, I remind them that I have a hearing problem.	1	2	3	4	5
21- When I must listen in a group, I try to sit where I'll be able to hear better.	1	2	3	4	5

1= rarely, 2= occasionally, 3= half-the-time, 4= often, 5= almost always

22- I feel embarrassed when I have to ask someone to repeat what they've said.	1	2	3	4	5
23- I avoid conversing with others because of my hearing loss.	1	2	3	4	5
24- I've asked my friends and people I work with to get my attention before speaking to me.	1	2	3	4	5
25- When there's background noise I position myself so that it's less distracting.	1	2	3	4	5
26- When I don't understand what someone has said, I pretend that I understood it.	1	2	3	4	5
27- When I don't understand what someone has said, I explain that I have a hearing loss.	1	2	3	4	5
28- When I'm having trouble following a conversation, I listen carefully and try to catch the main points.	1	2	3	4	5
29- I avoid talking to strangers because of my hearing loss.	1	2	3	4	5
30- When I think a person is speaking too softly, I ask them to speak up.	1	2	3	4	5
31- If possible, I try to watch a person's face when he or she is speaking.	1	2	3	4	5
32- When I don't understand what someone has said, I ignore them.	1	2	3	4	5

Part II. The items in this section describe a variety of feelings, attitudes and beliefs about hearing loss and communication. Some of the items describe your reactions and the reactions of those around you to some common problems associated with hearing loss. Read each item carefully and decide whether you agree or disagree with the idea expressed.

5= Strongly Agree
4= Agree
3= Uncertain
2=Disagree
1= Strongly Disagree

33- My hearing loss makes me mad.	1	2	3	4	5
34- People should be more patient when they're talking to me.	1	2	3	4	5
35- My hearing loss is my problem and I hate to bother others with it.	1	2	3	4	5
36- I feel depressed as a result of my hearing loss.	1	2	3	4	5
37- I feel threatened by many communication situations due to difficulty hearing.	1	2	3	4	5
38- I feel left out of conversations because I have trouble understanding.	1	2	3	4	5
39- Sometimes I feel left out when I can't follow the conversation of those I'm with.	1	2	3	4	5
40- I get aggravated when others don't speak up.	1	2	3	4	5
41- If people speak where I can't see them, they shouldn't expect me to answer them.	1	2	3	4	5
42- I feel guilty about asking people to repeat for me.	1	2	3	4	5
43- I get discouraged because of my hearing loss.	1	2	3	4	5
44- I'm not very relaxed when conversing with others.	1	2	3	4	5

5= strongly agree, 4= agree, 3= uncertain, 2= disagree, 1=strongly disagree

45- I withdraw from social talk because of my hearing loss.	1	2	3	4	5
46- I sometimes get annoyed when I have trouble hearing.	1	2	3	4	5
47- Sometimes I'm ashamed of my hearing problems.	1	2	3	4	5
48- I get impatient with people who aren't willing to repeat for me.	1	2	3	4	5
49- If people want me to understand them, it's up to them to speak more clearly.	1	2	3	4	5
50- I hate to ask others for special consideration just because I have a hearing problem.	1	2	3	4	5
51- The problems I have communicating with others really get me down.	1	2	3	4	5
52- I'm not very comfortable in most communication situations.	1	2	3	4	5
53- Because of my hearing loss I keep to myself.	1	2	3	4	5
54- When I have trouble hearing, I feel frustrated.	1	2	3	4	5
55- I'm sensitive about my hearing loss.	1	2	3	4	5
56- Questions about my hearing loss really irritate me.	1	2	3	4	5
57- Others should be more understanding about my hearing problems.	1	2	3	4	5
58- I feel bad about the inconvenience I cause others because of my hearing loss.	1	2	3	4	5

5= strongly agree, 4=agree, 3= uncertain, 2= disagree, 1= strongly disagree

59- When I can't understand people, sometimes I just don't care anymore.	1	2	3	4	5
60- When I have trouble hearing, I become nervous.	1	2	3	4	5
61- Since I have trouble hearing, I don't enjoy going places with friends as much.	1	2	3	4	5
62- It's frustrating when people refuse to repeat what they've said.	1	2	3	4	5
63- I find it difficult to admit to others that I have a hearing problem.	1	2	3	4	5
64- I really get annoyed when people shout at me as if I'm deaf.	1	2	3	4	5
65- I've asked friends and people I work with to get my attention before speaking to me.	1	2	3	4	5
66- I try not to bother anyone else when I'm having trouble hearing.	1	2	3	4	5
67- I let my hearing problems get me down.	1	2	3	4	5
68- Sometimes I miss so much of what's being said that I feel left out.	1	2	3	4	5
69- Sometimes when I misunderstand what someone has said I feel foolish.	1	2	3	4	5
70- At times my hearing loss makes me feel incompetent.	1	2	3	4	5
71- It bothers me to admit that I have a hearing loss.	1	2	3	4	5
72- I get angry when I can't understand what someone is saying.	1	2	3	4	5

5= strongly agree, 4= agree, 3= uncertain, 2= disagree, 1= strongly disagree

73- I don't like to ask other people to help me with my hearing problems.	1	2	3	4	5
74- Not being able to understand is very discouraging.	1	2	3	4	5
75- I worry about looking stupid when I can't understand what someone has said.	1	2	3	4	5
76- Feeling isolated is part of having a hearing impairment.	1	2	3	4	5
77- I sometimes get angry with myself when I can't hear what people are saying.	1	2	3	4	5
78- Because of my hearing loss I have feelings of inadequacy.	1	2	3	4	5
79- I can't talk to people about my hearing loss.	1	2	3	4	5
80- Straining to hear upsets me.	1	2	3	4	5
81- The difficulties I have with my hearing restrict my social and personal life.	1	2	3	4	5
82- Sometimes I feel tense when I can't understand what someone is saying.	1	2	3	4	5
83- I feel self-conscious because of my hearing loss.	1	2	3	4	5
84- I have a hard time accepting the fact that I have a hearing loss.	1	2	3	4	5
85- When I can't understand what's being said, I feel tense and anxious.	1	2	3	4	5
86- I sometimes feel embarrassed when I misunderstand what someone has said.	1	2	3	4	5
87- I'd rather miss part of a conversation than admit that I have a hearing loss.	1	2	3	4	5
88- I get very tense because of my hearing loss.	1	2	3	4	5

CPHI Scoring

Scale	Item Numbers
Communication Strategies	
Maladaptive Behaviors *	1, 6, 11, 15, 19, 23, 26, 29, 32
Verbal Strategies	2, 7, 12, 16, 20, 24, 27, 30
Nonverbal Strategies	3, 8, 13, 17, 21, 25, 28, 31
Personal Adjustment	
Self-Acceptance*	4, 9, 14, 18, 22, 70, 78, 83
Acceptance of Loss*	5, 10, 47, 55, 63, 71, 79, 84, 87
Anger *	33, 40, 48, 56, 64, 72
Exaggeration of Responsibility*	35, 42, 50, 58, 66, 73
Stress*	37, 44, 52, 88, 60, 75, 80, 85
Withdrawal*	38, 45, 53, 61, 68, 76, 81
Denial	39, 46, 54, 62, 69, 77, 82, 86
Displacement of Responsibility*	34, 41, 49, 57, 65

* indicates numbers should be reversed for scoring

APPENDIX C

Forms

Letter to subjects

Consent form

Information sheet

Data sheet

Instructions and categories for loudness discomfort level testing (Hawkins, et al. , 1987)

Worksheet for applying NAL target gain formula (based on Byrne and Dillon, 1986)

Instructions for tolerated signal-to-noise test (based on Nabelek et al., 1991)

Dear

I am a research audiologist in the Department of Audiology and Speech Pathology at the University of Tennessee. I am conducting a study to learn how to better predict a new hearing aid user's performance and satisfaction with his or her hearing aid(s). I am hoping that, since you will soon be wearing hearing aids for the first time, you will consider taking part in this study.

Your participation in the study would involve making an extra visit to the University for some additional listening tests. This visit will only take one hour or less. You will also be asked to complete two questionnaire-type tests, one before you receive your hearing aids and one afterwards. You will be paid $15.00 to thank you for your time and to cover your costs of transportation.

I will be calling you in the next week to see if you are interested in helping with the study. Please know that there is no obligation on your part to participate, but I would be very grateful for your consideration.

Sincerely,

Hilary Crowley, M.A.
Research Audiologist

CONSENT FOR PARTICIPATION IN RESEARCH

Title of Project: Unaided Factors Predicting Client-Assessed Hearing Aid Performance, Use and Satisfaction

Investigator: Hilary Crowley, M.A.
Advisor: Igor V. Nabelek, Ph.D.

The purpose of this study is to find out what information can be used, before a new hearing aid is ordered, to predict how satisfied the user will be with his or her new hearing aid in different listening situations. There are no direct benefits that you can expect from this research. It is hoped that the results of the study will help audiologists provide better counseling for new hearing aid users and help potential hearing aid users in deciding whether or not to purchase a hearing aid.

If you participate in this study, the investigator will obtain information regarding your hearing and your hearing aid fitting from your records at the UT Hearing Clinic. You will be asked to take two questionnaire-type tests, one before your hearing aid fitting and one after. Some of the questions will ask about your feelings and others will ask about how well you are hearing with your hearing aid. You will also be given some auditory tests similar to those you received before your hearing aid was ordered. Two of the tests involve listening to speech in background noise. In one you will be asked to repeat words, and in the other you will be asked to turn down the background noise to a volume that is tolerable for listening to and understanding the speech. In a third test you will be asked to state when speech becomes uncomfortably loud. Altogether, participation in this study will require about two hours of your time in addition to the time you are at the clinic for your hearing test and hearing aid fitting.

Risks involved in participating in this project are no greater than those ordinarily encountered in routine hearing aid evaluations. All data obtained during the course of this study will be kept confidential and accessible only to the investigators in this project. Feel free to ask any questions you may have about the study. Your participation in this study is totally voluntary. You may refuse to participate or choose to withdraw from this study at any time without negative consequences.

I have read this consent form and I understand the procedures to be used in this study and the possible risks, inconveniences, and/or discomforts that may be involved. All of my questions have been answered. I freely and voluntarily choose to participate. I understand that I may withdraw at any time.

_____ _____

Signature Date

Subject Information

Date of Interview_____

Name_____ Birthdate_____

Address_____ Age_____

_____ Phone_____

Occupation_____ Years of Education_____

% Employment (incl. volunteer)_____

Reason for pursuing hearing aid use: 1- Self-motivated, 2- Family encouragement, 3- Encouraged by professional (M.D., etc.)

Number of years experiencing difficulty hearing: RE_____ LE_____

Mode of onset and progression of loss: 1- gradual 2- sudden

Situations in which hearing is most difficult _____

_____

Medical History:

Family history of hearing loss: 1- Yes 2- No

Otitis media: 1- Yes 2- No

Tinnitus: 1- Yes 2- No

Vertigo or dizziness: 1- Yes 2- No

Number of Medications taken daily_____

Ear Surgery: 1- Yes 2- No

Noise Exposure: 1- Yes 2- No

Hearing Aid Information:

Where was hearing aid obtained?_____

Date of purchase_____ Ear_____

Make_____ Model_____

Data Sheet- Subject_____

Predictive Factors

1. Audiogram

Aided Ear PTA_____ Unaided Ear PTA_____ Mean_____

Right Ear Slope: Mean of 500 + 1000 _____

Mean of 2000 + 4000 _____ Difference_____

Left Ear Slope: Mean of 500 + 1000 _____

Mean of 2000 + 4000 _____ Difference_____

Mean slope (right & left) _____

Right Ear MCL_____ Left Ear MCL_____ Mean_____

Difference between NAL target and actual insertion gain:
(based on clinic printout)

Right Ear: 500_____ 1000_____ 2000_____ 4000 _____

Left Ear: 500_____ 1000 _____ 2000_____ 4000 _____

Average Right_____ Average Left_____ Mean R & L _____

2. Case History

Age_____ Sex_____

Percent Time Employed _____ Number Medications _____

Reason for Hearing Aid: 1- self 2- family 3- professional

Years of Education _____

3. Testing Session

Right Ear Dynamic Range: SRT _____ Speech LDL _____

Left Ear Dynamic Range: SRT _____ Speech LDL _____

Right DR _____ Left DR _____ Mean DR _____

Pure tone LDLs (nearest 2 dB):

Right Ear: 500 _____ 1000 _____ 2000 _____

Left Ear: 500 _____ 1000 _____ 2000 _____

Mean (R&L) LDL: 500 _____ 1000 _____ 2000 _____

SPIN: SRT for babble (nearest 2 dB) _____

SPIN % Correct (30 dB SL; 8 dB S/N) _____

Right Ear Tolerated S/N: MCL for connected speech on dial _____

Tolerated level babble _____

Tolerated S/N for babble _____

Tolerated level for speech spectrum _____

Tolerated S/N for speech spectrum _____

Left Ear Tolerated S/N: MCL for connected speech _____

Tolerated level babble _____

Tolerated S/N for babble _____

Tolerated level for speech spectrum _____

Tolerated S/N for speech spectrum _____

Mean Tolerated S/N for babble (R & L) _____

Mean Tolerated S/N for speech spectrum noise _____

Communication Profile for the Hearing Impaired:

Communication Strategies _____ Personal Adjustment _____

4. Follow-up

Perceived Performance: PHAP Subscale Scores:

Familiar Talkers _____

Ease of Communication _____

Communication in Reverberation _____

Communication in Background Noise _____

Communication with Reduced Cues _____

Aversiveness of Sounds _____

Distortion of Sounds _____

Hearing Aid Satisfaction Rating _____

Hearing Aid Use:

Hours of Daily HA Use _____

Hours of Desired Use _____

Hours napping, noise, exercising _____

Comments on Expectations:

_____

_____

_____

_____

LDL INSTRUCTIONS

The following test is performed to help the audiologist select your hearing aid and set the controls on your hearing aid so that sounds will not be uncomfortably loud for you. You will hear some recorded speech and then some tones through an earphone. After each of the sounds I want you to tell me which of the loudness categories on this sheet (hand loudness chart to subject) best describes the sound to you. For example, after each sound, tell me if it was "comfortable", or "comfortable, but slightly loud", or "uncomfortably loud", etc. I will be zeroing in on the uncomfortably loud category because that is where we want your hearing aid to stop and not get any louder. So after each sound, tell me which category best describes the sound to you.

LEVELS OF LOUDNESS

PAINFULLY LOUD

EXTREMELY UNCOMFORTABLE

UNCOMFORTABLY LOUD

LOUD, BUT O.K.

COMFORTABLE, BUT SLIGHTLY LOUD

COMFORTABLE

COMFORTABLE, BUT SLIGHTLY SOFT

SOFT

VERY SOFT

Categories of Loudness for testing loudness discomfort levels, from Hawkins, Walden, Montgomery and Prosek (1987)

Worksheet for National Acoustic Laboratories' (NAL) Target Gain

Subject _____ Desired NAL Gain

	250		500		1000		2000		4000	
	L	R	L	R	L	R	L	R	L	R
Hearing Level (HL) in dB										
X + 0.31 HL										
Correction for Real-ear gain	-12		-3		+6		+4		+3	
Desired insertion gain										
Right + Left/2										
Correction for earphone	+10		+1		-2		-6		-3	
Desired gain thru earphone										
Gain adjustment to 0 base (dB)										
Desired equalizer setting										
Actual setting VU-meter reading										

X= 0.05 (TH500 + Th1000 + Th2000)

X= RE_____ X= LE _____

Instructions for Tolerated S/N Levels

1- Through the earphone you will hear a story read by a woman. Using the dial on the right, adjust the volume to a level that you would feel comfortable listening to for a long period of time. Do this by increasing the volume one step at a time (point out numbers on digital display; each increase or decrease in the number by one is being referred to as a step) until you have passed the most comfortable volume, then decrease the volume one step at a time until you are just below the most comfortable volume. Increase and decrease the volume again one to two times, zeroing in on the most comfortable level.

2- Next you will hear background noise in addition to the story through the earphone. Using the dial on the left, adjust the noise to the highest possible level that you would be willing to tolerate or "put up with" without becoming tense and tired when listening to and following the story. Do this by decreasing the volume one step at a time until you have passed the highest tolerable level. Repeat 2-3 times until you have zeroed in on the highest level of the noise you find tolerable.

APPENDIX D

Raw Data

Key to Abbreviations

Babble	Tolerated signal-to-noise level for babble
CLL	Comfortable Loudness Level
CS	Communication Strategies score from the Communication Profile for the Hearing Impaired
Educ.	Education
Emp.	Employment
Med.	Medications
NAL	Difference between National Acoustic Laboratories' target gain and measured insertion gain
PA	Personal Adjustment scores from the Communication Profile for the Hearing Impaired
PTA	Pure tone average
Motivation	Motivation for pursuing hearing aids: 1=self-motivation, 2=family encouragement, 3=professional encouragement
SPIN	Speech Perception in Noise test score
Sp. Spect.	Tolerated signal-to-noise level for speech spectrum noise
AV	Aversiveness of Sounds subscale of the Profile of Hearing Aid Performance
BN	Background Noise subscale of the Profile of Hearing Aid Performance
DS	Distortion of Sounds subscale of the Profile of Hearing Aid Performance
EC	Ease of Communication subscale of the Profile of Hearing Aid Performance
FT	Familiar Talkers subscale of the Profile of Hearing Aid Performance

Key to Abbreviations, Continued

RC	Reduced Cues subscale of the Profile of Hearing Aid Performance
RV	Reverberation subscale of the Profile of Hearing Aid Performance
Sat.	Satisfaction rating on a scale of 1-7, with 1 being best
Use	Hours of daily hearing aid use

Predictive Variables

Subject Number	Age in Years	Babble (dB)	CLL (dB)	CS	DR (dB)	Educ (years)	Emp (%time)	Gender
1	78	+5.5	62.5	2.64	82.0	8	0	F
2	63	+0.5	62.5	3.27	71.0	12	100	M
3	75	+9.5	72.5	3.43	55.0	16	50	F
4	74	+15.5	70.0	3.86	79.0	14	50	M
5	52	+5.5	55.0	3.65	89.0	21	100	M
6	66	+21.5	70.0	3.71	52.0	12	100	M
7	65	+4.0	72.5	3.66	93.0	16	10	M
8	70	+7.5	77.5	3.14	45.0	12	0	F
9	52	+1.0	70.0	4.04	62.0	17	100	F
10	62	0	65.0	2.65	81.0	14	0	M
11	62	+11.5	70.0	2.84	84.0	18	25	M
12	66	+8.5	62.5	3.37	65.0	12	100	F
13	73	+5.5	55.0	2.38	62.0	12	0	M
14	82	+7.5	57.5	3.50	47.0	16	30	F
15	86	+12.5	75.0	3.59	64.5	10	0	M
16	73	+2.5	57.5	3.01	81.0	19	100	M
17	68	+12	55.0	4.11	74.0	9	0	M
18	62	+12.5	67.5	4.28	63.0	12	50	M
19	63	+10	67.5	4.10	45.0	14	0	M
20	74	+4.5	65.0	3.24	61.0	15	30	F
21	71	+3	70.0	3.53	42.0	12	0	M
22	69	+10.5	57.5	3.62	57.0	14.5	0	F
23	65	0	55.0	2.84	84.0	16	0	M

Predictive Variables, Continued

Subject Number	Age (years)	Babble (dB)	CLL (dB)	CS	DR (dB)	Educ. (years)	Emp. (%time)	Gender
24	72	+8.0	67.5	3.15	59.0	8	0	M
25	73	+3.5	70.0	4.80	85.0	13	50	F
26	72	+8.5	70.0	4.66	52.0	16	0	M
27	66	+8.0	70.0	4.11	63.0	18	25	M
28	67	+1.0	65.0	4.36	58.0	16	5	M
29	55	+0.5	60.0	3.69	90.0	16	100	M
30	66	+15.0	62.5	3.06	82.0	12	50	M
31	75	+13.5	60.0	3.41	39.0	12	0	F
32	82	+2.0	75.0	3.66	70.0	17	0	M
33	61	+10.0	82.5	3.70	37.0	4	0	F
34	61	+14.0	57.5	4.06	43.0	12	100	F
35	58	+2.5	50.0	3.85	76.0	14	100	M
36	74	+6.5	62.5	2.80	60.0	12	0	M
37	68	+6.5	67.5	3.28	78.0	17	100	M
38	81	+0.5	82.5	4.11	61.0	15	0	M
39	59	+17.5	62.5	4.01	58.0	6	100	M
40	77	-0.5	55.0	3.39	59.0	18	100	M
41	66	+2.5	65.0	4.06	71.0	14	100	M
42	65	+26.0	67.5	4.09	31.0	12	100	M
43	73	+3.5	67.5	4.46	57.0	15	0	F
44	66	+24.0	72.5	3.82	70.0	12	0	F
45	72	0	55.0	3.53	76.0	16	50	M
46	78	+7.5	50.0	3.94	61.0	18	0	F

Predictive Variables, Continued

Subject Number	Med. (#)	NAL (dB)	PA	PTA (dB)	Motiv-ation	Slope (dB,-)	SPIN (%)	Sp. Spect. (dB)
1	0	3.00	4.28	29.5	2	27.50	54	+5.5
2	1	3.25	3.29	37.5	1	36.25	66	+2.5
3	1	9.00	3.74	43.0	1	12.50	76	+12.5
4	7	1.87	3.20	26.5	2	29.00	72	+17.5
5	0	2.25	3.28	10.0	1	27.50	94	+7.0
6	0	2.50	2.99	41.5	2	37.50	60	+24.5
7	3	5.50	4.25	28.5	2	66.25	68	+6.5
8	1	3.25	2.66	45.5	2	6.25	78	+9.5
9	0	3.13	2.85	32.5	1	3.75	86	+1.0
10	3	2.13	3.42	10.0	1	33.75	66	+4.5
11	3	4.38	3.36	23.5	3	42.50	46	+10.0
12	1	3.38	3.15	31.5	1	18.75	88	+14.5
13	0	1.38	4.56	33.5	2	42.50	46	+1.5
14	2	5.00	4.24	35.0	1	10.00	64	+9.5
15	6	2.63	3.10	32.5	1	21.25	40	0
16	1	2.87	4.19	13.5	1	32.50	78	+1.5
17	4	3.37	3.72	11.5	1.5	33.75	90	+5.5
18	3	2.37	2.99	37.5	1	35.00	58	+13.0
19	2	2.75	3.73	45.0	1	53.75	36	+5.0
20	4	5.12	3.15	22.5	1	22.50	66	+7.5
21	0	3.50	3.17	43.0	1	22.50	82	+4.5
22	4	4.12	3.19	36.5	1	8.75	90	+10.5
23	0	1.87	4.16	15.5	2	37.50	90	-2.5

Predictive Variables, Continued

Subject Number	Med. (#)	NAL (dB)	PA	PTA (dB)	Motiv-ation	Slope (dB,-)	SPIN (%)	Sp. Spect. (dB)
24	1	2.25	2.89	43.5	1	37.50	68	+3.0
25	0	5.00	3.89	30.0	1	20.0	38	+3.0
26	2	2.00	3.65	26.0	1	44.00	44	+8.0
27	6	3.62	3.29	26.0	2	41.25	70	0
28	2	0.50	3.59	33.0	1	31.25	63	-1.0
29	0	5.12	4.06	21.5	1	57.50	60	+0.5
30	1	1.62	3.23	16.0	2	36.0	66	+13.0
31	2	1.12	2.79	43.5	2	2.5	83	+14.5
32	0	1.75	3.03	36.0	2	40.00	74	+1.0
33	4	5.12	2.10	50.5	1	+6.25	96	+3.0
34	1	2.37	3.34	43.0	1	6.50	74	+10.5
35	2	2.00	3.91	27.0	1	46.25	80	+1.5
36	0	2.00	4.09	33.5	2	27.50	78	+6.5
37	4	13.50	2.63	30.0	1.5	45.00	64	+1.5
38	2	2.37	3.30	40.5	2	40.00	37.5	+4.5
39	2	1.62	2.26	23.5	1	32.50	66	+15.0
40	3	3.75	3.77	38.0	1	32.50	60	+5.5
41	1	1.87	3.95	24.5	1	16.25	65	-0.5
42	0	2.40	3.17	48.0	2	3.75	80	+26.0
43	5	1.12	3.75	35.5	1	13.75	80	-1.0
44	3	2.37	3.33	45.0	2	57.50	43	+28.0
45	1	1.00	3.73	30.5	2	37.50	68	-4.5
46	4	10.5	2.89	30.5	1	7.50	92	+7.5

Response Variables

Subject Number	AV (%)	BN (%)	DS (%)	EC (%)	FT (%)	RC (%)	RV (%)	Sat. Rating	Use (hours)
1	52.1	32.7	60.3	19.4	10.4	38.8	22.0	2	4
2	73.5	21.0	41.3	27.2	12.3	39.1	46.5	6	12
3	29.2	24.9	18.7	6.0	2.6	36.0	42.9	7	5
4	77.9	64.6	74.8	71.4	13.9	53.9	59.6	5	3
5	52.9	28.7	27.0	71.4	4.1	48.4	14.0	1	17
6	67.3	28.0	41.5	19.4	5.7	28.1	26.1	2	8
7	8.5	11.4	37.8	4.1	2.6	16.6	7.3	3	6
8	30.4	50.7	35.3	45.0	19.3	48.0	59.3	5	8
9	19.9	21.7	22.8	12.6	7.3	35.8	20.8	1	10
10	9.4	21.6	12.7	21.0	12.0	29.1	26.1	3	4
11	16.3	29.5	39.3	26.4	13.9	32.9	26.0	3	3
12	10.3	10.2	4.7	7.3	4.1	6.5	5.4	1	9
13	38.4	8.0	13.3	1.0	1.0	25.6	17.3	1	3
14	11.5	26.4	16.3	14.7	2.6	28.9	23.6	2	13
15	64.3	41.3	70.7	57.1	18.0	51.3	51.5	1	9
16	18.7	24.7	9.8	21.3	8.9	15.2	24.7	2	6
17	31.8	39.7	47.7	46.3	7.3	42.8	23.3	2	10
18	39.5	23.3	33.2	5.7	1.0	36.1	23.8	2	5
19	6.5	33.4	47.8	19.7	5.7	56.3	45.4	3	16
20	46.8	38.3	43.3	23.6	4.1	28.0	29.2	2	6
21	40.9	34.2	22.7	17.6	4.1	27.9	36.0	2	7
22	20.9	28.8	16.3	14.1	21.3	23.2	27.6	2	5
23	3.9	16.9	10.5	12.0	7.3	13.7	14.9	2	16

Response Variables, Continued

Subject Number	AV (%)	BN (%)	DS (%)	EC (%)	FT (%)	RC (%)	RV (%)	Sat. Rating	Use (hours)
24	27.1	24.2	37.5	28.3	4.4	30.7	14.0	2	8
25	90.8	45.0	28.7	24.7	6.0	36.1	37.5	4	4
26	63.4	32.8	45.8	17.4	4.1	44.1	38.9	3	4
27	7.4	46.9	43.7	30.3	30.3	45.8	50.0	6	3
28	50.8	31.8	14.2	9.1	2.6	19.7	22.1	2	3
29	30.1	35.1	26.8	13.9	13.9	31.7	23.3	2	12
30	42.9	42.1	39.5	13.9	13.9	52.4	26.1	6	4
31	84.6	38.3	26.8	17.7	4.4	45.3	28.3	5	4
32	38.5	39.9	37.3	12.6	9.1	32.9	55.2	2	4
33	18.9	41.1	55.7	42.6	25.0	43.6	27.8	1	8
34	56.3	61.6	41.7	30.3	32.3	65.2	49.9	4	10
35	18.3	3.2	1.0	1.0	2.6	28.3	6.4	5	8
36	20.5	12.4	16.7	10.7	5.7	27.7	27.7	2	5
37	36.4	27.2	22.8	28.4	25.0	22.0	23.4	4	1
38	68.2	63.0	60.3	65.9	7.3	58.1	60.8	7	4
39	35.5	50.7	43.7	24.9	16.0	52.6	59.6	1	12
40	4.7	17.1	9.8	7.3	7.6	35.9	20.9	4	1
41	52.2	21.6	64.2	13.9	13.9	26.4	27.6	2	10
42	12.7	16.1	10.5	10.7	14.9	12.2	17.7	1	16
43	35.7	28.9	37.3	17.7	2.6	15.1	19.1	1	2
44	56.2	44.5	45.8	35.7	30.3	50.0	55.4	3	8
45	25.3	15.9	20.8	16.3	12.0	21.7	12.0	2	4
46	65.6	21.3	2.8	9.4	1.0	36.2	44.3	2	4

APPENDIX E

Regression printout example

```
n= 46     Regression Models for Dependent Variable: USE

           Rsq     C(p)      MSE Variables in Model
  In

     1 0.20375  -1.170  14.295 AGE
     1 0.12640   2.797  15.683 MED
     1 0.07858   5.249  16.542 EMP
     1 0.03993   7.231  17.236 SPIN
     1 0.03346   7.563  17.352 BABBLE
 ------------------------------------
     2 0.27622  -2.886  13.296 AGE MED
     2 0.24420  -1.244  13.884 DR AGE
     2 0.22798  -0.412  14.182 AGE BABBLE
     2 0.22380  -0.198  14.259 AGE SLOPE
     2 0.22379  -0.197  14.259 AGE EDUC
 ------------------------------------
     3 0.32134  -3.199  12.764 AGE MED BABBLE
     3 0.31321  -2.783  12.917 DR AGE MED
     3 0.29562  -1.881  13.248 AGE MED EDUC
     3 0.29451  -1.824  13.268 AGE MED SLOPE
     3 0.28845  -1.513  13.382 AGE MED SPSPECT
 -------------------------------------------
     4 0.35220  -2.782  12.481 AGE MED REASON BABBLE
     4 0.34303  -2.312  12.657 AGE MED SPSPECT BABBLE
     4 0.33467  -1.883  12.818 DR AGE MED BABBLE
     4 0.33437  -1.868  12.824 AGE MED SPIN BABBLE
     4 0.33347  -1.821  12.842 PTA DR AGE MED
 -------------------------------------------
     5 0.37855  -2.133  12.272 AGE MED SPSPECT REASON BABBLE
     5 0.36450  -1.413  12.550 AGE MED SPIN REASON BABBLE
     5 0.36317  -1.344  12.576 AGE MED PA REASON BABBLE
     5 0.36087  -1.227  12.621 AGE MED NAL REASON BABBLE
     5 0.35966  -1.164  12.645 PTA DR AGE MED BABBLE
 -------------------------------------------
     6 0.39243  -0.845  12.306 AGE MED SPIN SPSPECT REASON BABBLE
     6 0.38984  -0.712  12.358 AGE MED PA SPSPECT REASON BABBLE
     6 0.38458  -0.442  12.465 AGE MED NAL SPSPECT REASON BABBLE
     6 0.38411  -0.418  12.474 MCL AGE MED SPSPECT REASON BABBLE
     6 0.38405  -0.415  12.476 AGE MED PA SPIN REASON BABBLE
       ---------------------------------------------
```

Example of computer printout showing "best" five models using one through six predictive variables for the response variable of "Use". (Printouts were actually obtained for models containing 1 through 16 variables.) Rsq is the coeficient of determination, MSE is mean squared error, and c(p) was not used for model selection.

APPENDIX F

Figures discussed in the text (1-11)

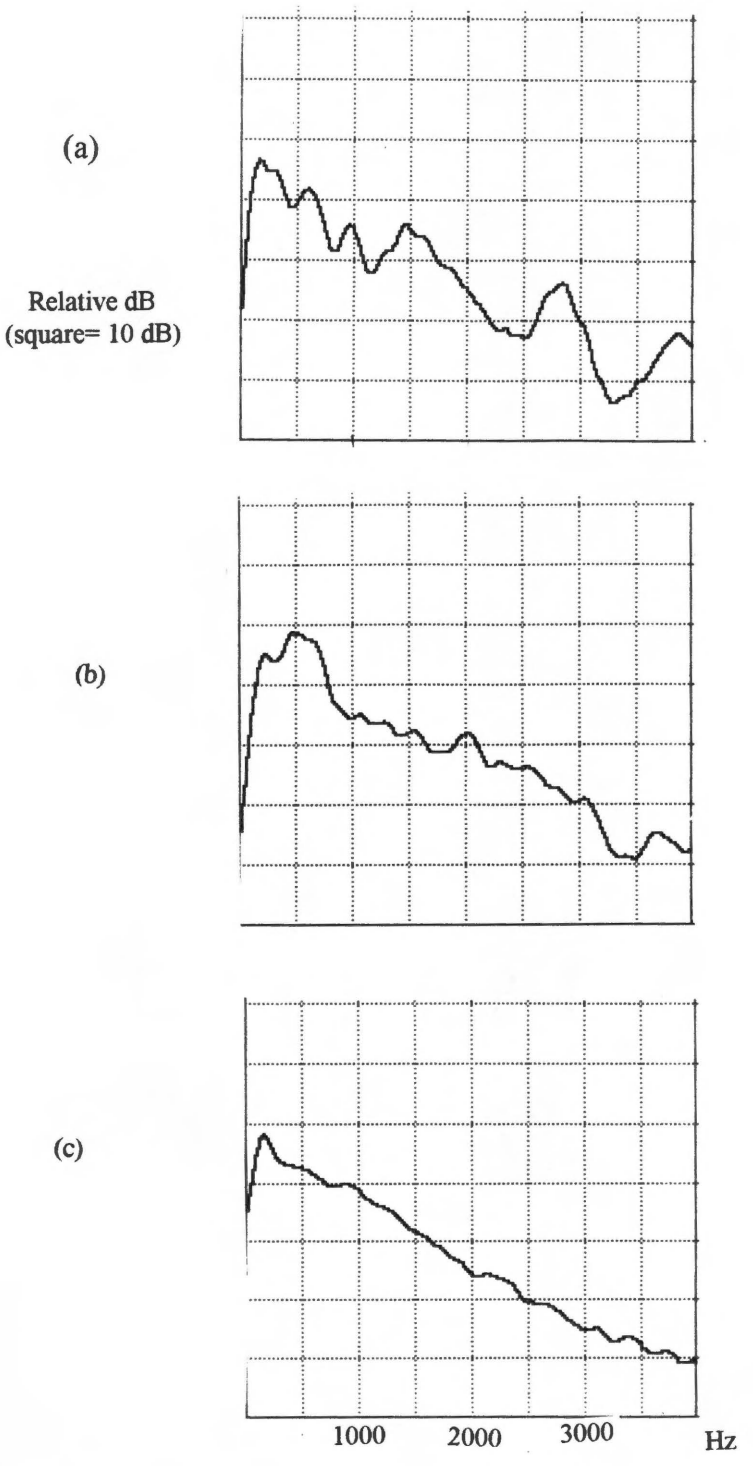


Figure 1. Power spectra of stimuli used for tolerated signal-to-noise testing: (a) Female speech, (b) Multitalker babble, and (c) Speech spectrum noise.

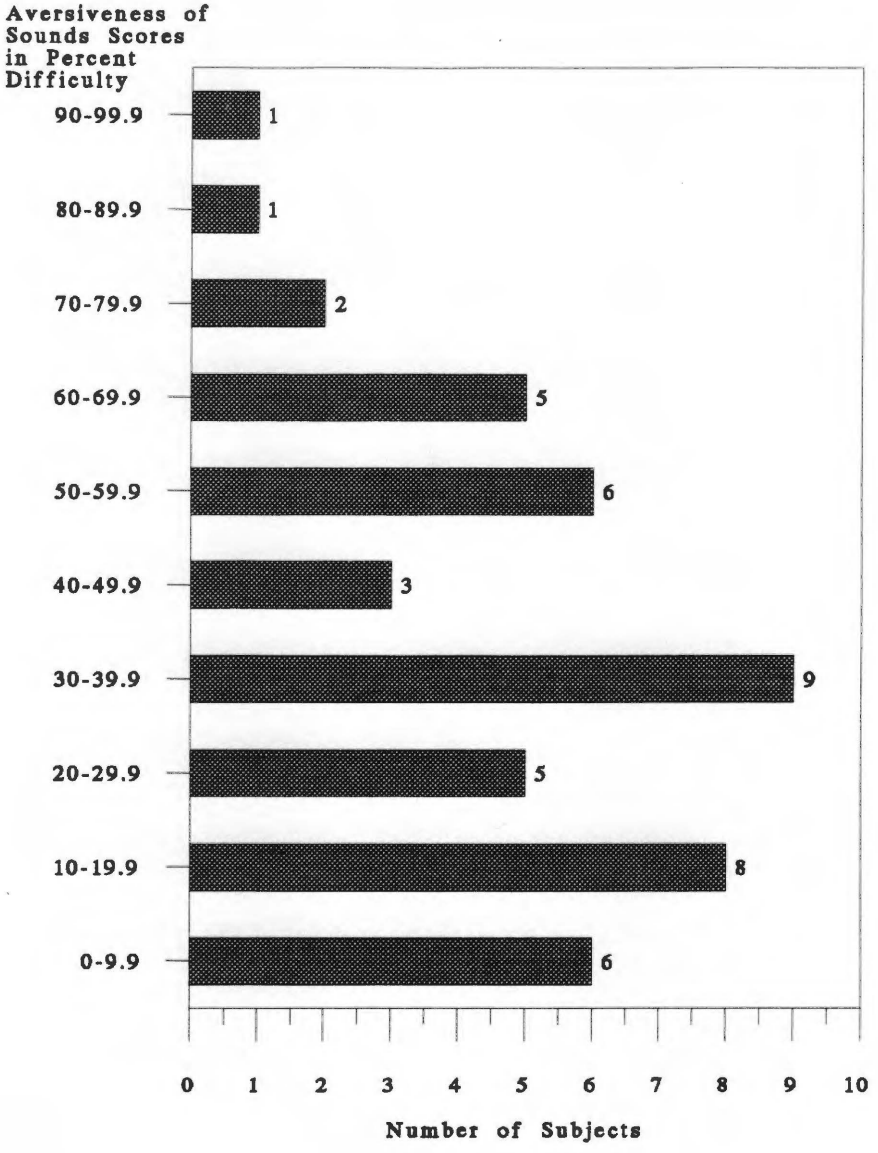


Figure 2. Distribution of scores for the Aversiveness of Sounds subscale of the PHAP.

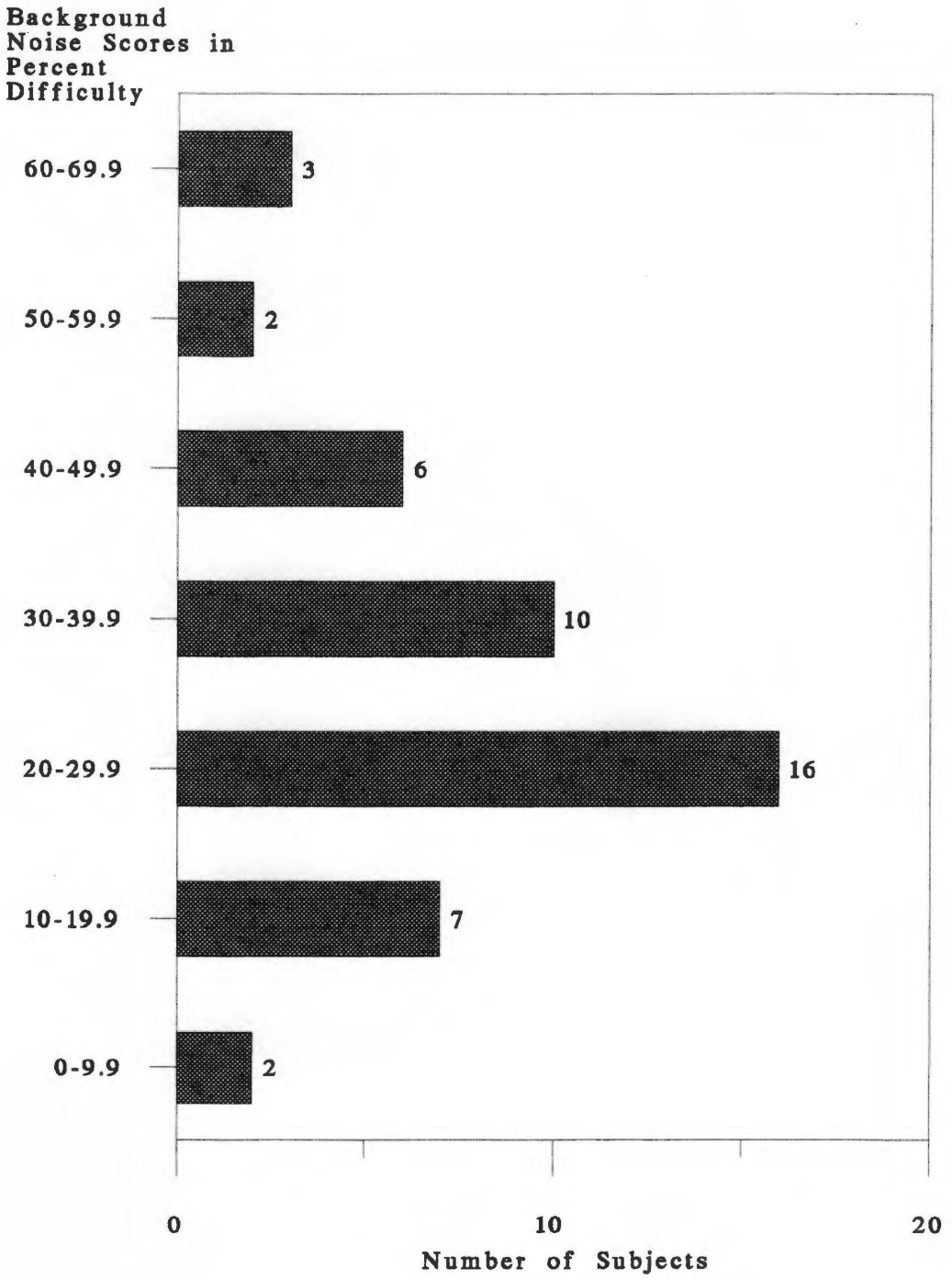


Figure 3. Distribution of scores for the Background Noise subscale of the PHAP.

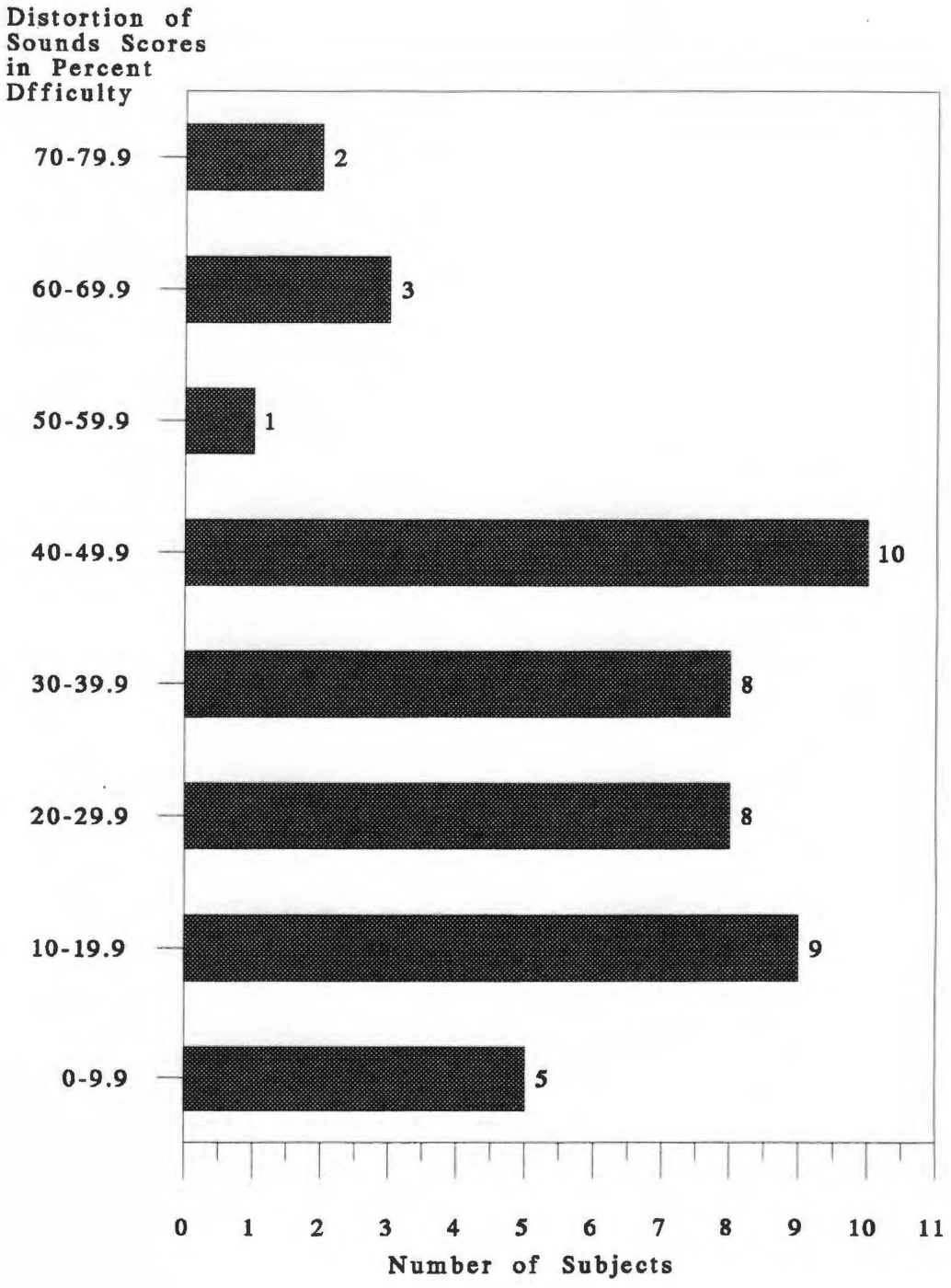


Figure 4. Distribution of scores for the Distortion of Sounds subscale of PHAP.

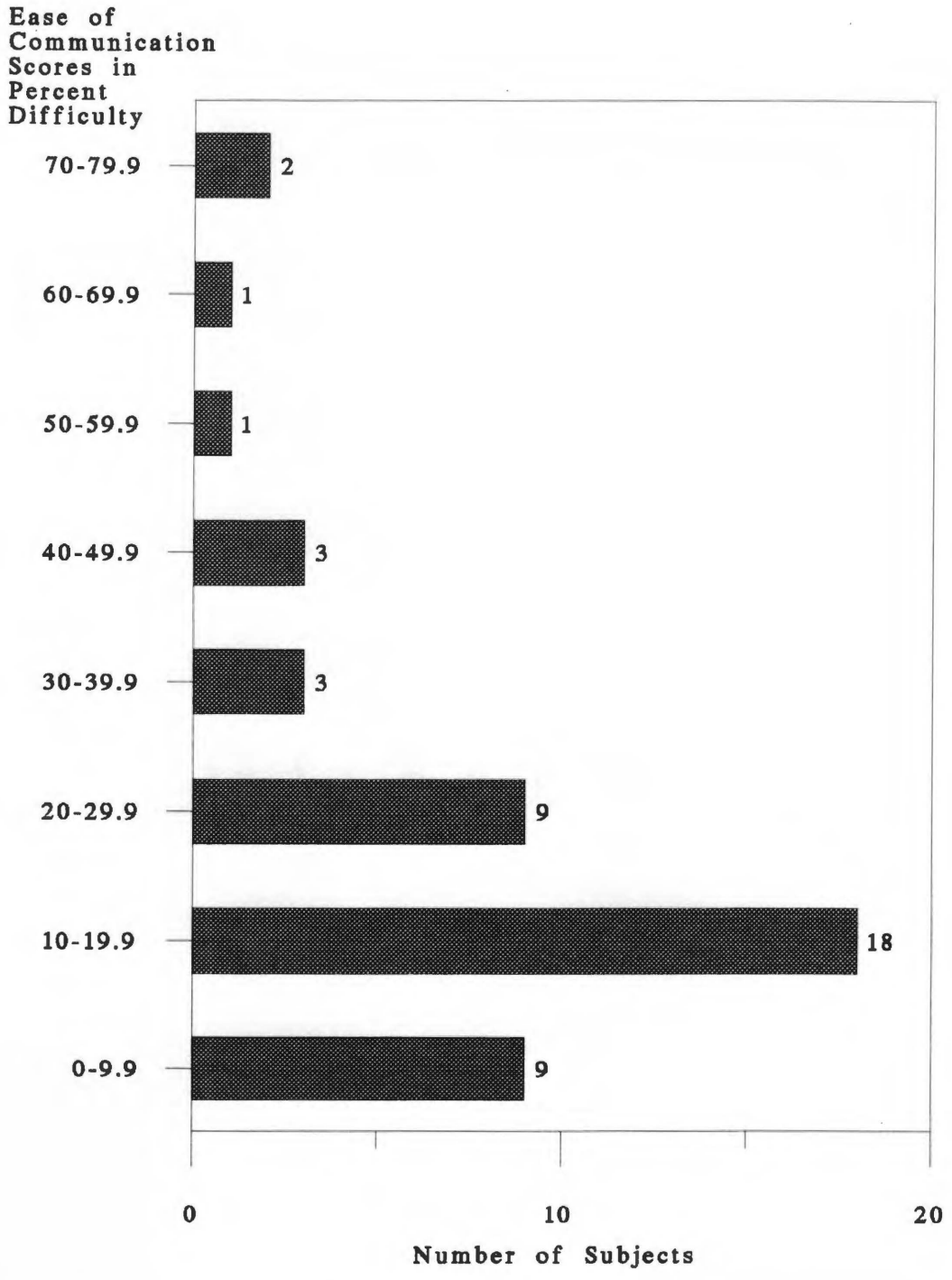


Figure 5. Distribution of scores for the Ease of Communication subscale of PHAP.

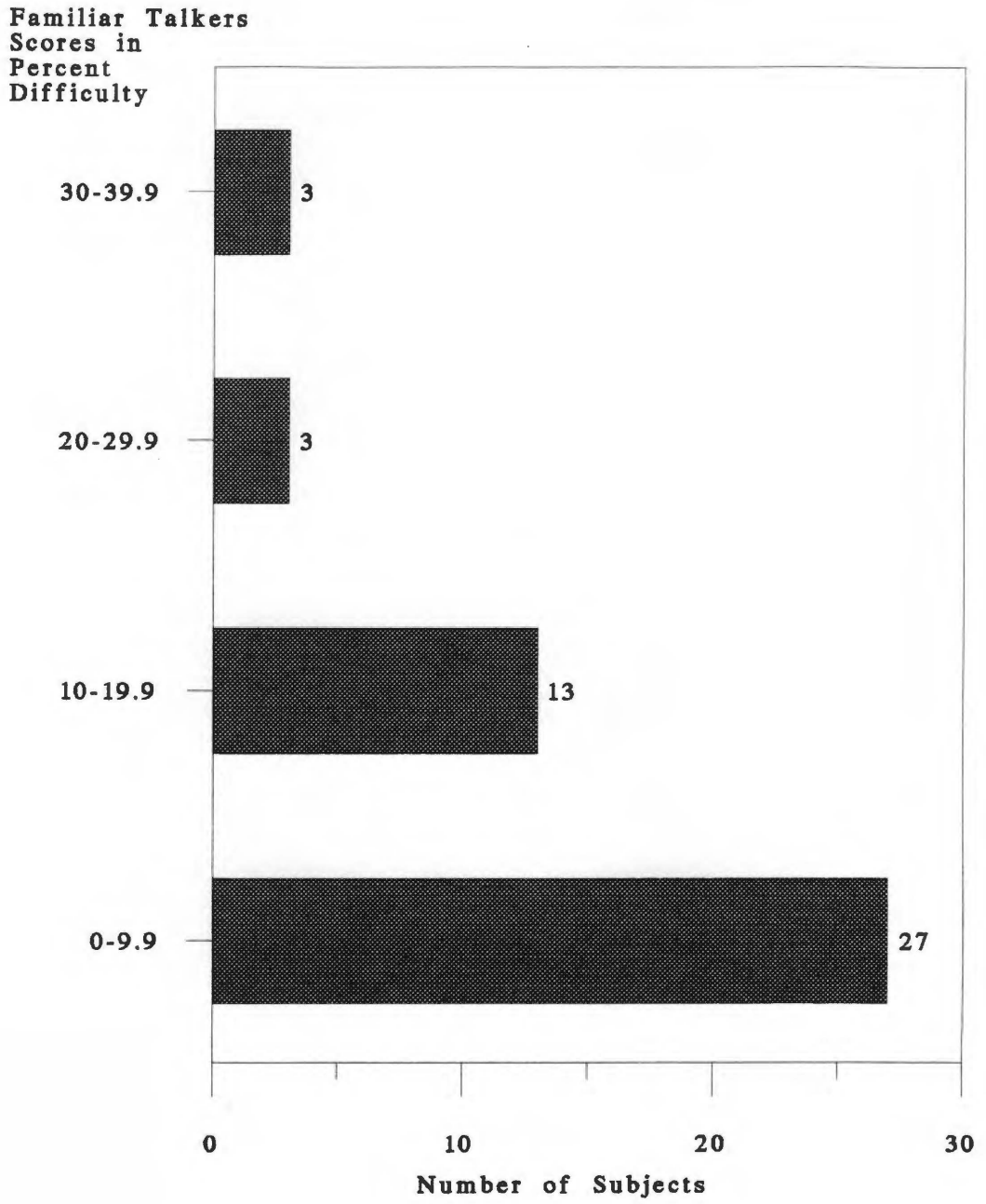


Figure 6. Distribution of scores for the Familiar Talkers subscale of the PHAP.

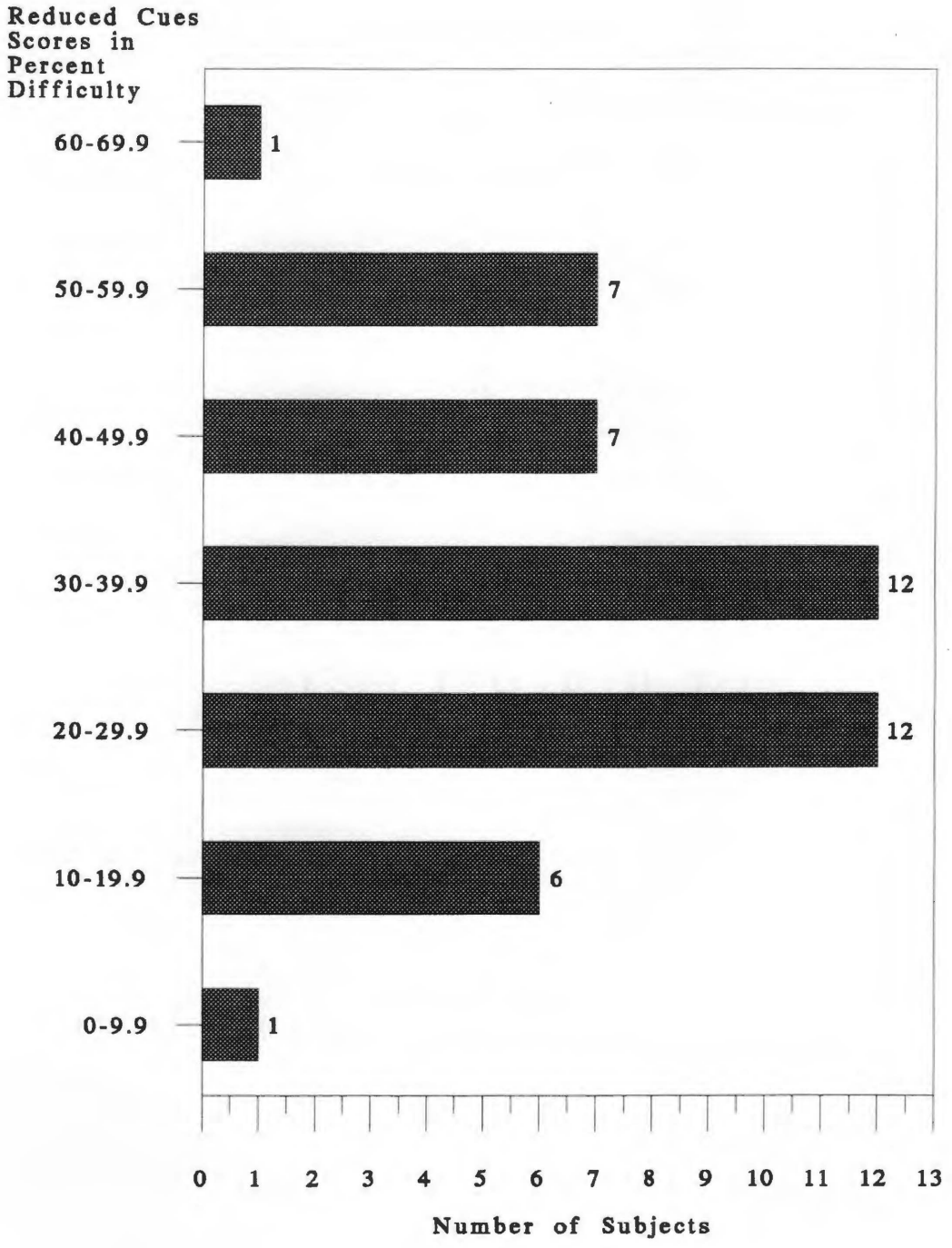


Figure 7. Distribution of scores for the Reduced Cues subscale of the PHAP.

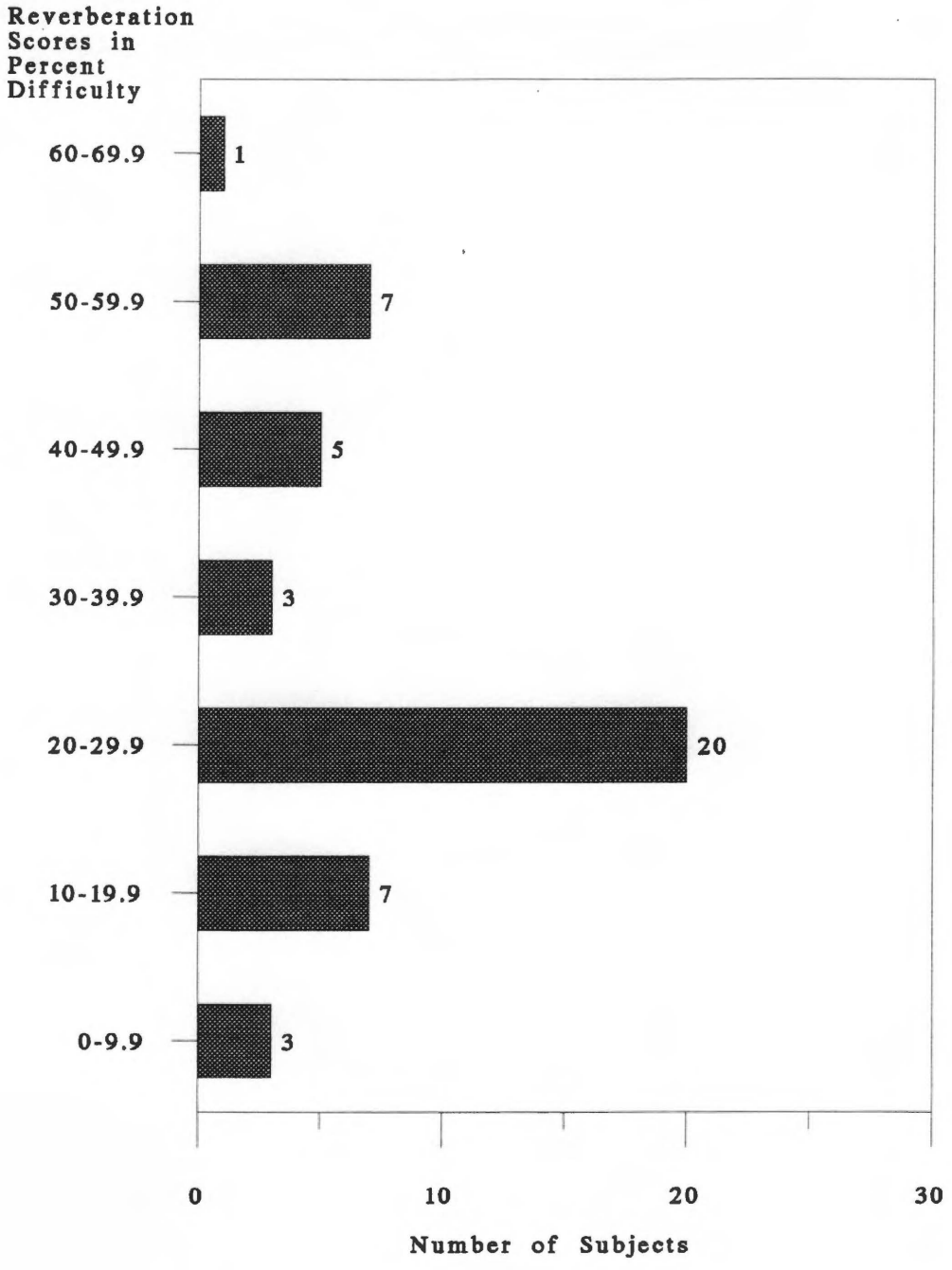


Figure 8. Distribution of scores for the Reverberation subscale of the PHAP.

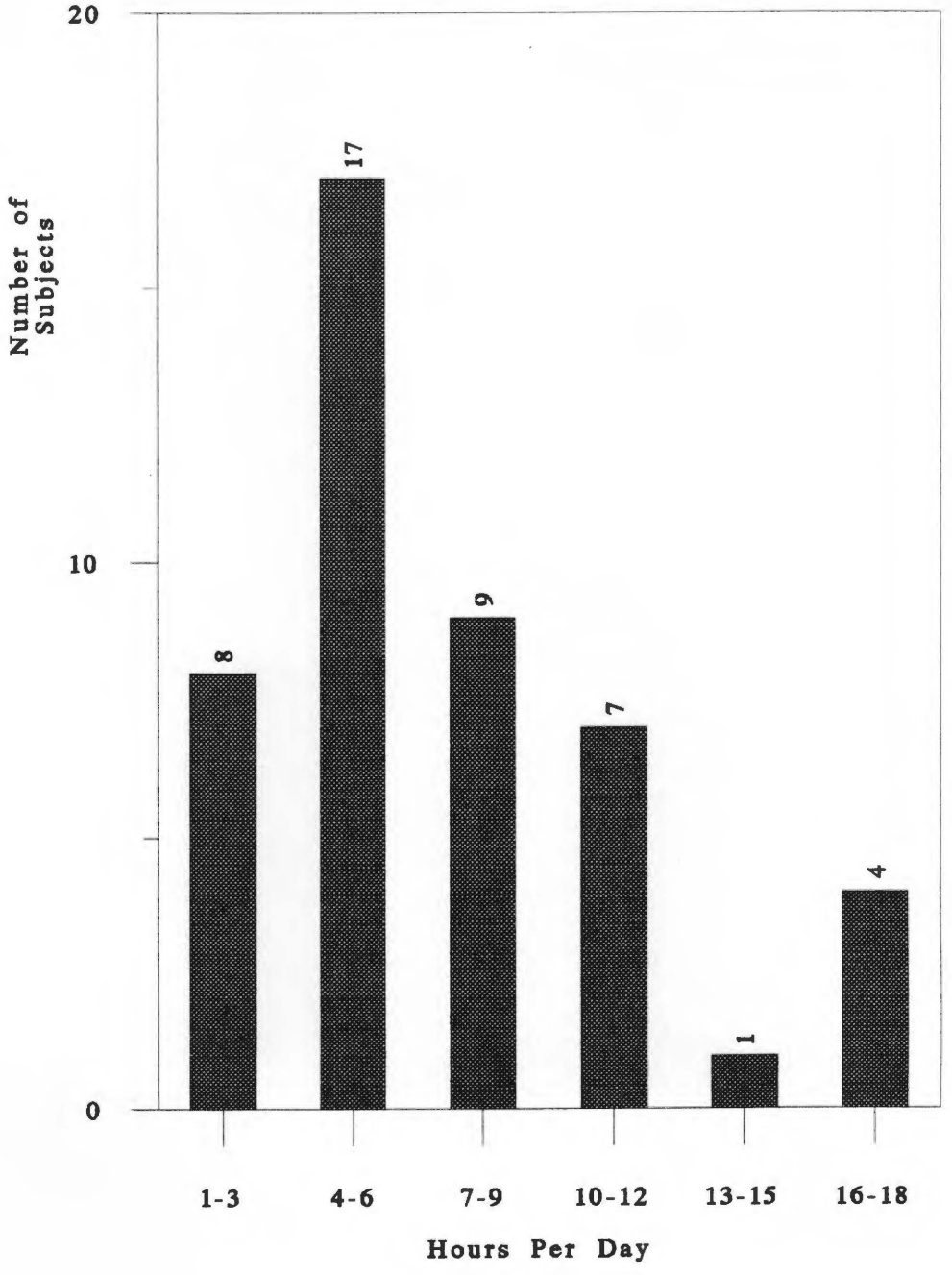


Figure 9. Distribution of hearing aid usage among the 46 subjects.

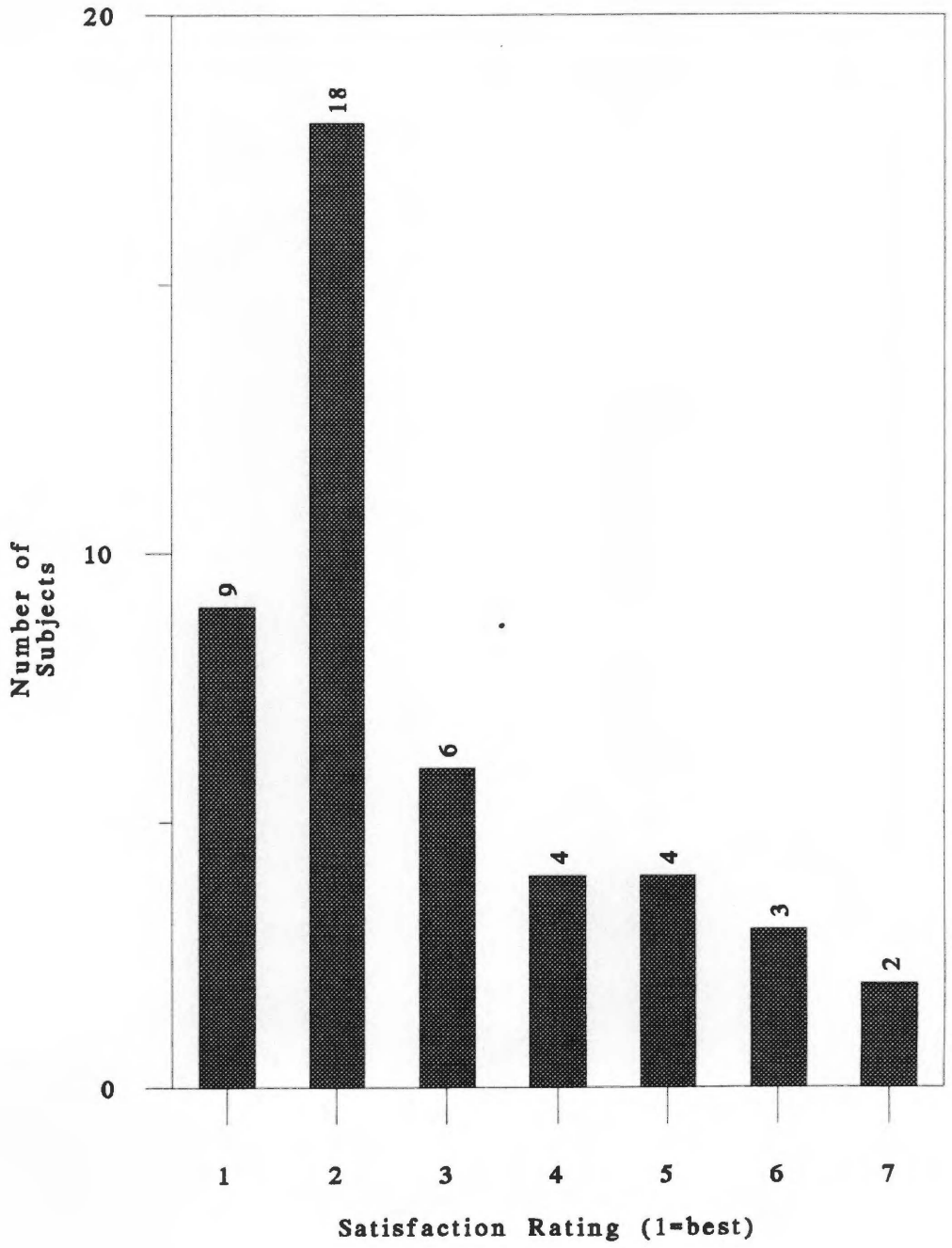


Figure 10. Distribution of hearing aid satisfaction ratings by the 46 subjects.

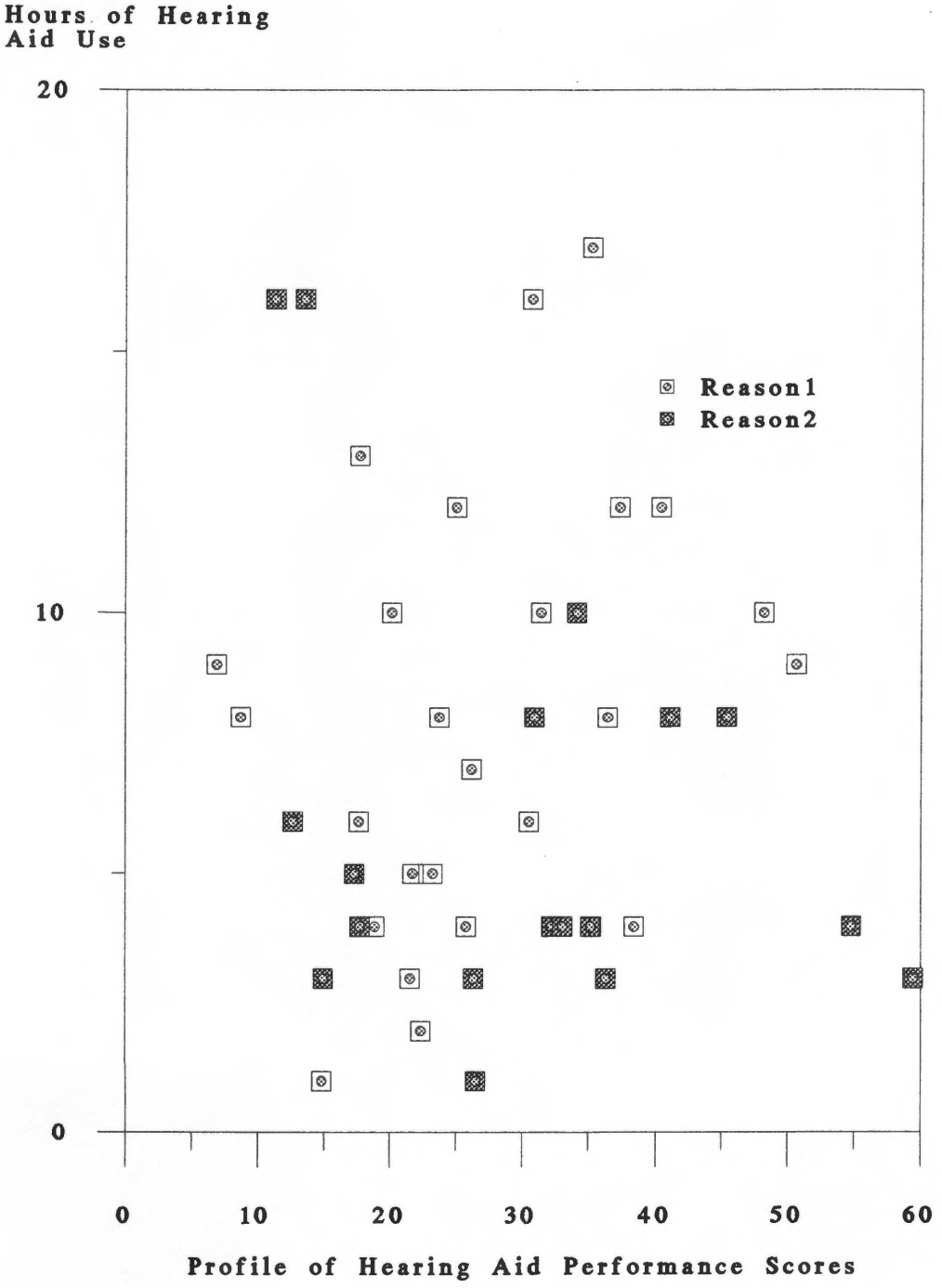


Figure 11. The relationship between performance (PHAP scores) and usage for subjects wearing hearing aids because of 1-self-motivation and 2- encouragement from others.

APPENDIX G

Graphs of relationships between selected predictive variables

(Figures 12- 108)

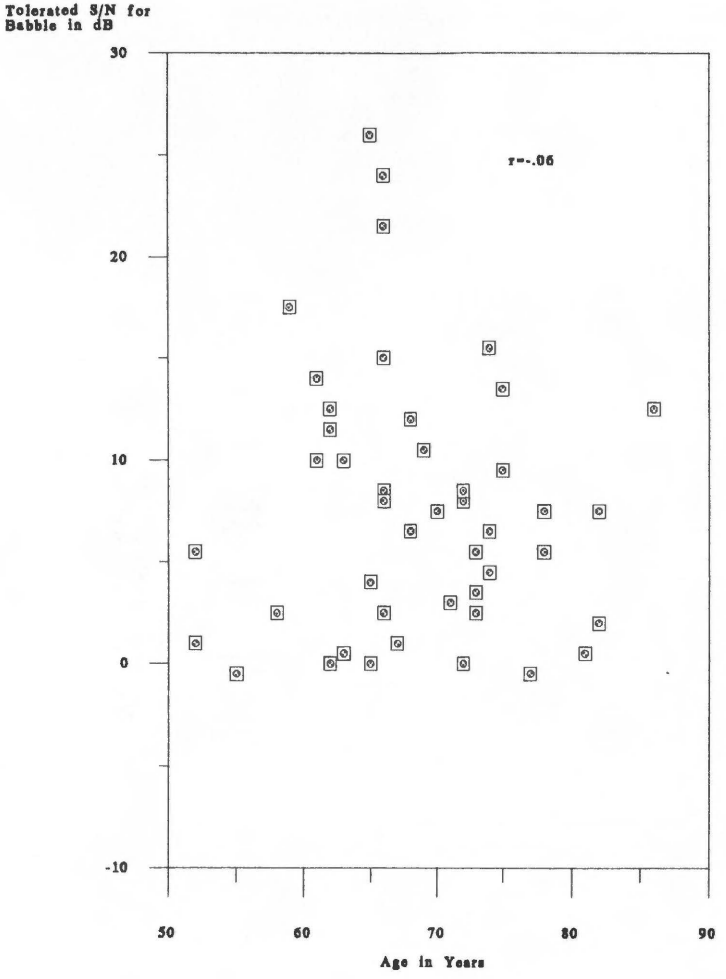


Figure 12. The relationship between age and tolerated S/N level for babble.

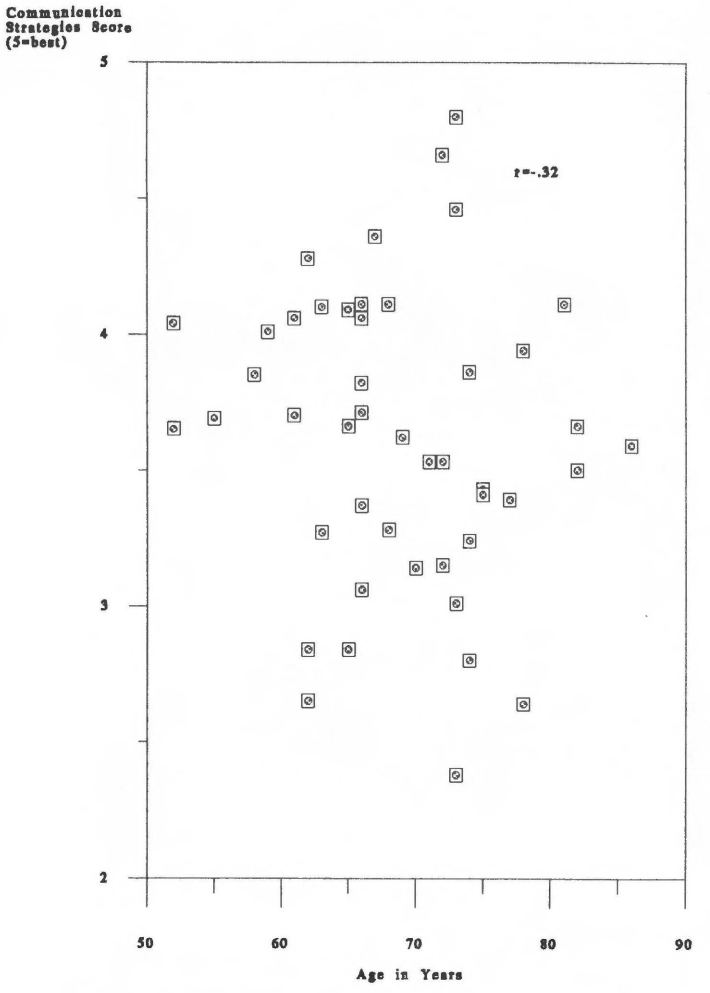


Figure 13. The relationship between age and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

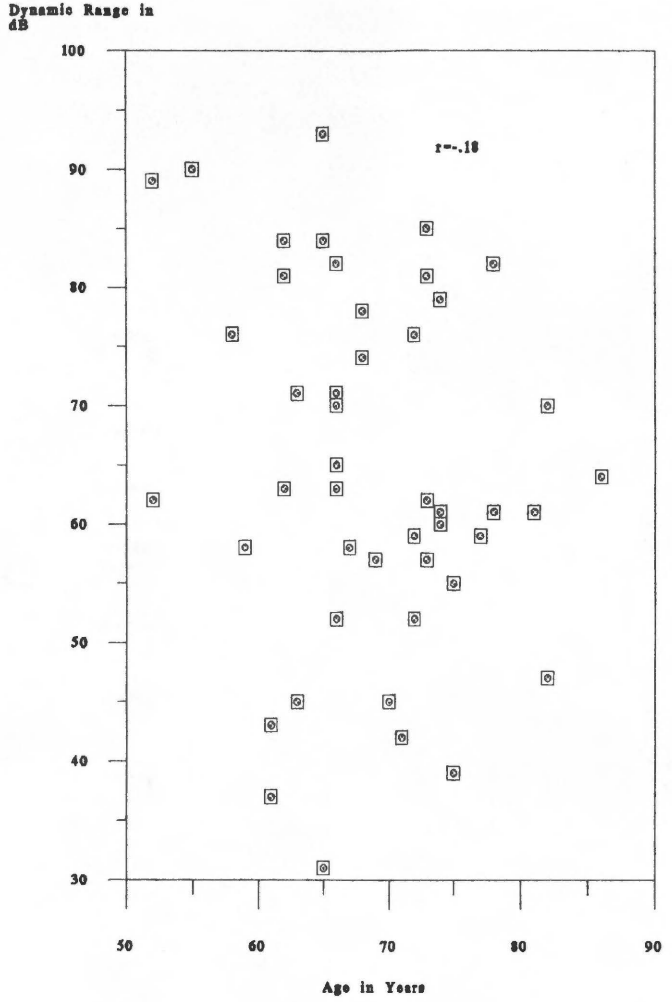


Figure 14. The relationship between age and dynamic range of hearing.

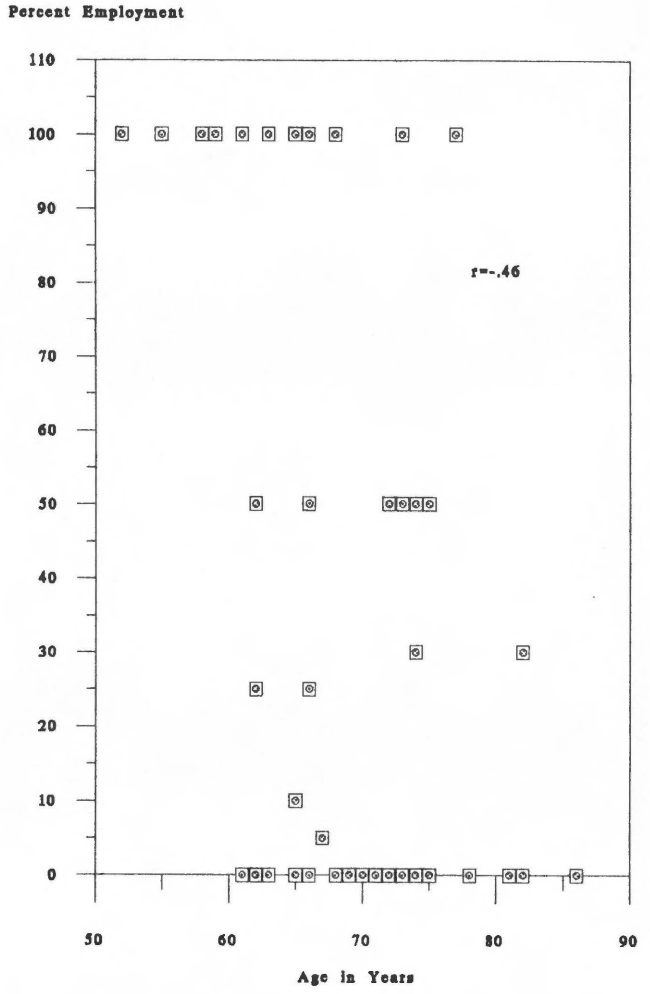


Figure 15. The relationship between age and percent employment.

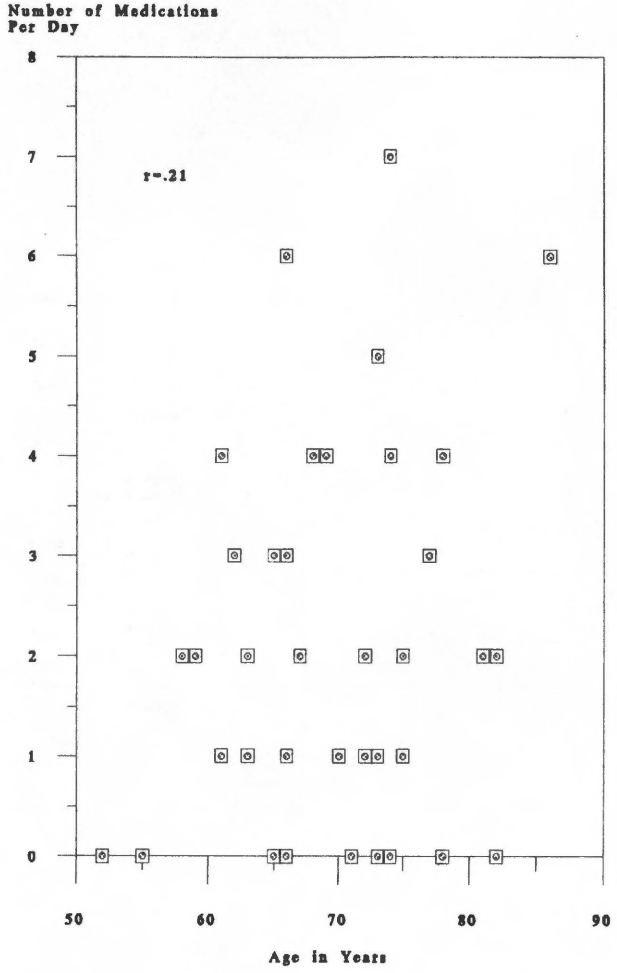


Figure 16. The relationship between age and number of medications taken per day.

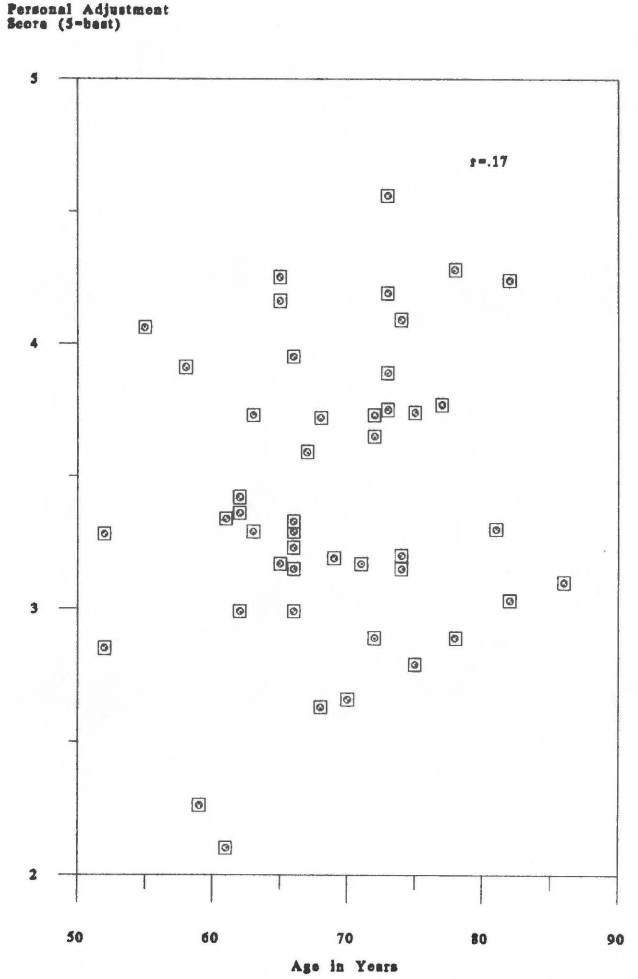


Figure 17. The relationship between age and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

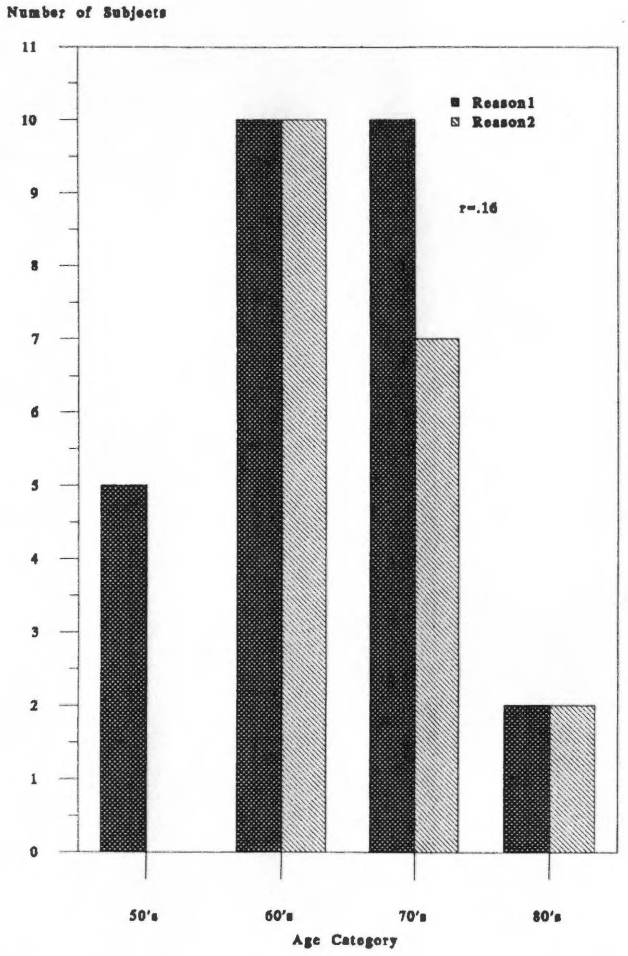


Figure 18. The number of subjects in each age category purchasing hearing aids because of 1-self-motivation and 2-encouragement from others.

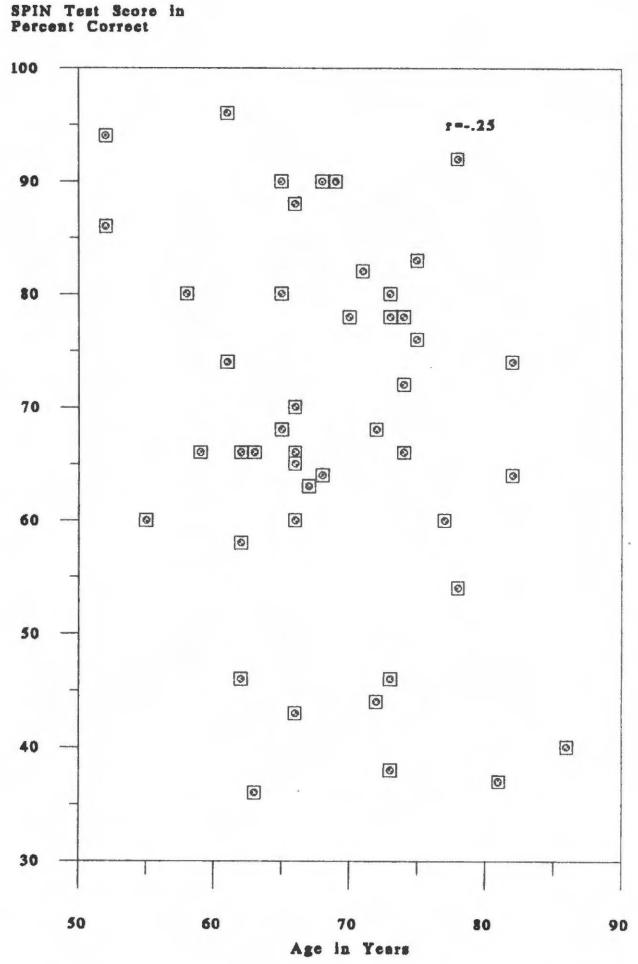


Figure 19. The relationship between age and SPIN test scores.

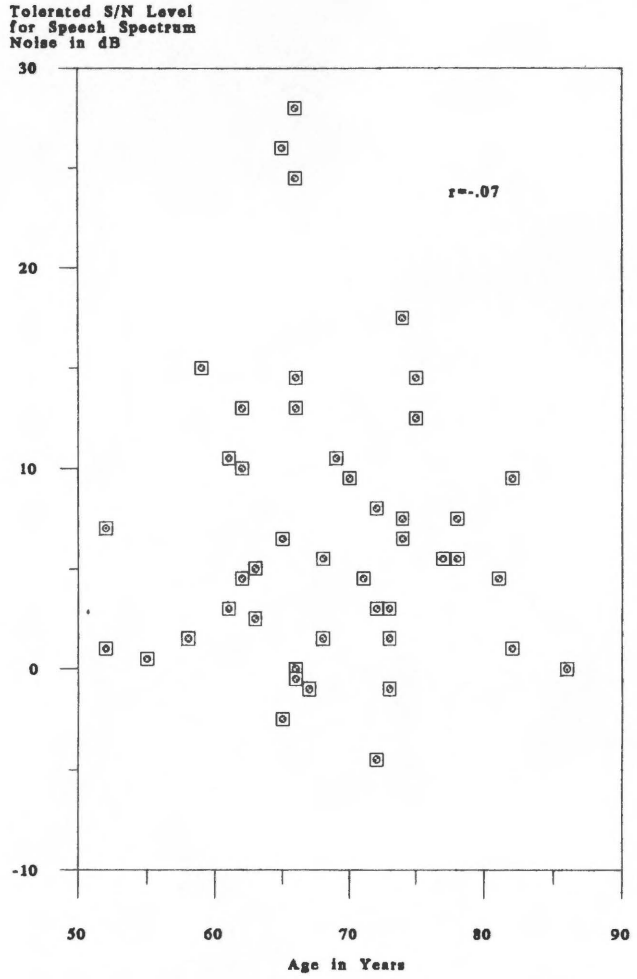


Figure 20. The relationship between age and tolerated S/N level for speech spectrum noise.

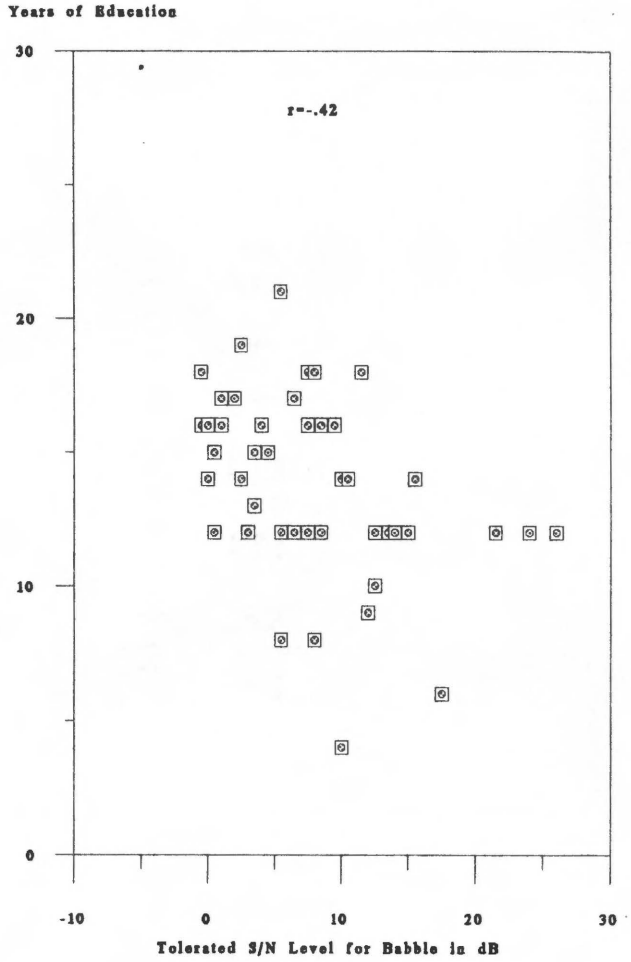


Figure 21. The relationship between tolerated S/N level for babble and education.

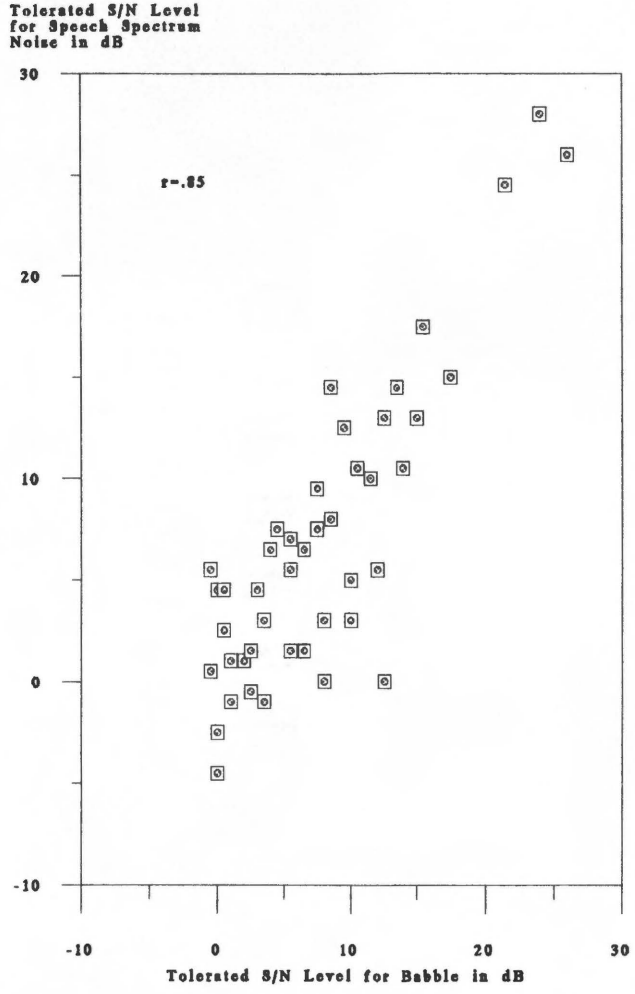


Figure 22. The relationship between tolerated S/N levels for babble and speech spectrum noise.

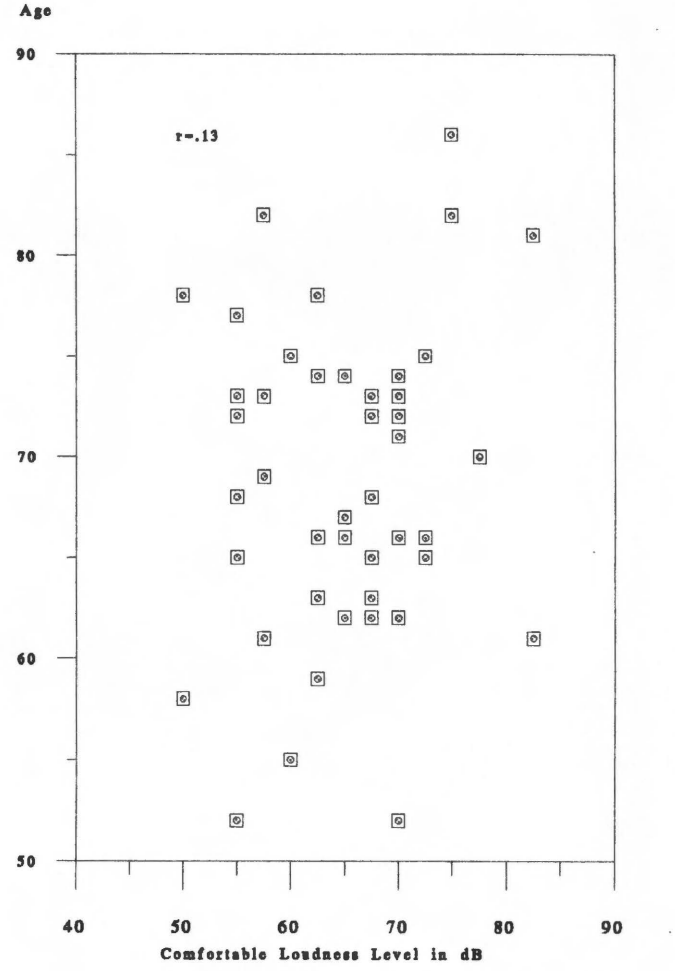


Figure 23. The relationship between comfortable loudness level and age.

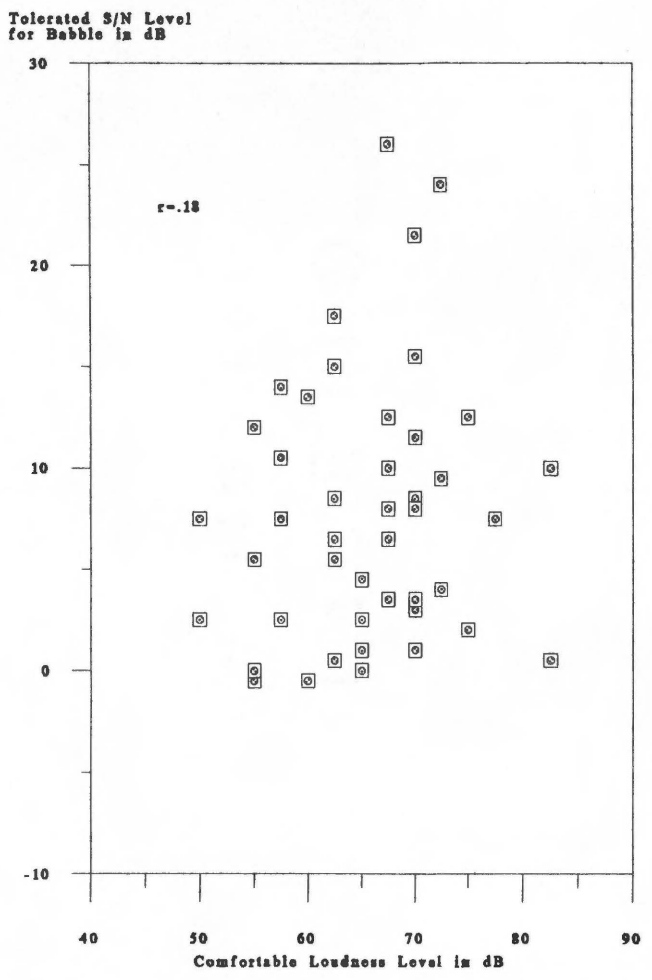


Figure 24. The relationship between comfortable loudness level and tolerated S/N level for babble.

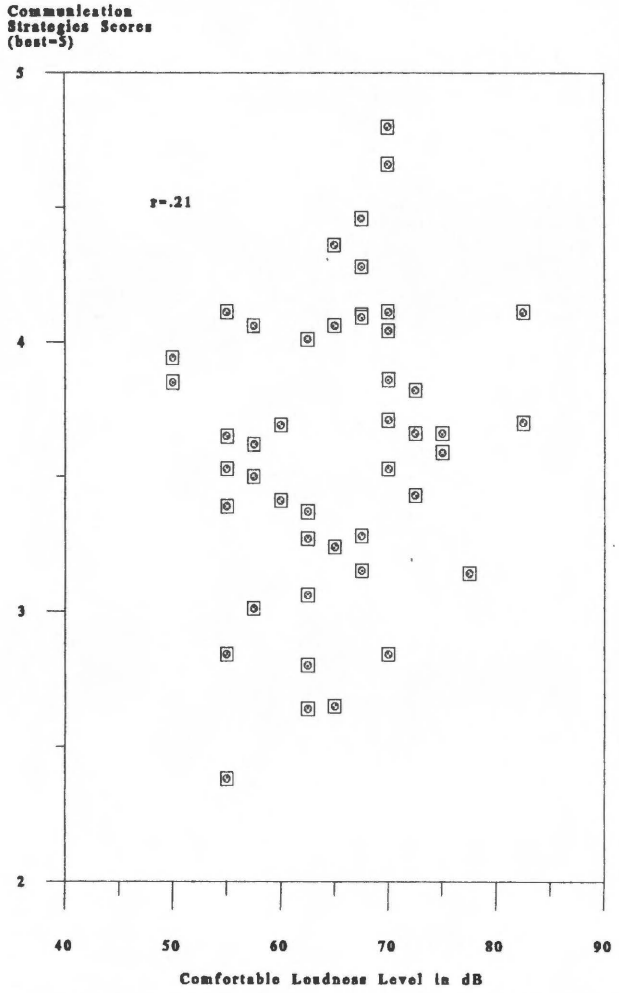


Figure 25. The relationship between comfortable loudness level and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

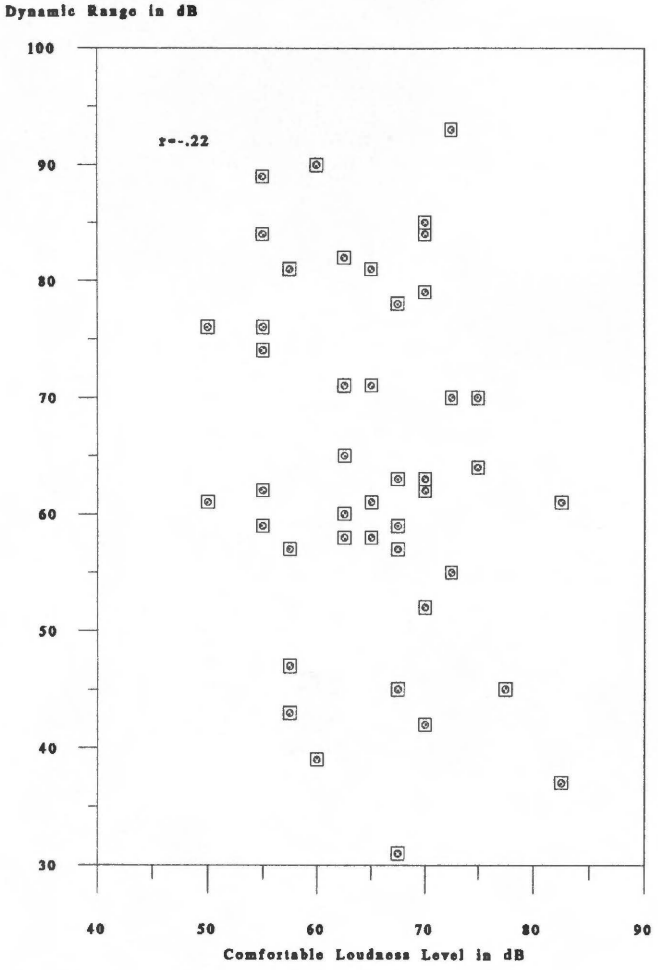


Figure 26. The relationship between comfortable loudness level and dynamic range of hearing.

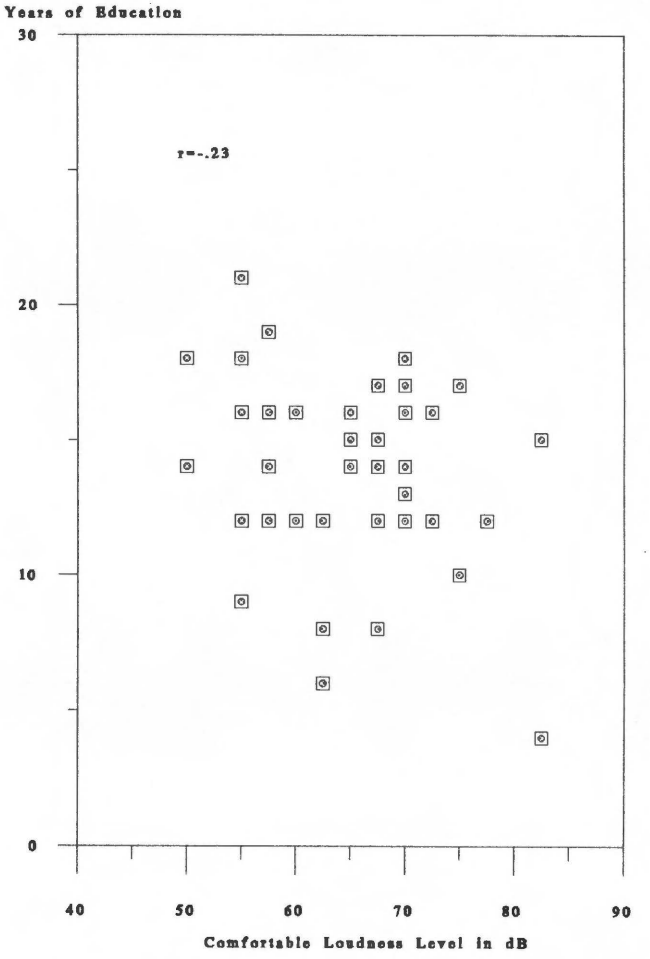


Figure 27. The relationship between comfortable loudness level and education.

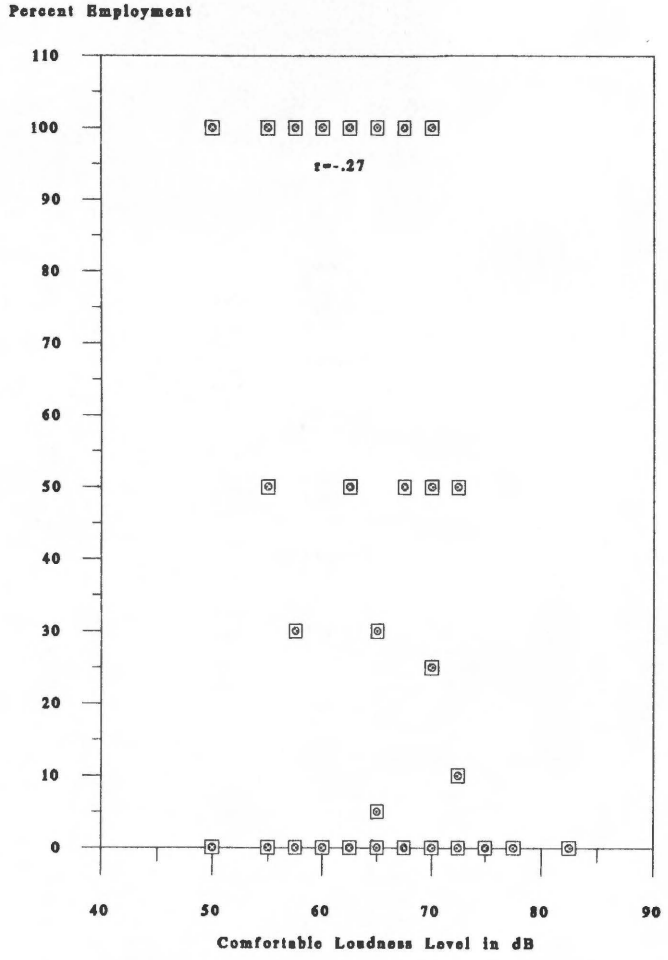


Figure 28. The relationship between comfortable loudness level and employment.

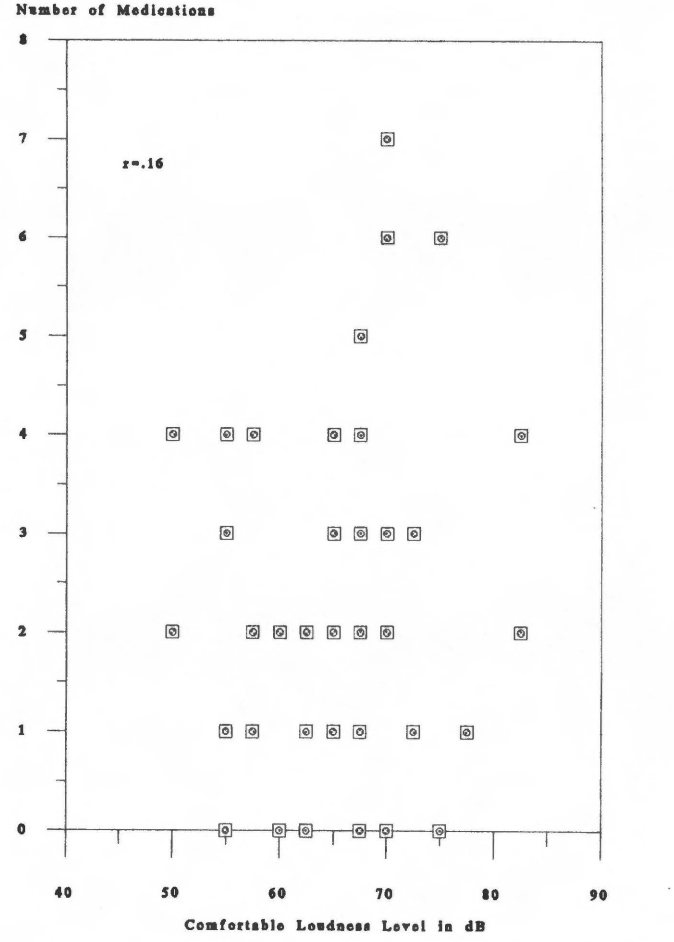


Figure 29. The relationship between comfortable loudness level and number of medications taken per day.

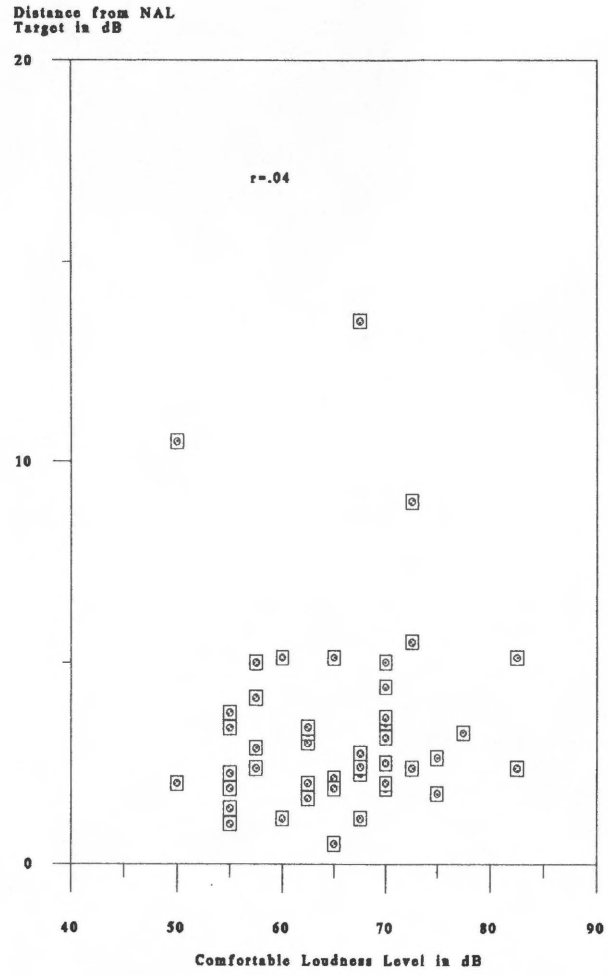


Figure 30. The relationship between comfortable loudness level and distance between National Acoustic Laboratories target gain and insertion gain.

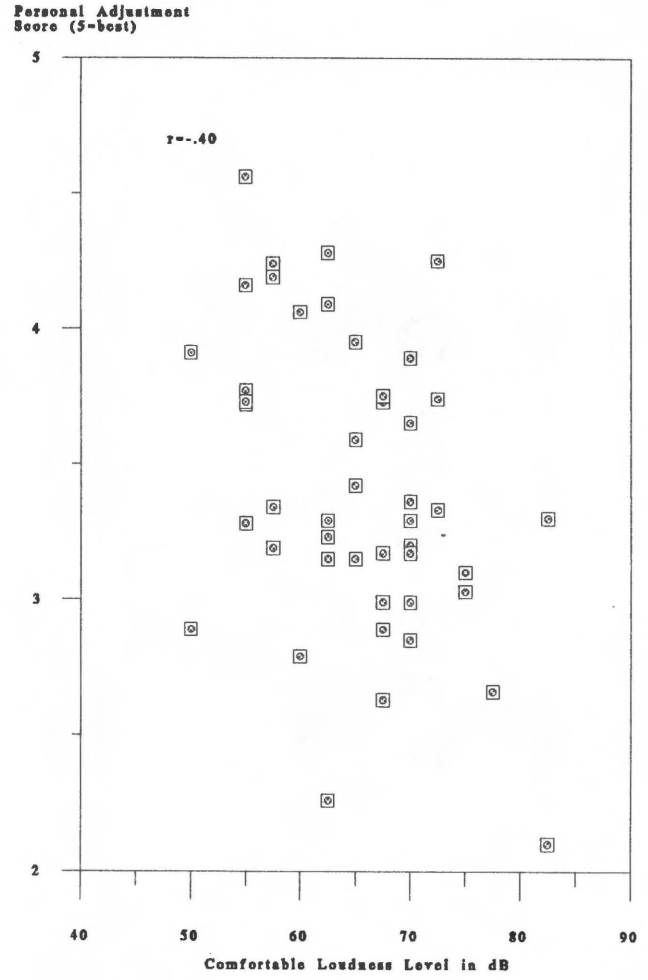


Figure 31. The relationship between comfortable loudness level and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

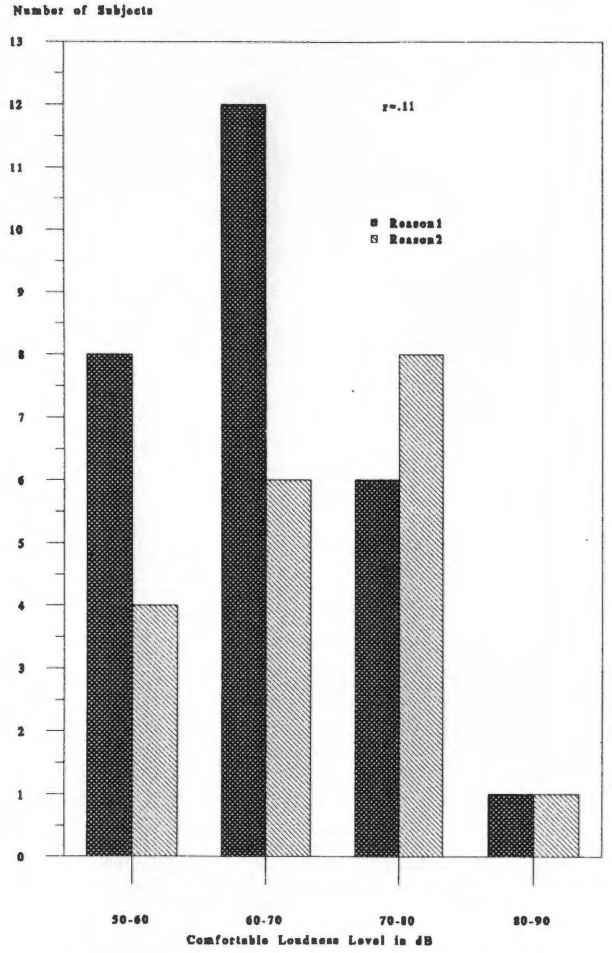


Figure 32. Number of subjects in each comfortable loudness level category purchasing hearing aids because of 1- self-motivation and 2- encouragement from others.

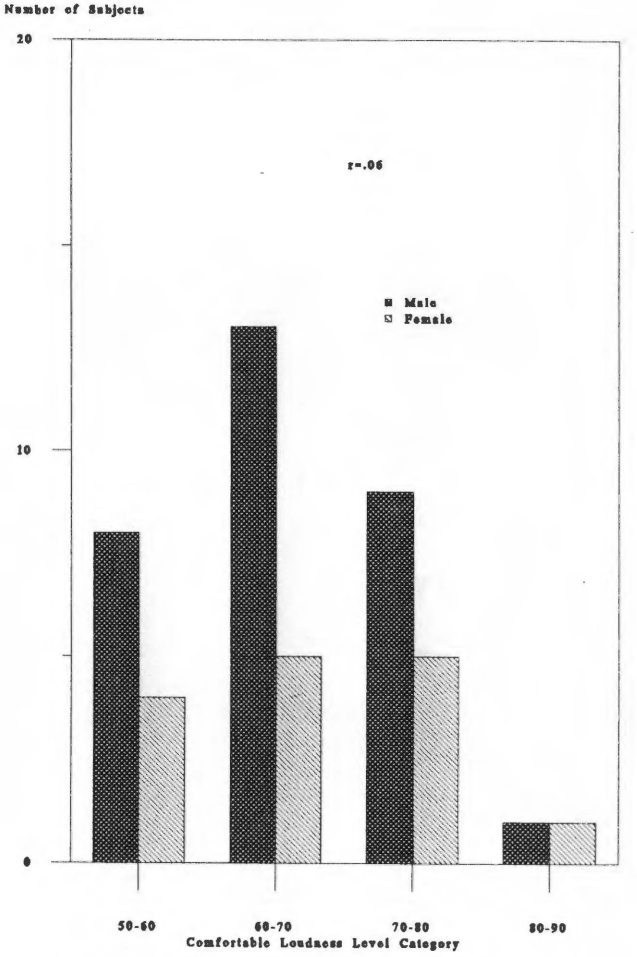


Figure 33. The number of male and female subjects in each comfortable loudness level category.

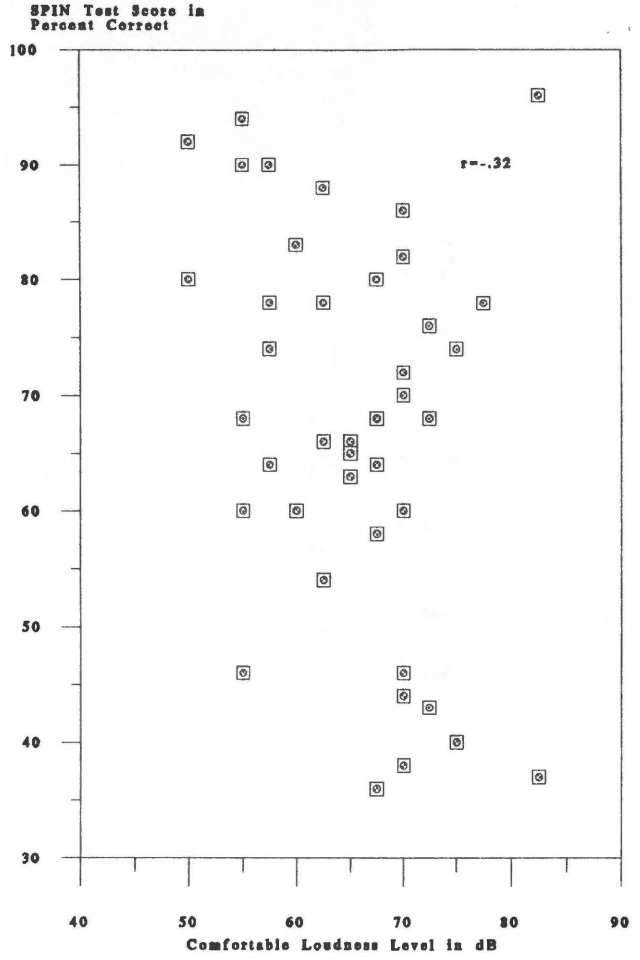


Figure 34. The relationship between comfortable loudness level and Speech Perception in Noise test scores.

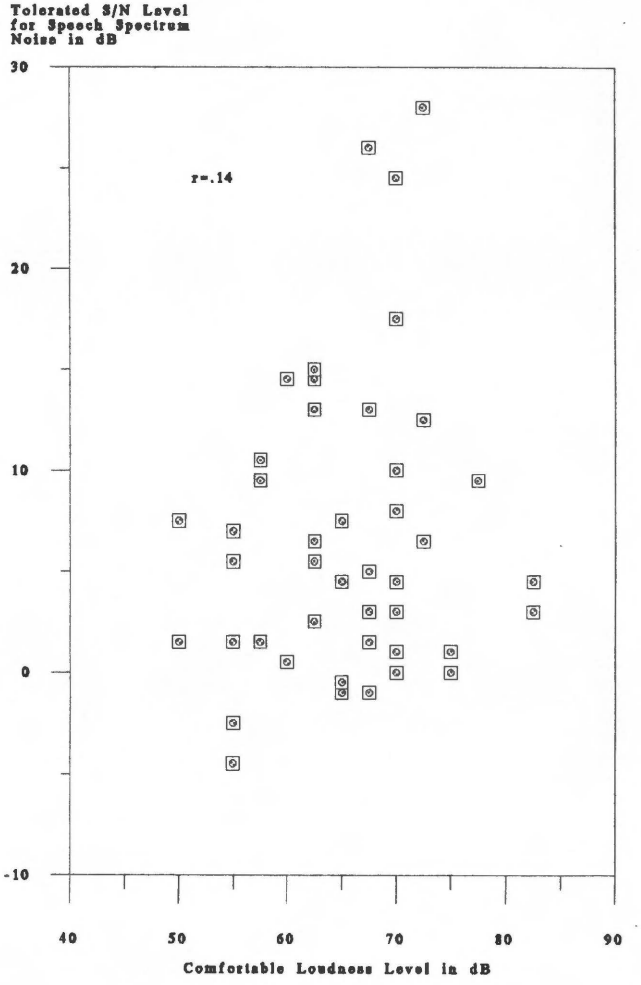


Figure 35. The relationship between comfortable loudness level and tolerated S/N level for speech spectrum noise.

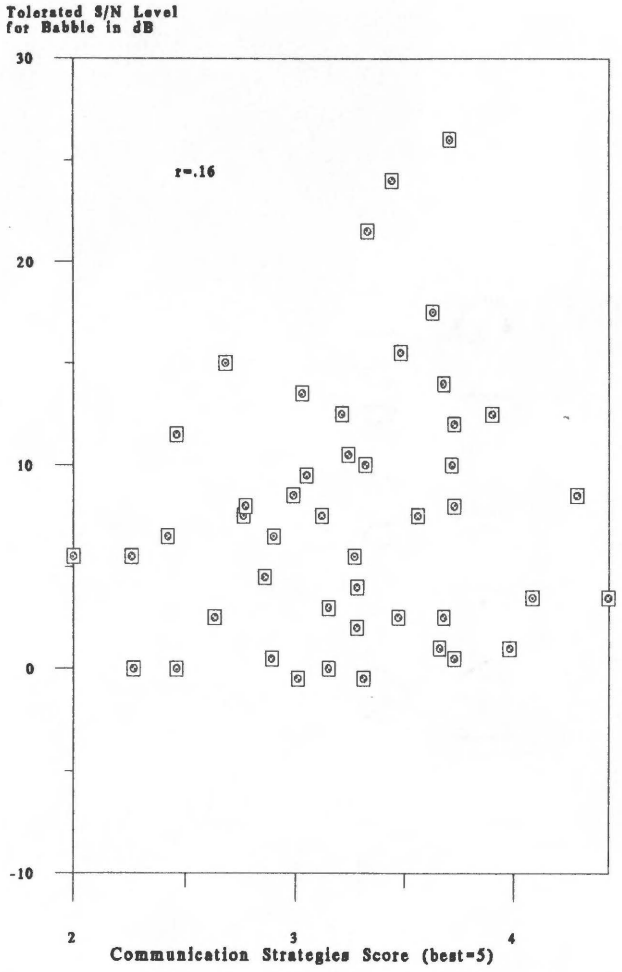


Figure 36. The relationship between Communication Strategies scores from the Communication Profile for the Hearing Impaired and tolerated S/N level for babble.

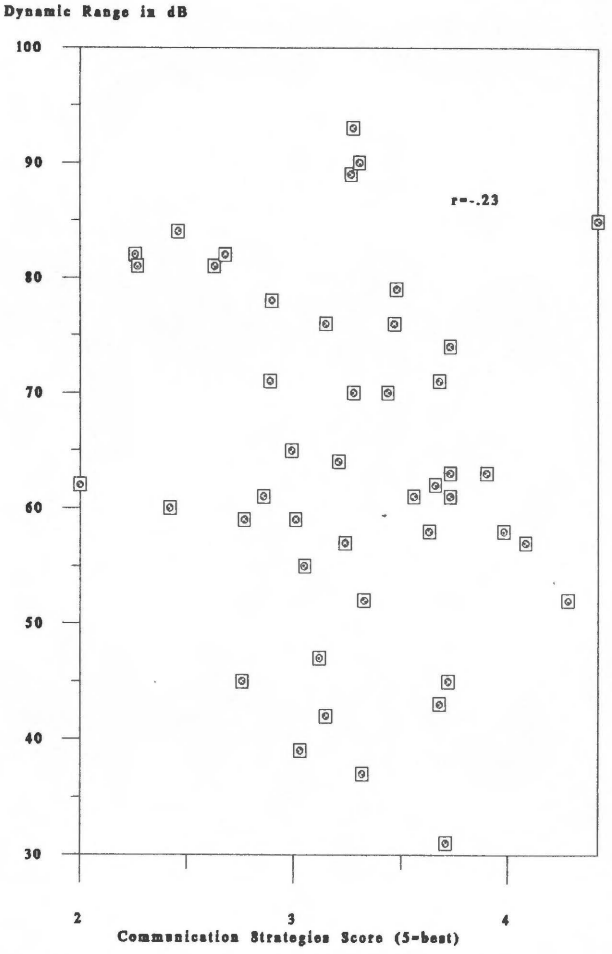


Figure 37. The relationship between Communication Strategies scores of the Communication Profile for the Hearing Impaired and dynamic range of hearing.

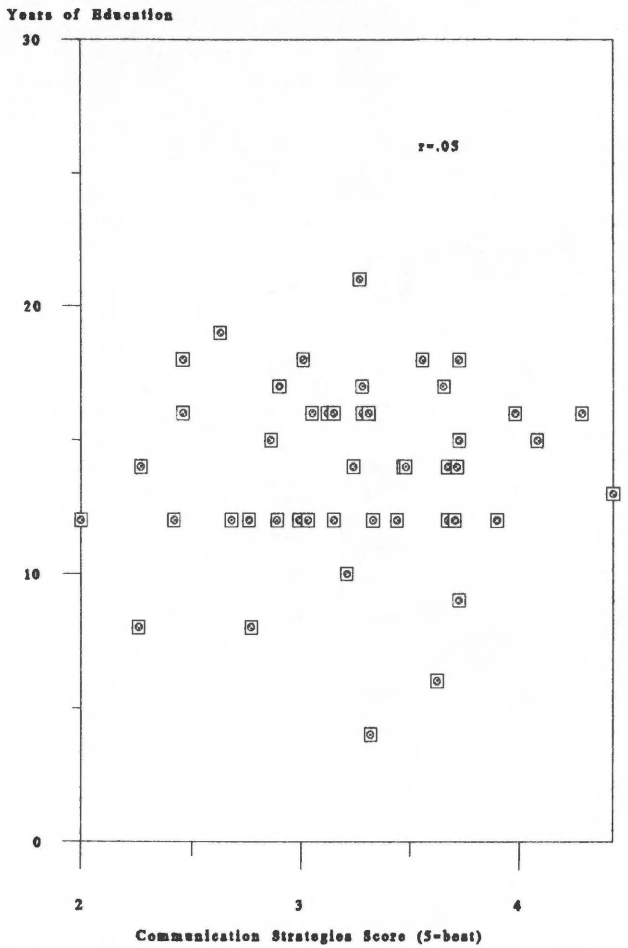


Figure 38. The relationship between Communication Strategies scores of the Communication Profile for the Hearing Impaired and education.

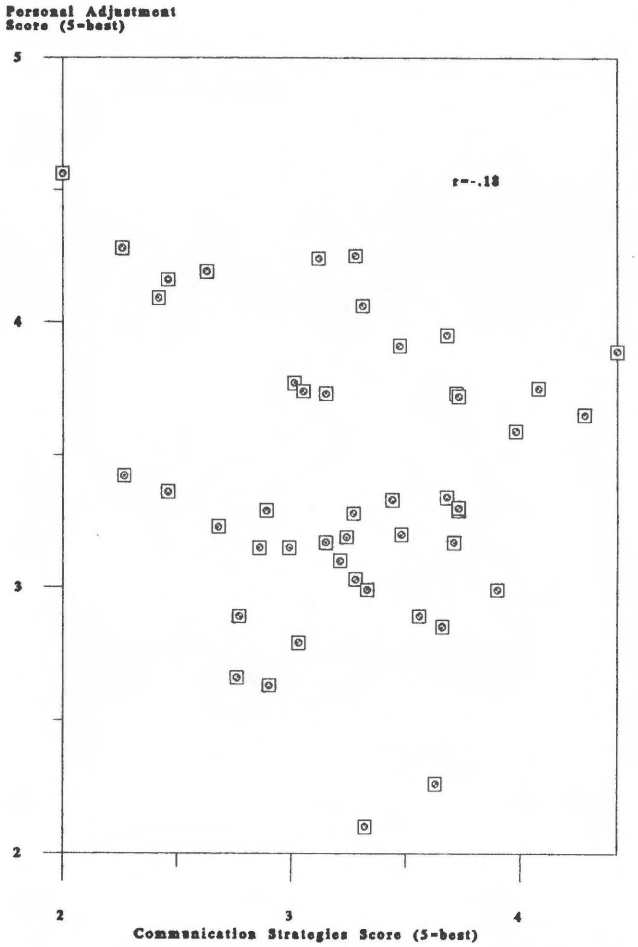


Figure 39. The relationship between Communication Strategies and Personal Adjustment scores of the Communication Profile for the Hearing Impaired.

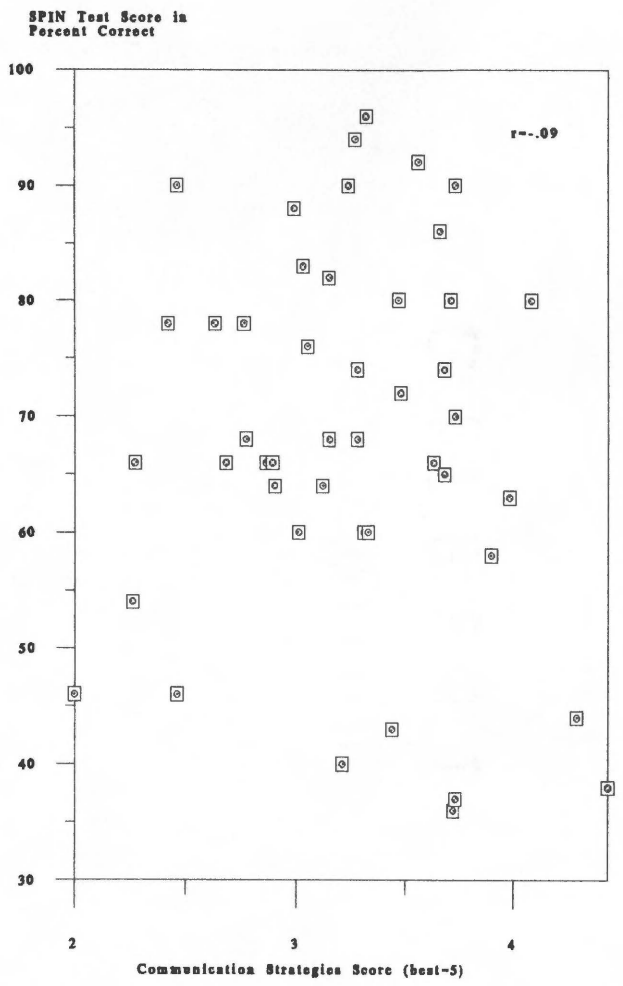


Figure 40. The relationship between Communication Strategies scores from the Communication Profile for the Hearing Impaired and Speech Perception in Noise test scores.

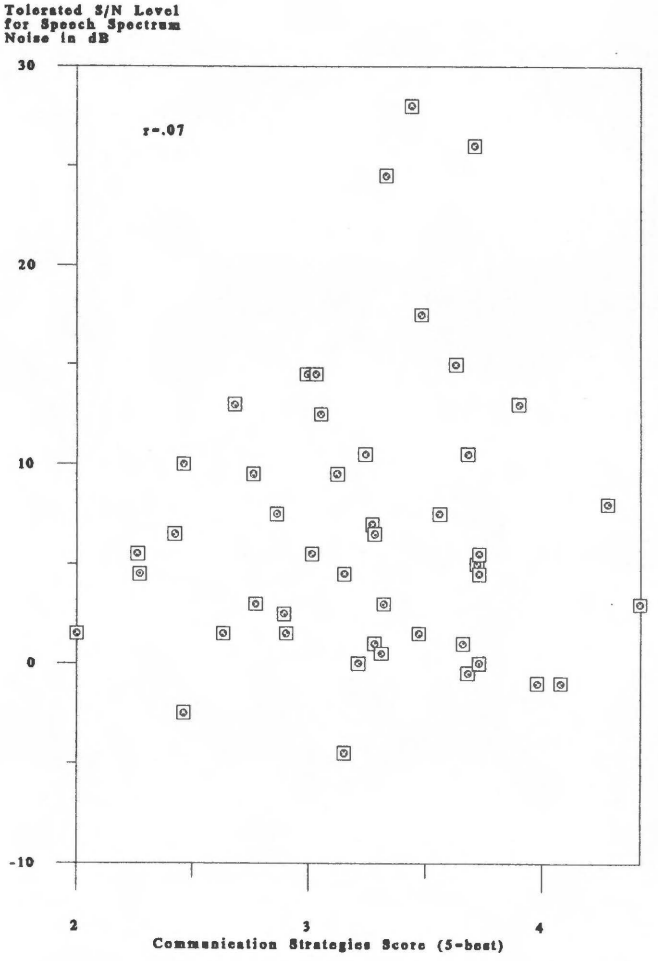


Figure 41. The relationship between Communication Strategies scores of the Communication Profile for the Hearing Impaired and tolerated S/N levels for speech spectrum noise.

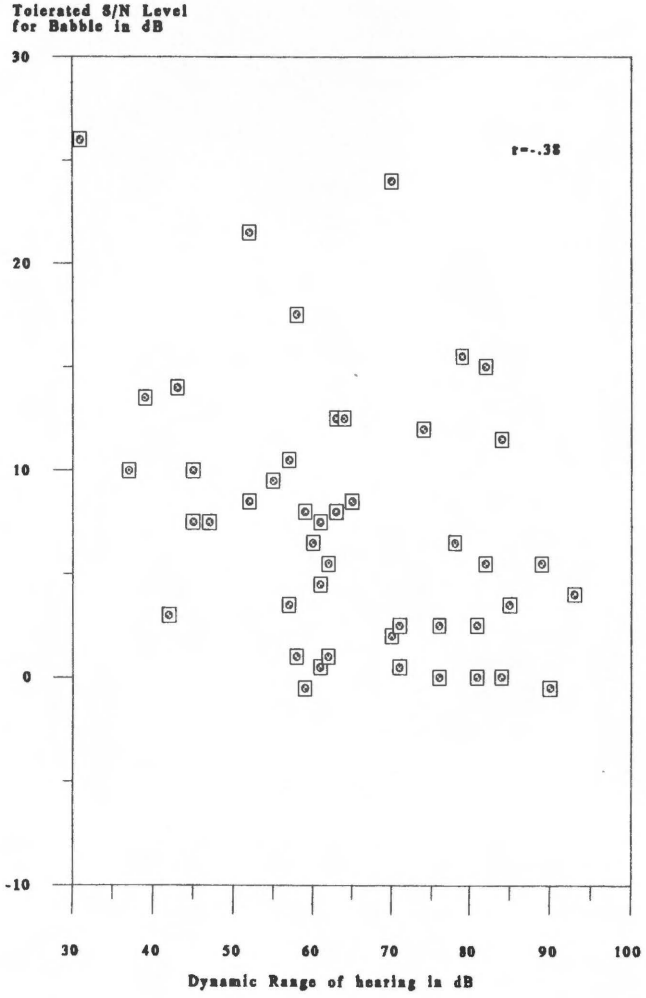


Figure 42. The relationship between dynamic range of hearing and tolerated S/N level for babble.

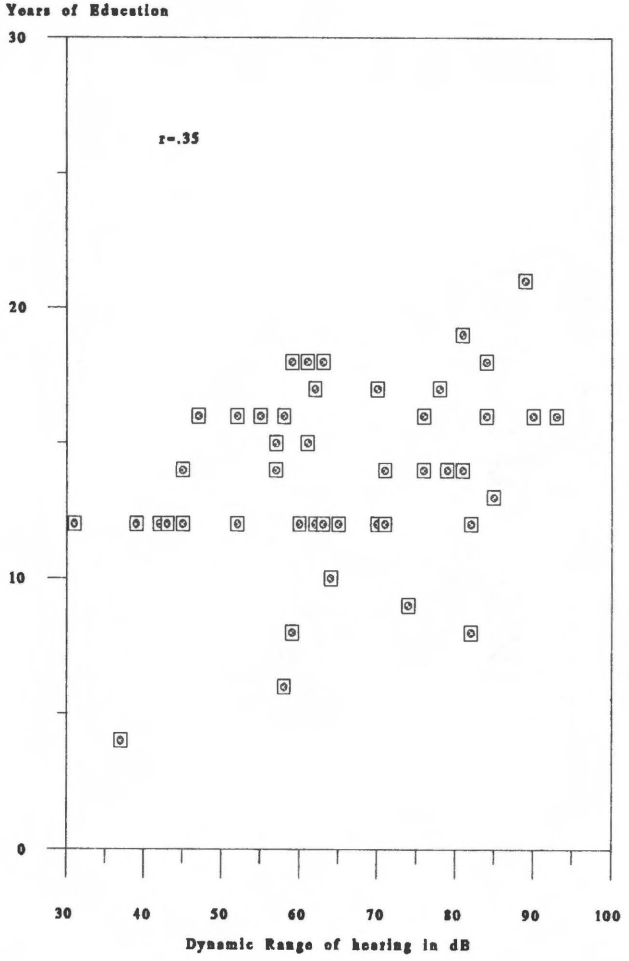


Figure 43. The relationship between dynamic range of hearing and years of education.

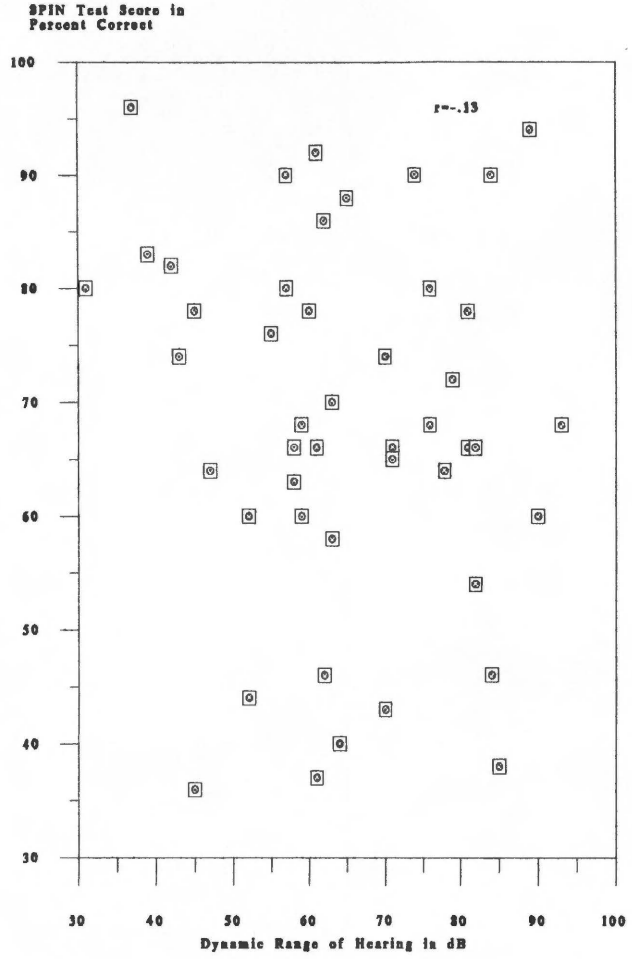


Figure 44. The relationship between dynamic range of hearing and Speech Perception in Noise test scores.

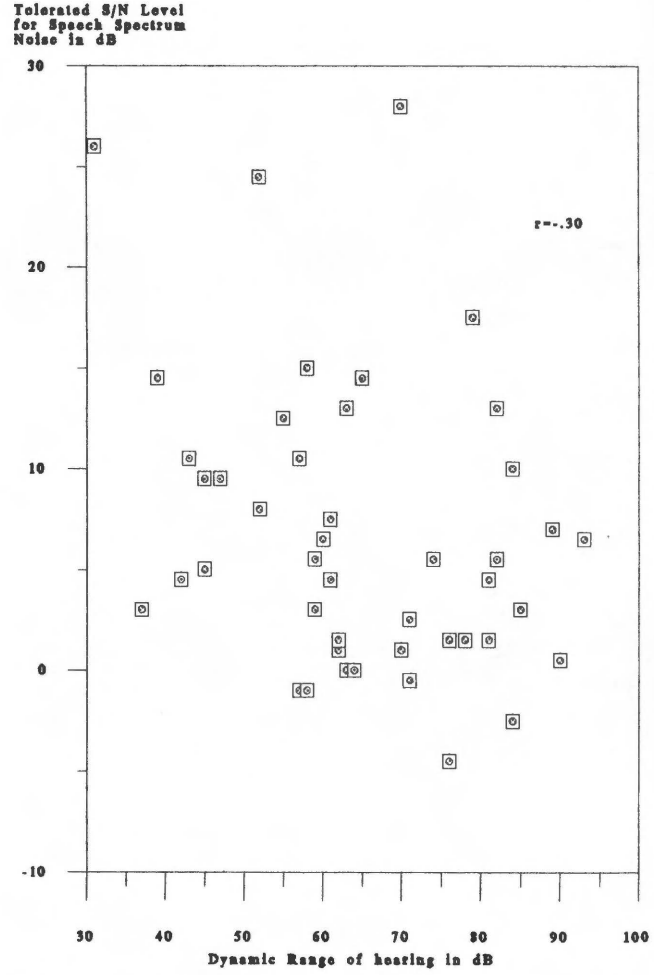


Figure 45. The relationship between dynamic range of hearing and tolerated S/N level for speech spectrum noise.

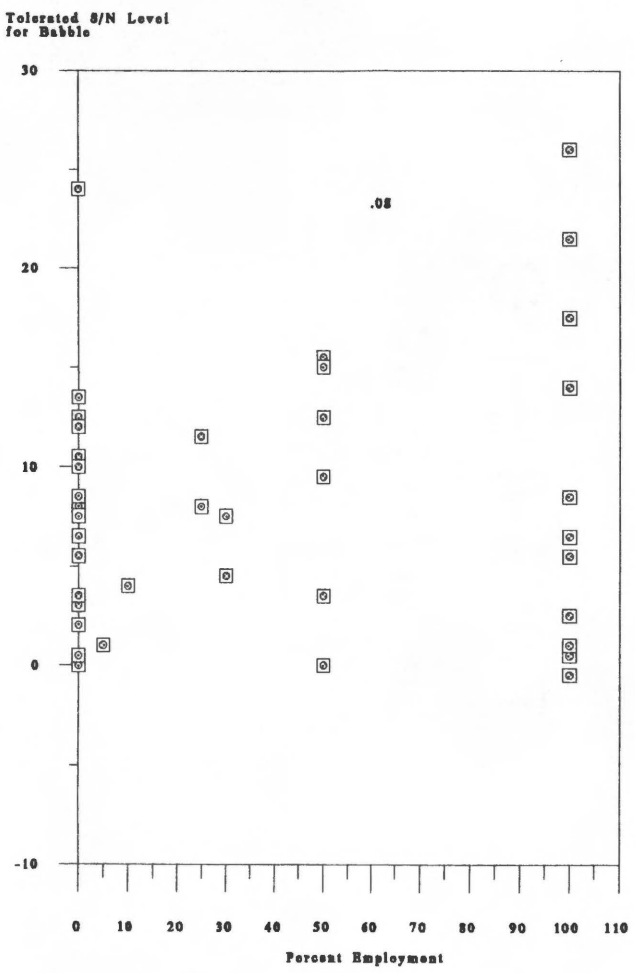


Figure 46. The relationship between employment and tolerated signal-to-noise level for babble.

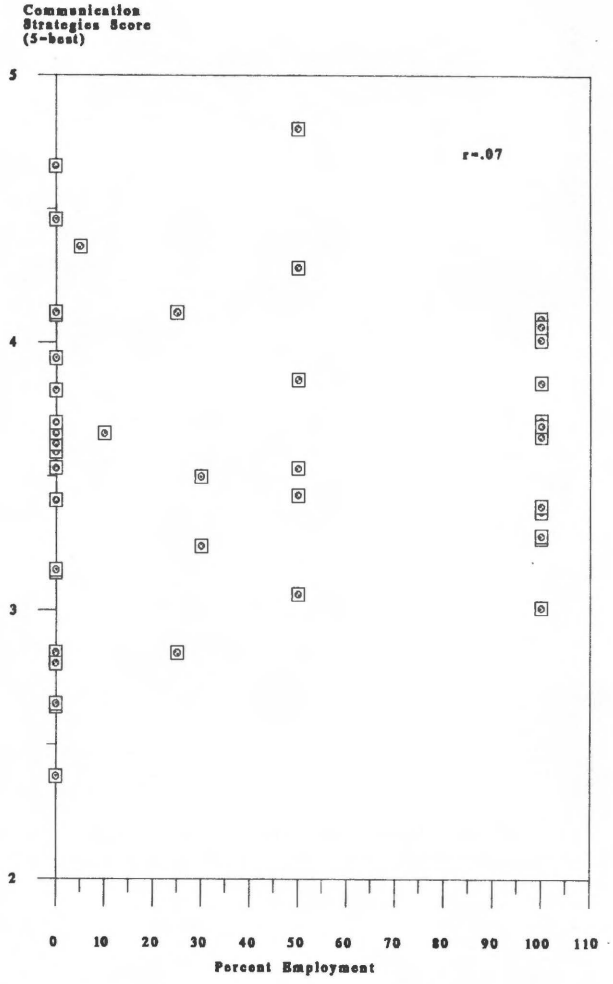


Figure 47. The relationship between percent employment and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

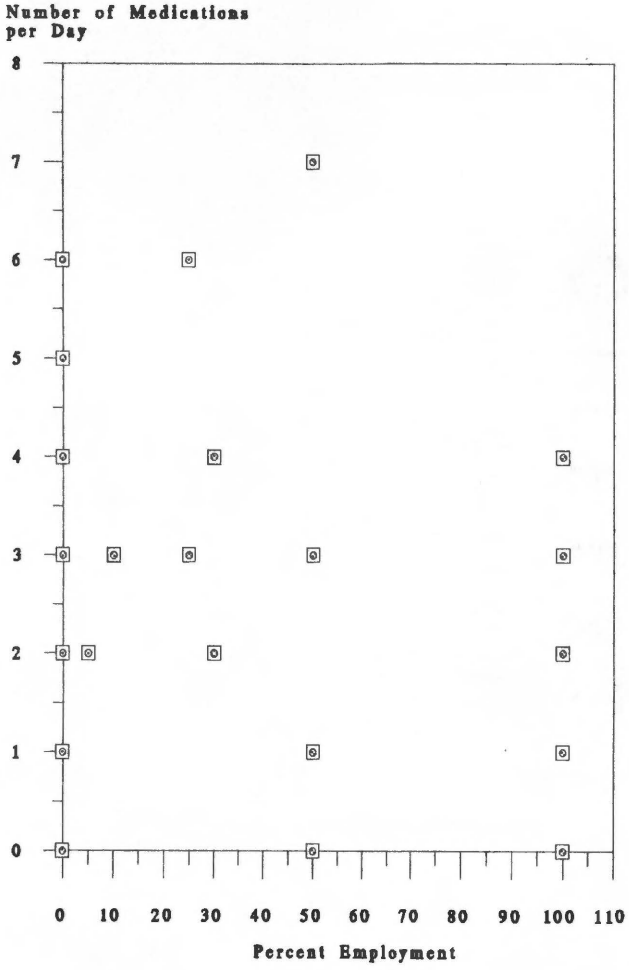


Figure 48. The relationship between percent employment and number of medications taken per day.

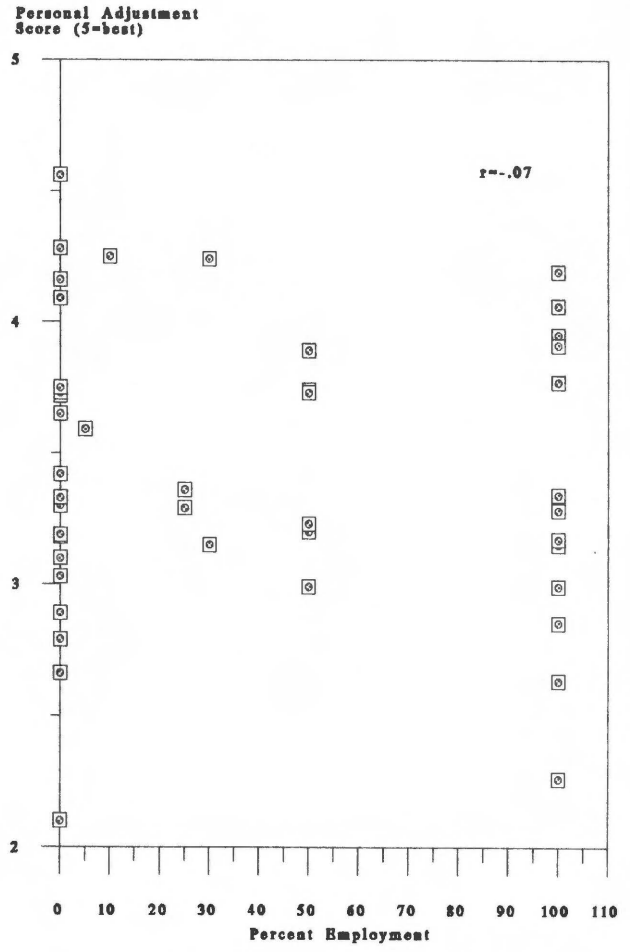


Figure 49. The relationship between employment and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

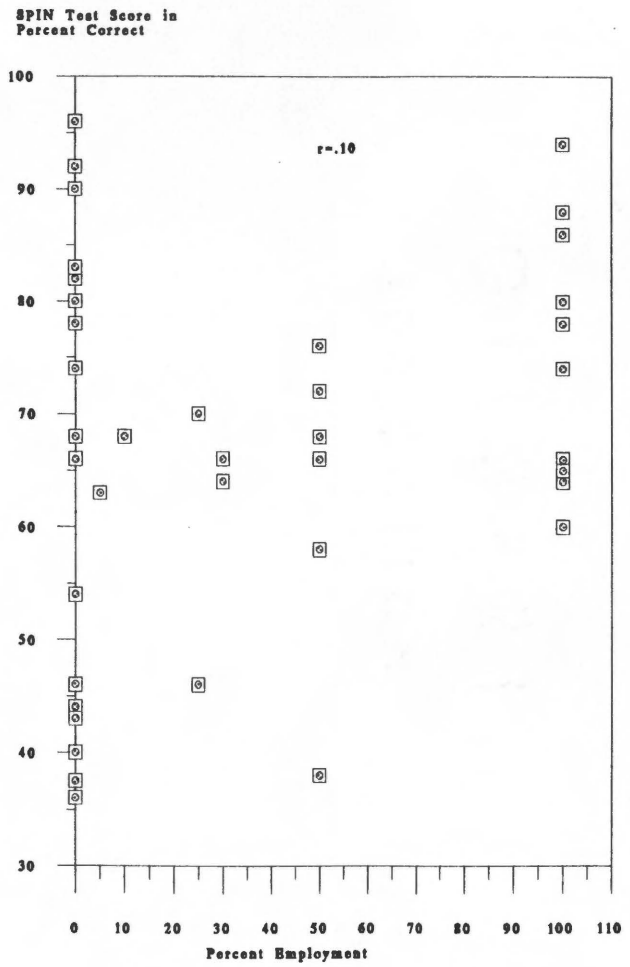


Figure 50. The relationship between percent employment and Speech Perception in Noise test scores.

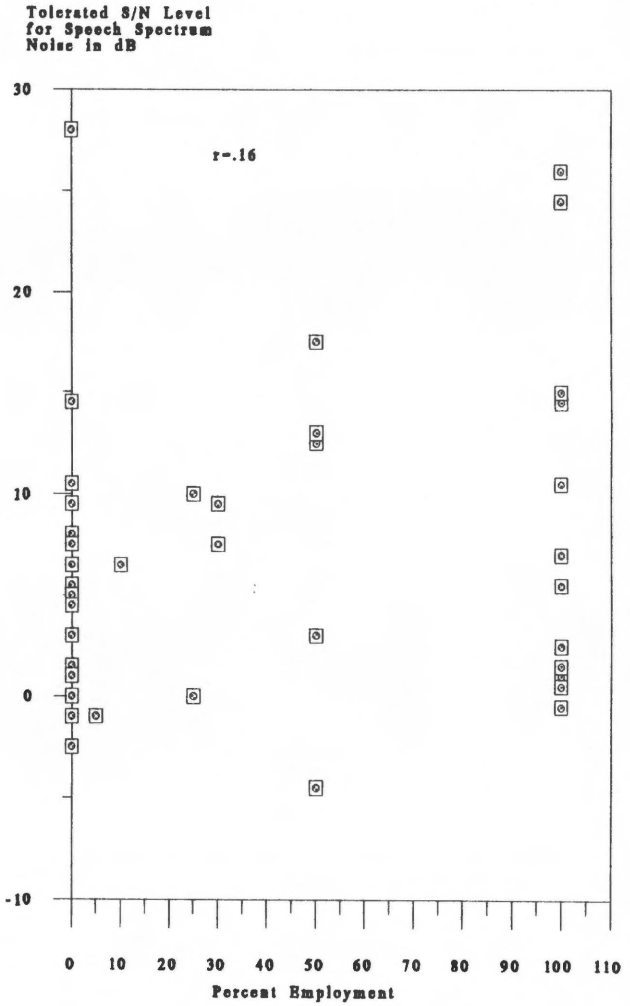


Figure 51. The relationship between percent employment and tolerated signal-to-noise level for speech spectrum noise.

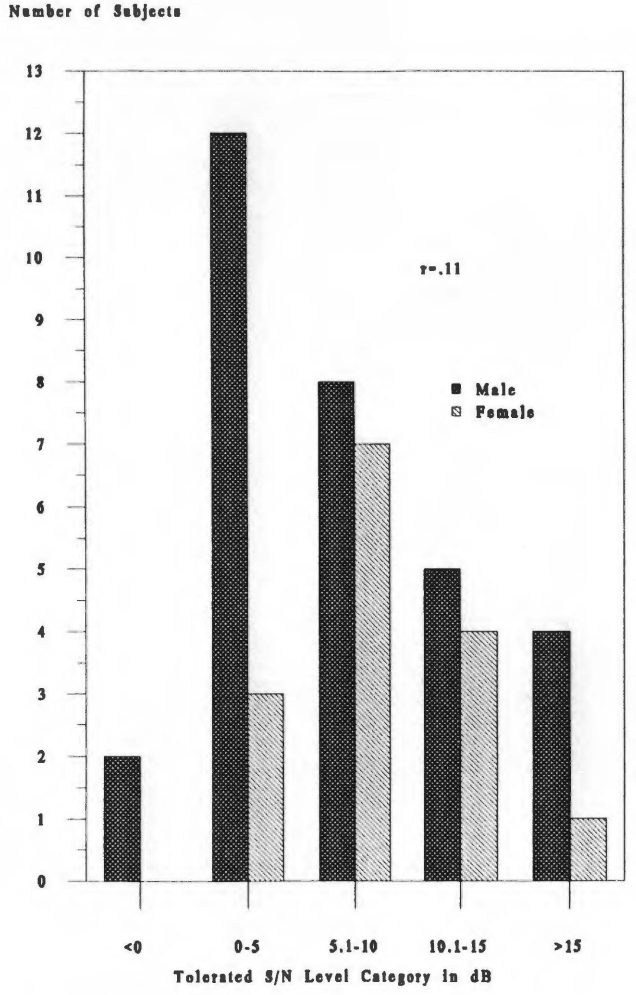


Figure 52. The number of male and female subjects in each tolerated signal-to-noise level category for multitalker babble stimulus.



Figure 53. The number of male and female subjects in each category of Communication Strategies scores from the Communication Profile for the Hearing Impaired.

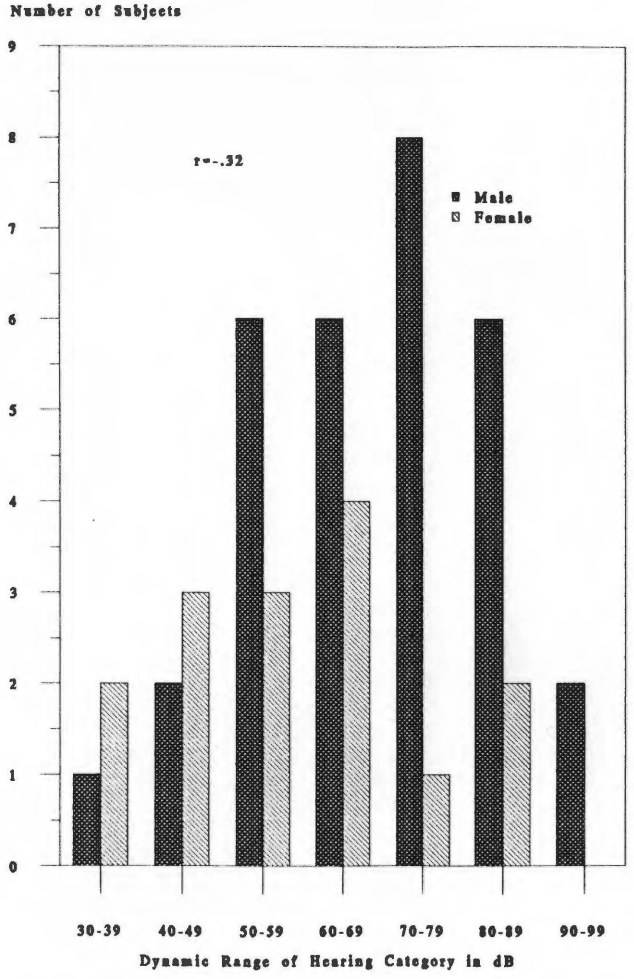


Figure 54. The number of male and female subjects in each of seven dynamic range categories.

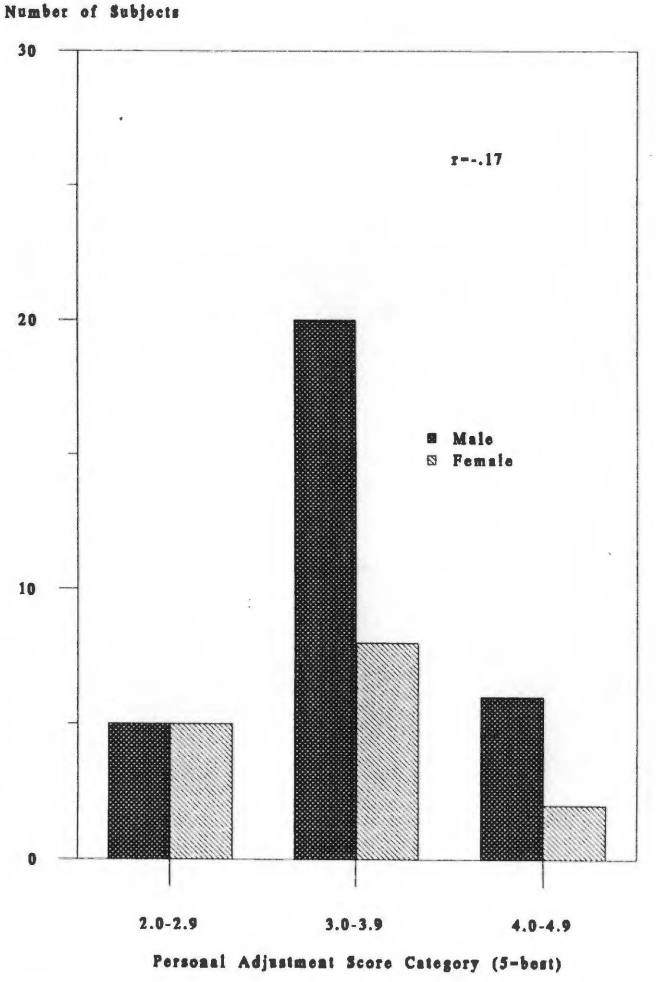


Figure 55. Number of male and female subjects in each of three Personal Adjustment score categories from the Communication Profile for the Hearing Impaired.

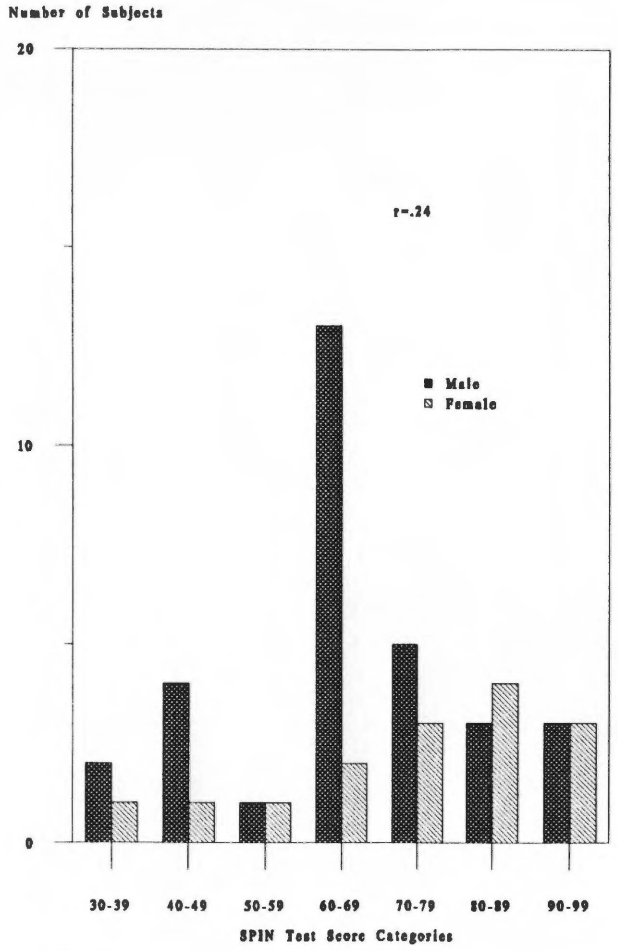


Figure 56. The number of male and female subjects in each of seven Speech Perception in Noise test score categories.

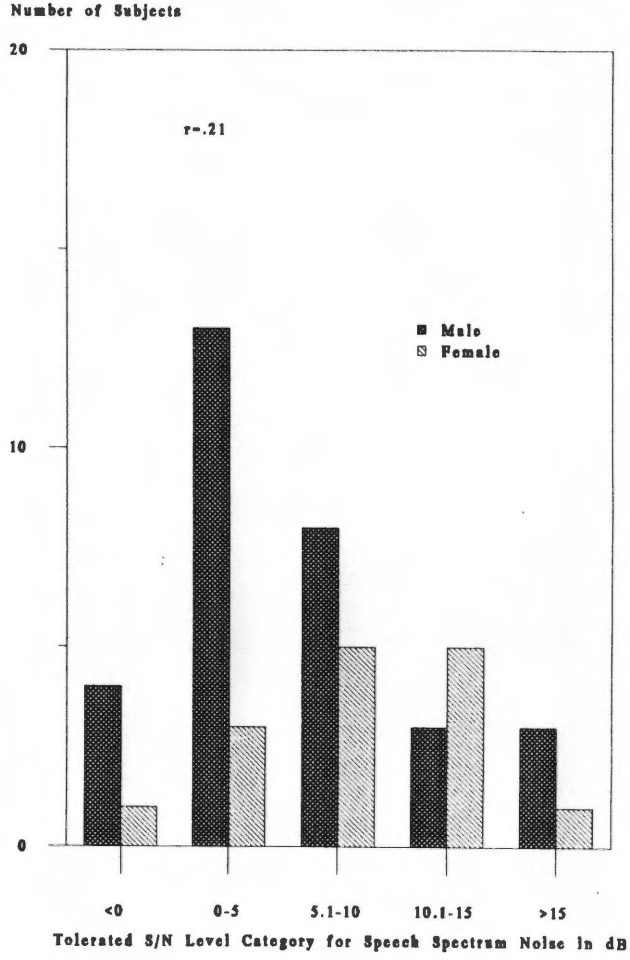


Figure 57. The number of male and female subjects in each of five tolerated signal-to-noise categories for speech spectrum noise stimulus.

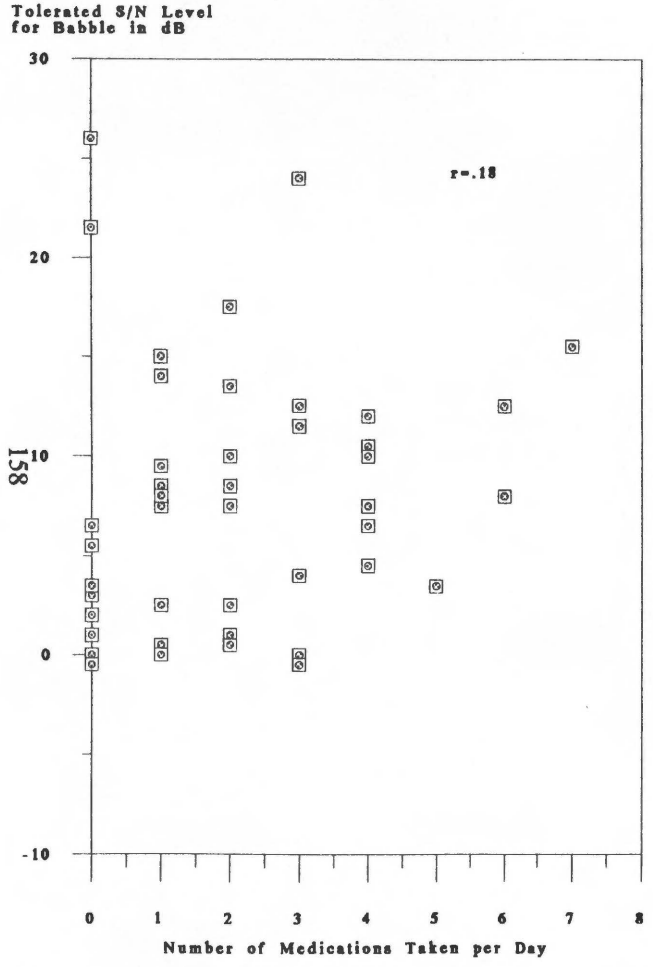


Figure 58. The relationship between number of medications taken per day and tolerated S/N level for babble.

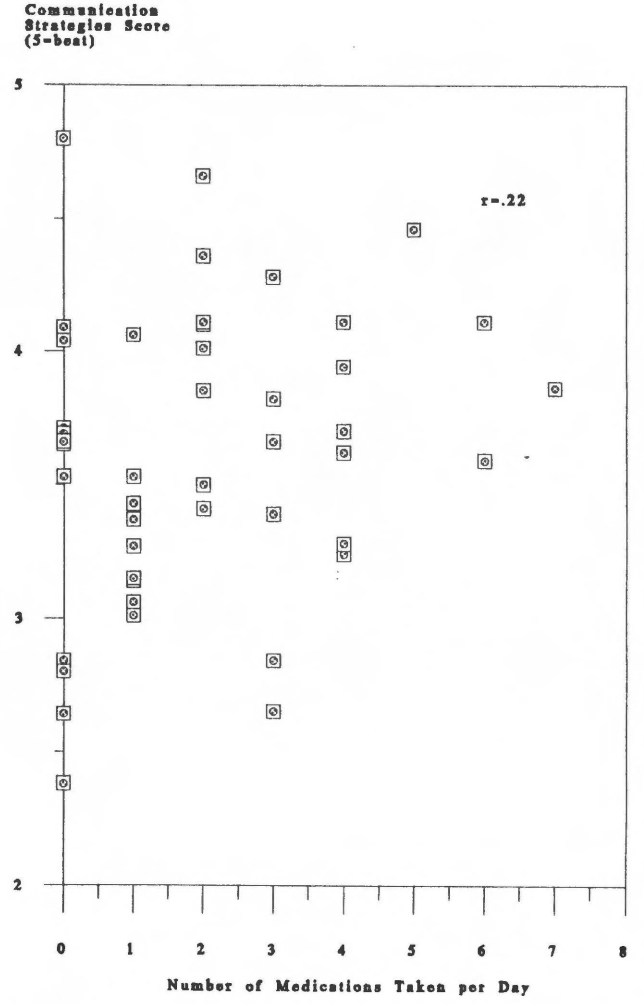


Figure 59. The relationship between number of medications taken per day and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

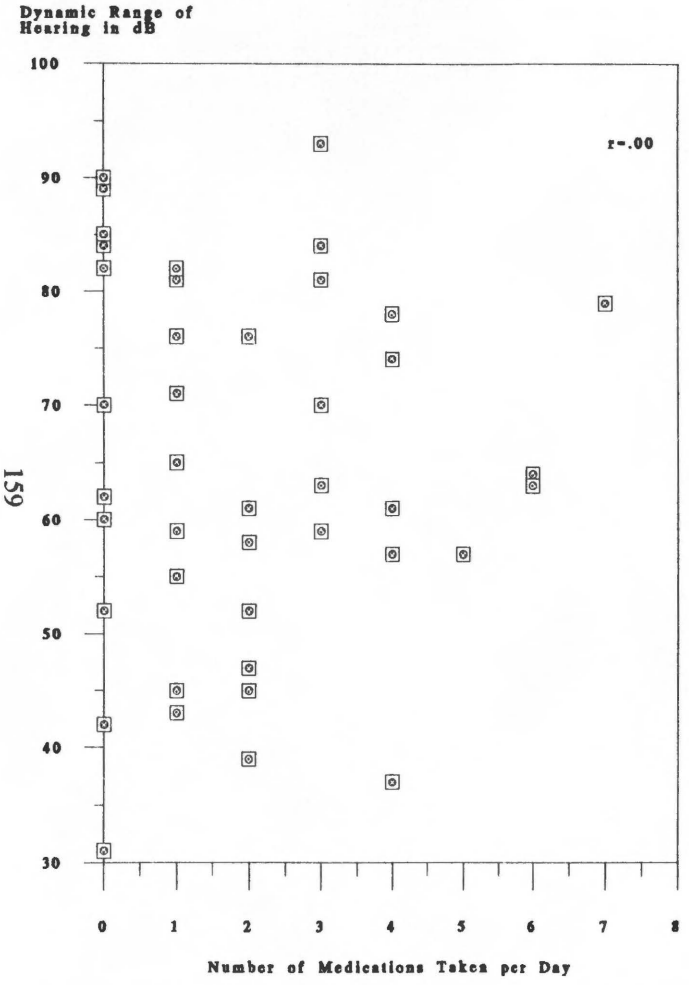


Figure 60. The relationship between the number of medications taken per day and dynamic range of hearing.

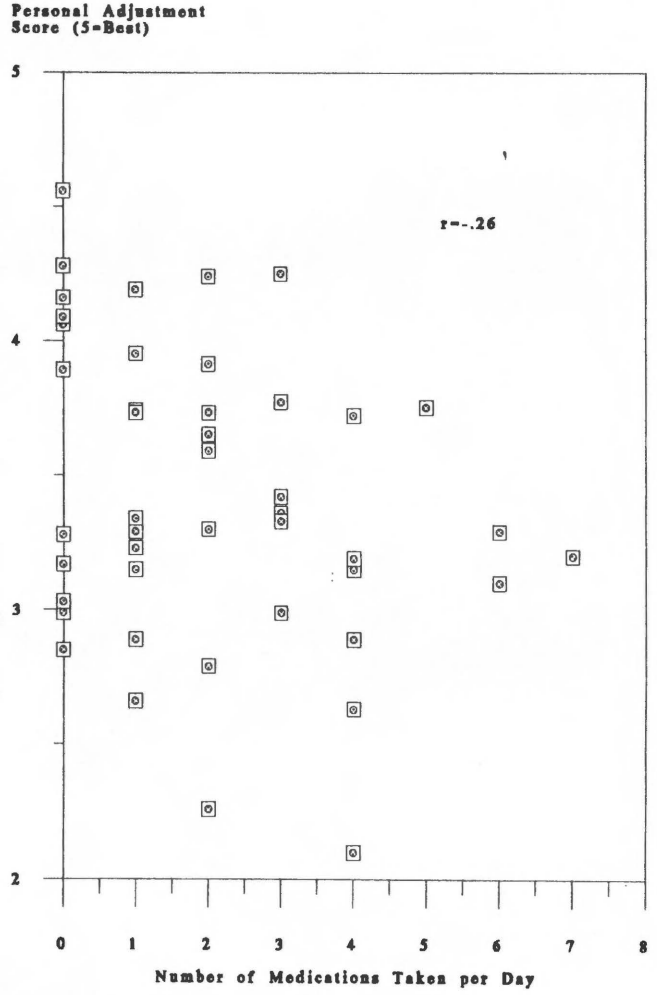


Figure 61. The relationship between number of medications taken per day and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

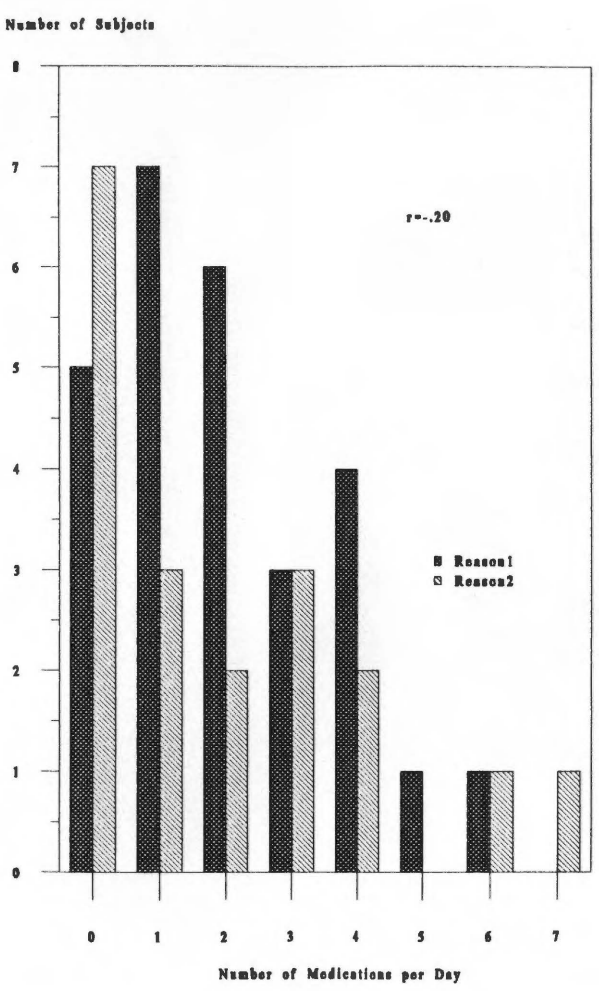


Figure 62. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for seven medication categories.

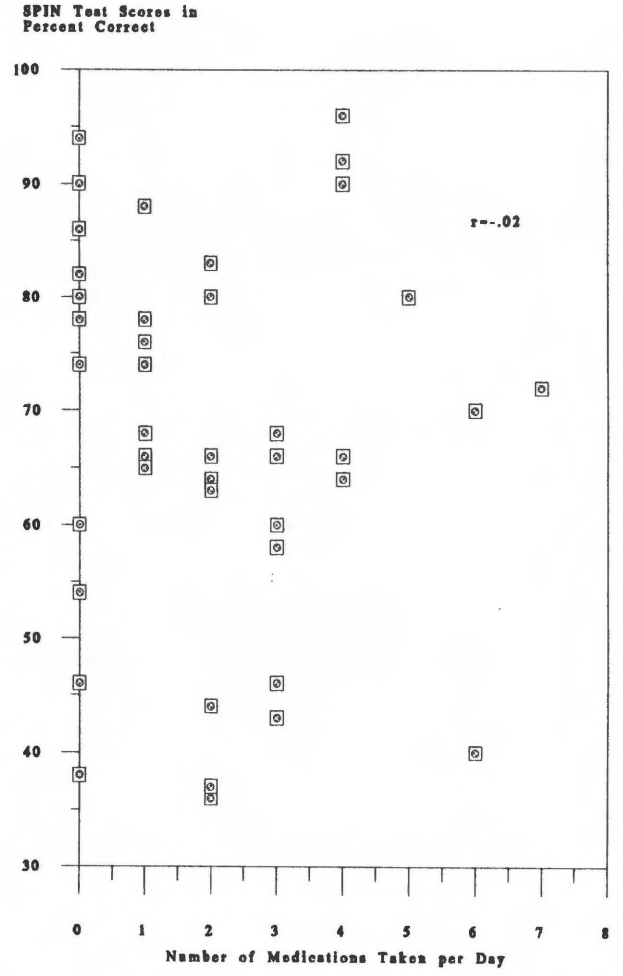


Figure 63. The relationship between number of medications taken per day and Speech Perception in Noise test scores.

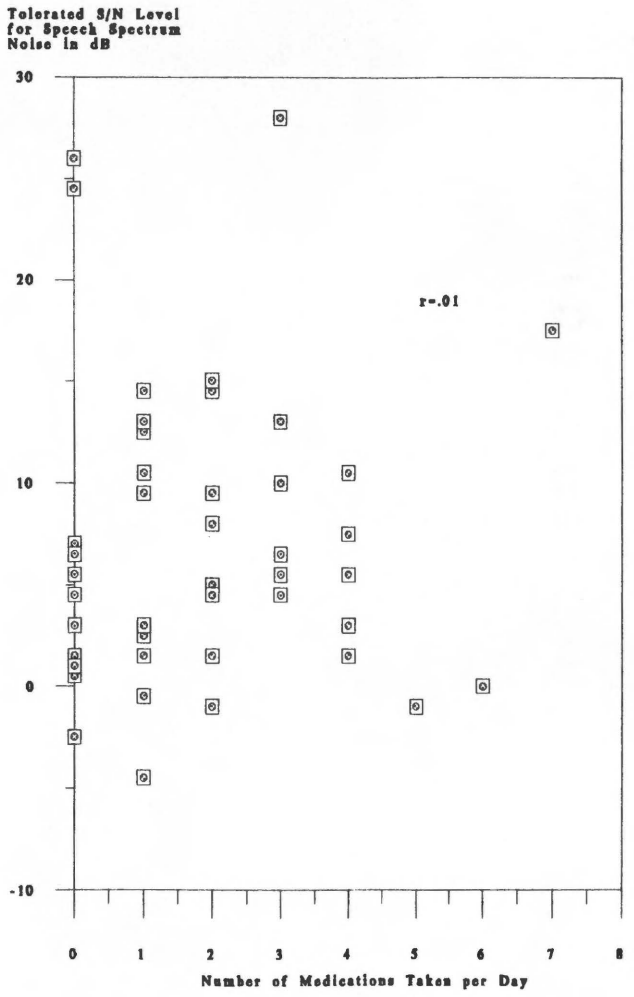


Figure 64. The relationship between number of medications taken per day and tolerated S/N level for speech spectrum noise.

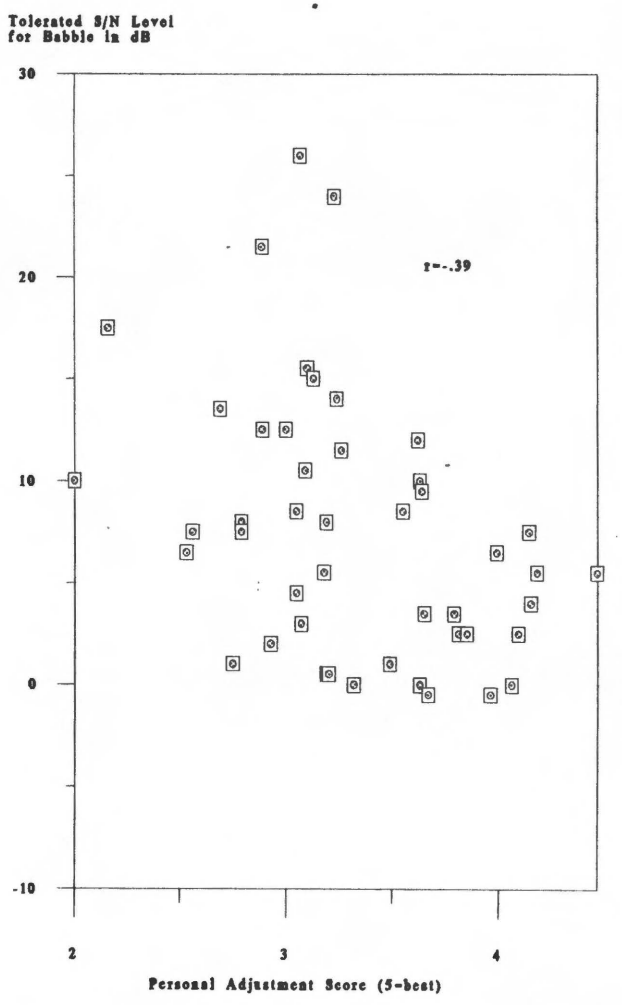


Figure 65. The relationship between Personal Adjustment scores from the Communication Profile for the Hearing Impaired and tolerated signal-to-noise levels for babble.

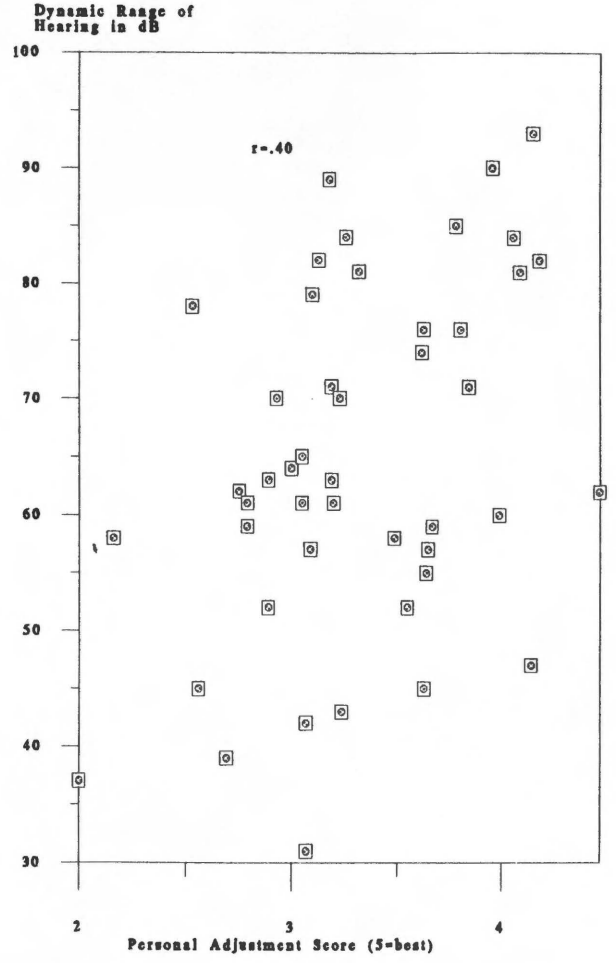


Figure 66. The relationship between Personal Adjustment scores from the Communication Profile for the Hearing Impaired and dynamic range of hearing.

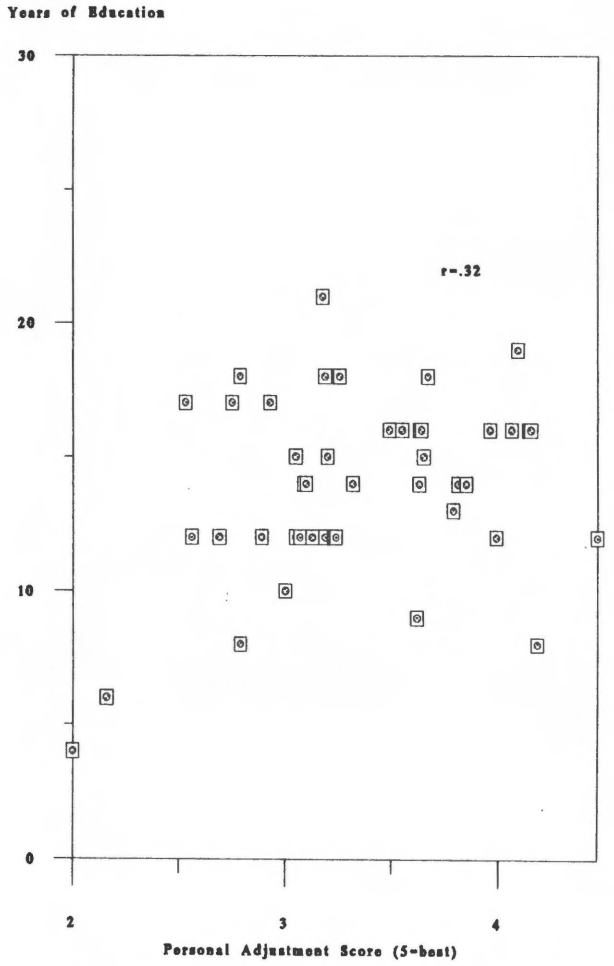


Figure 67. The relationship between Personal Adjustment scores from the Communication Profile for the Hearing Impaired and years of education.

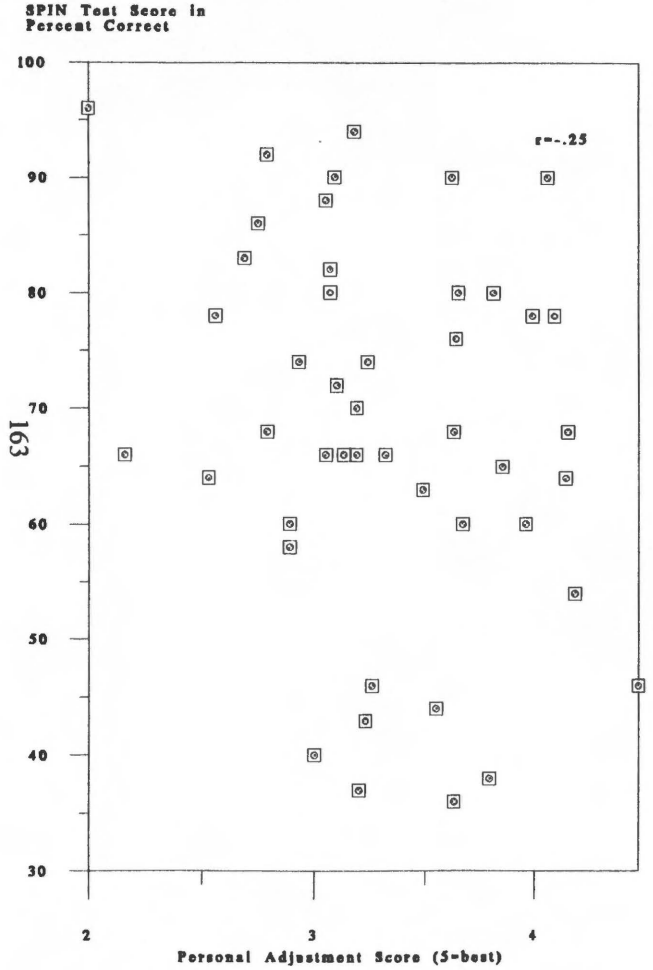


Figure 68. The relationship between Personal Adjustment scores from the Communication Profile for the Hearing Impaired and Speech Perception in Noise test scores.

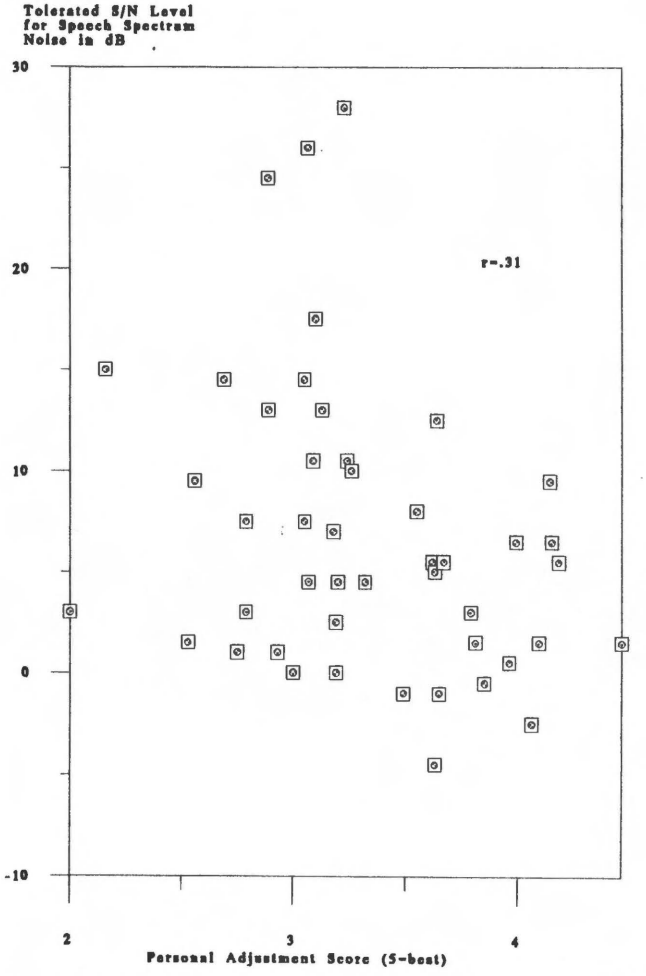


Figure 69. The relationship between Personal Adjustment scores from the Communication Profile for the Hearing Impaired and tolerated signal-to-noise levels for speech spectrum noise.

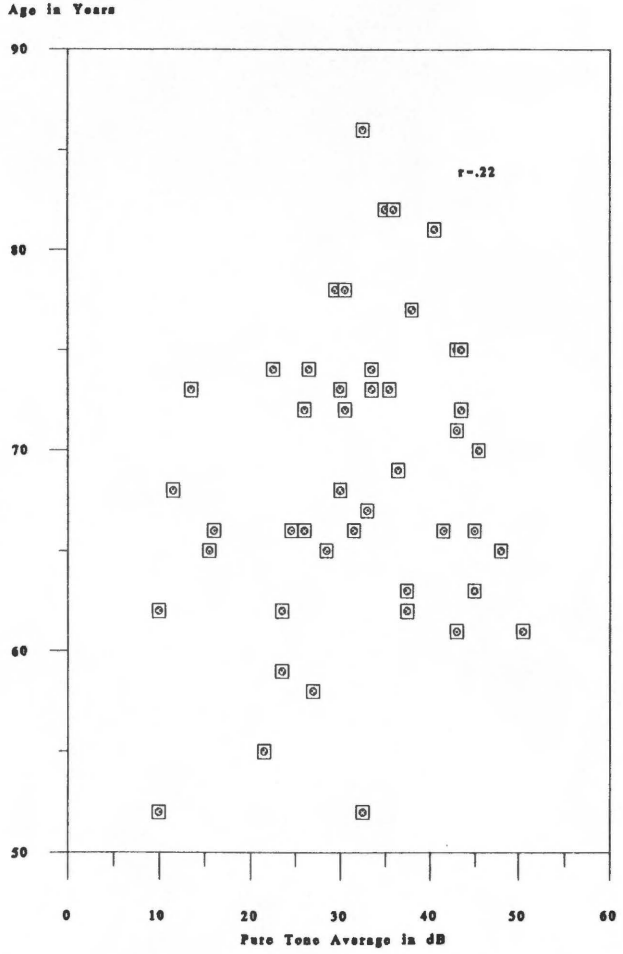


Figure 70. The relationship between pure tone average and age.

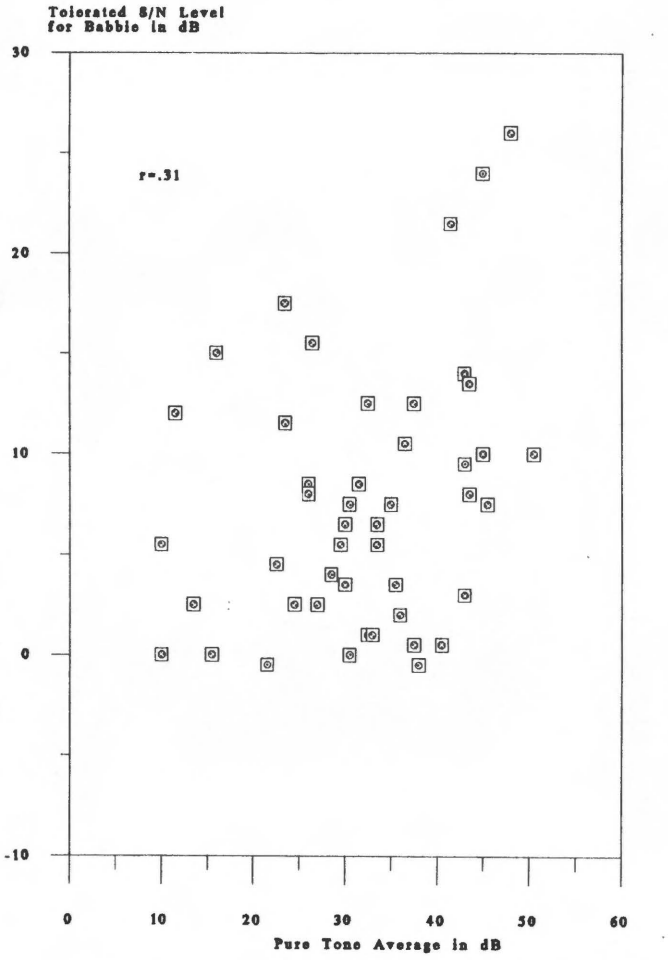


Figure 71. The relationship between pure tone average and tolerated signal-to-noise level for babble.

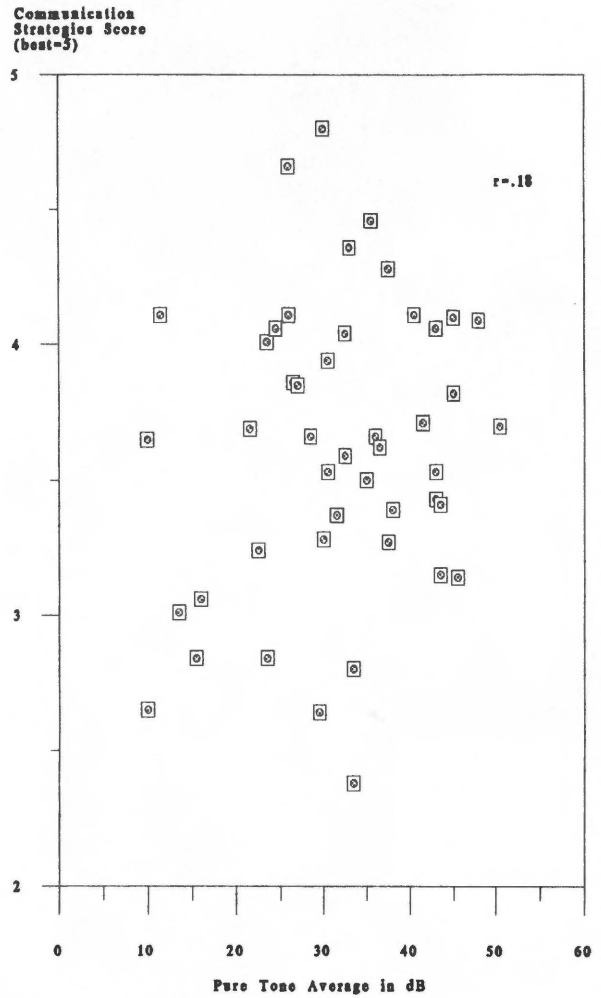


Figure 72. The relationship between pure tone average and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

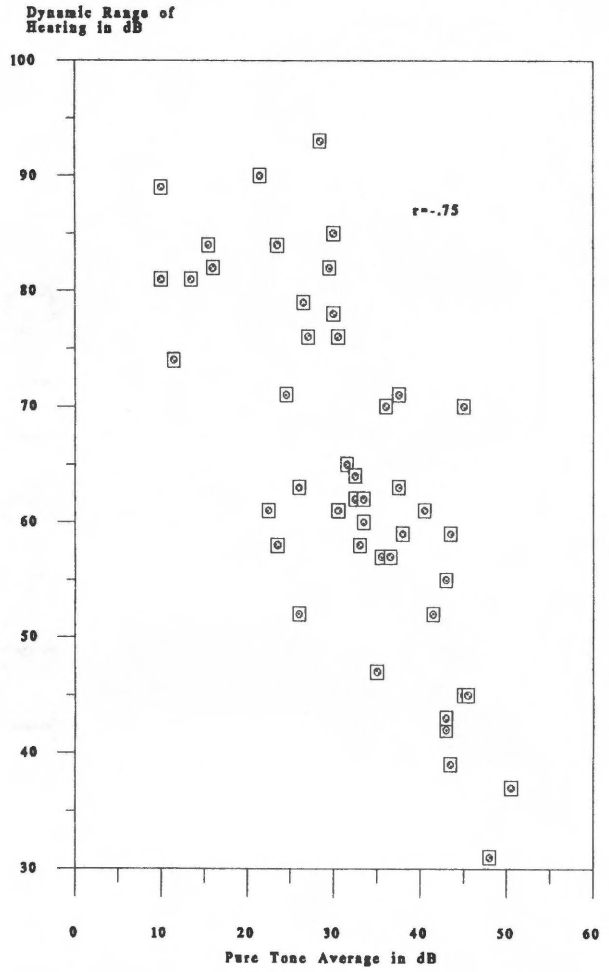


Figure 73. The relationship between pure tone average and dynamic range of hearing.

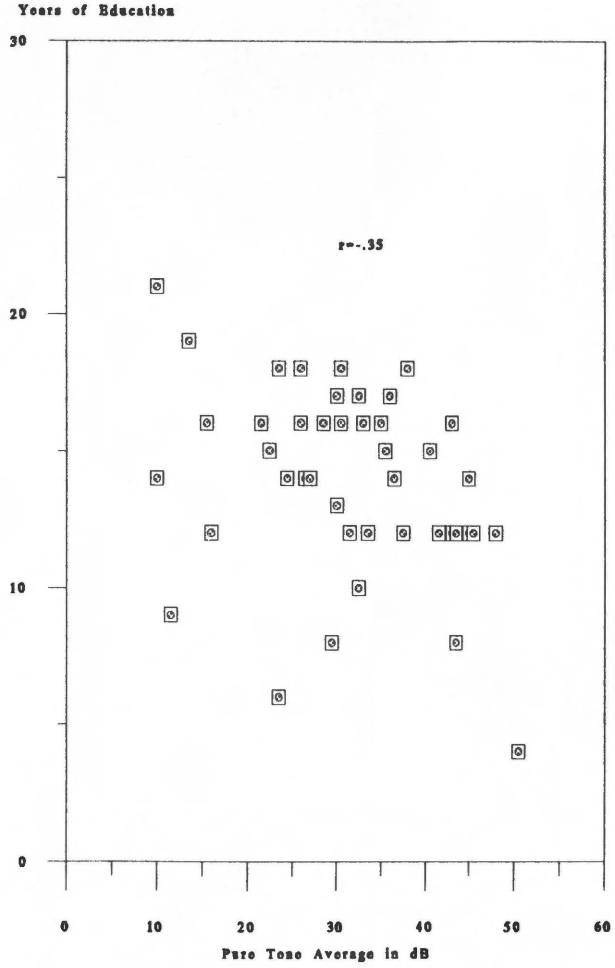


Figure 74. The relationship between pure tone average and education.

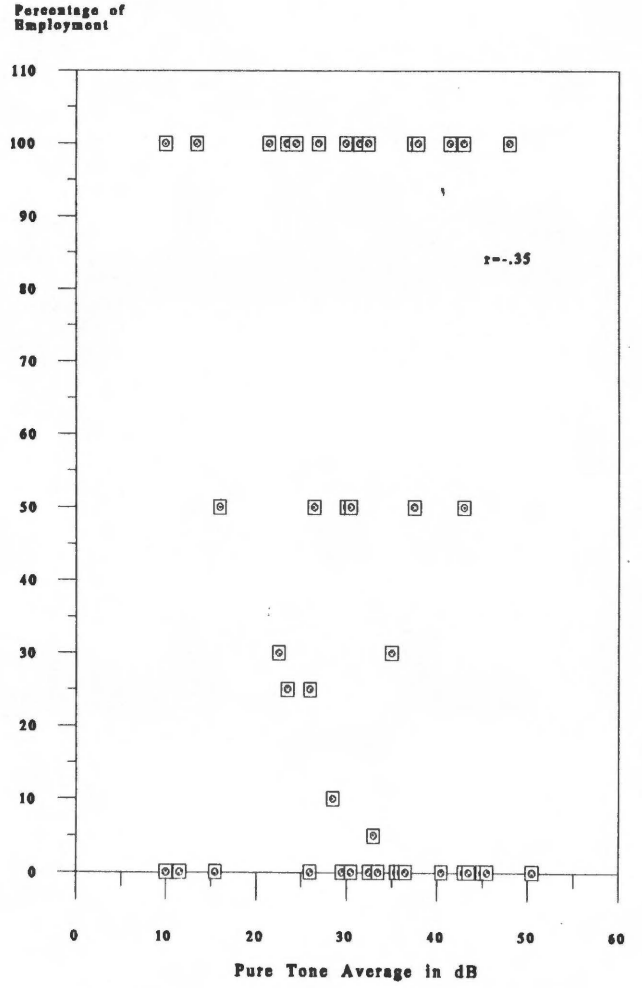


Figure 75. The relationship between pure tone average and employment.

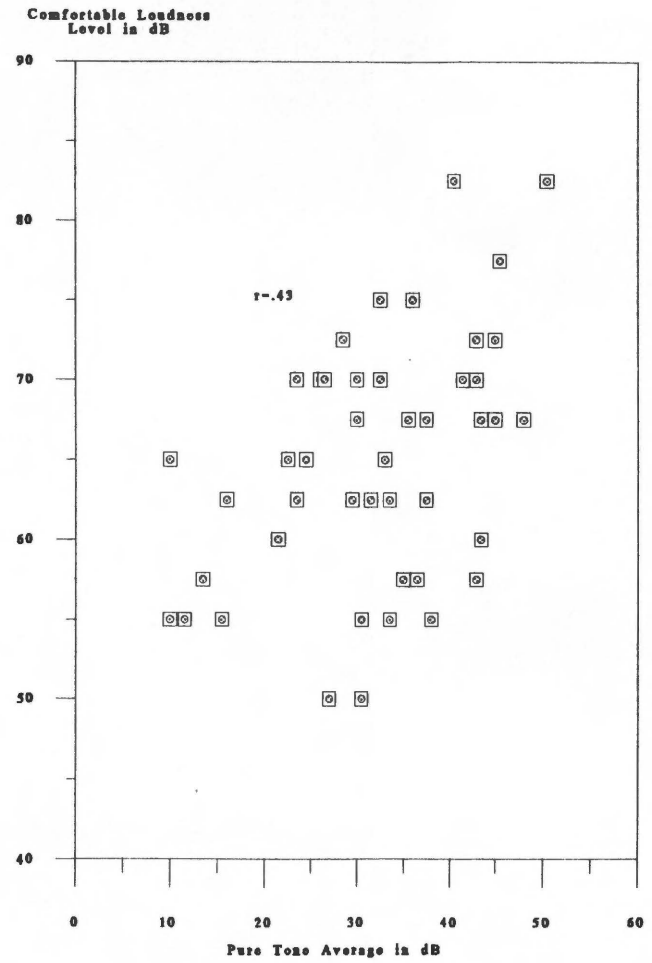


Figure 76. The relationship between pure tone average and comfortable loudness level.

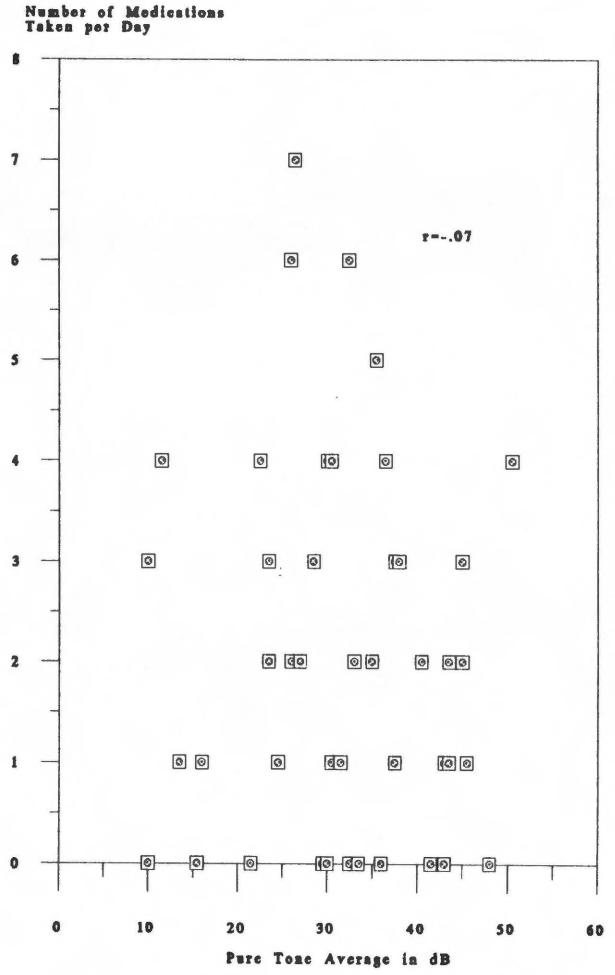


Figure 77. The relationship between pure tone average and number of medications taken per day.

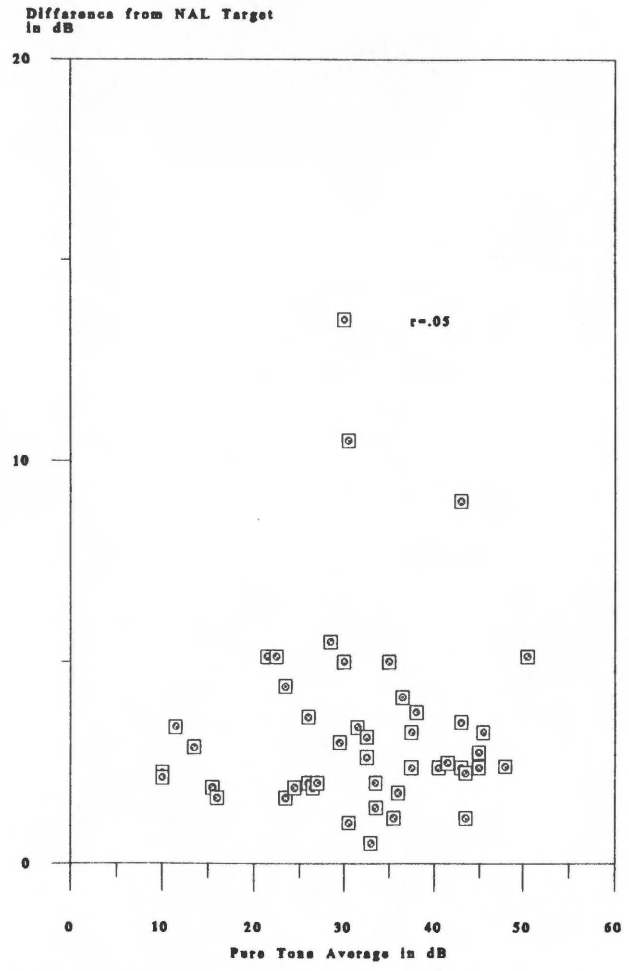


Figure 78. The relationship between pure tone average and the difference between National Acoustic Laboratories' target gain and actual insertion gain.

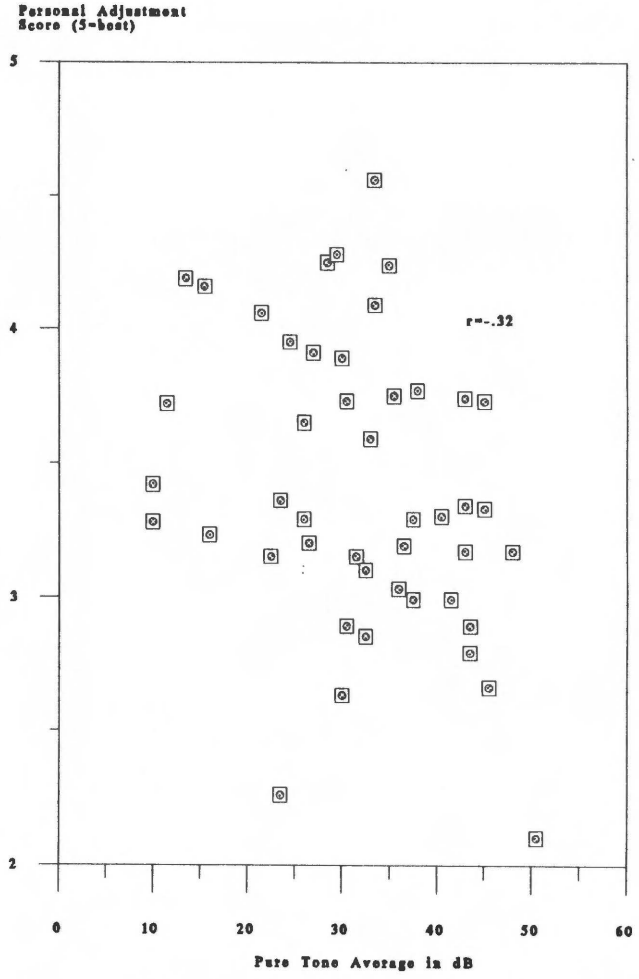


Figure 79. The relationship between pure tone average and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

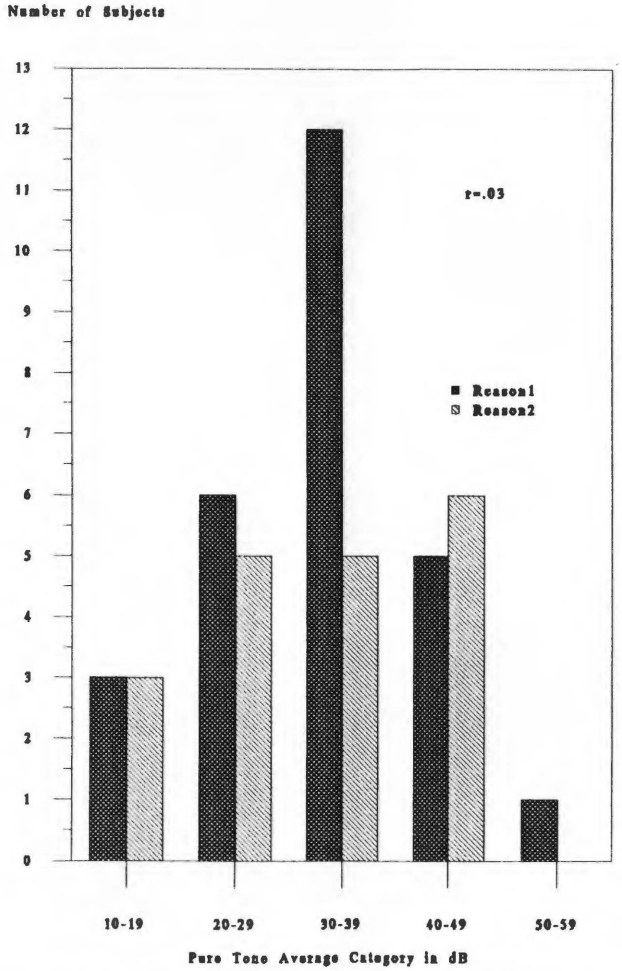


Figure 80. The number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for five pure tone average categories.

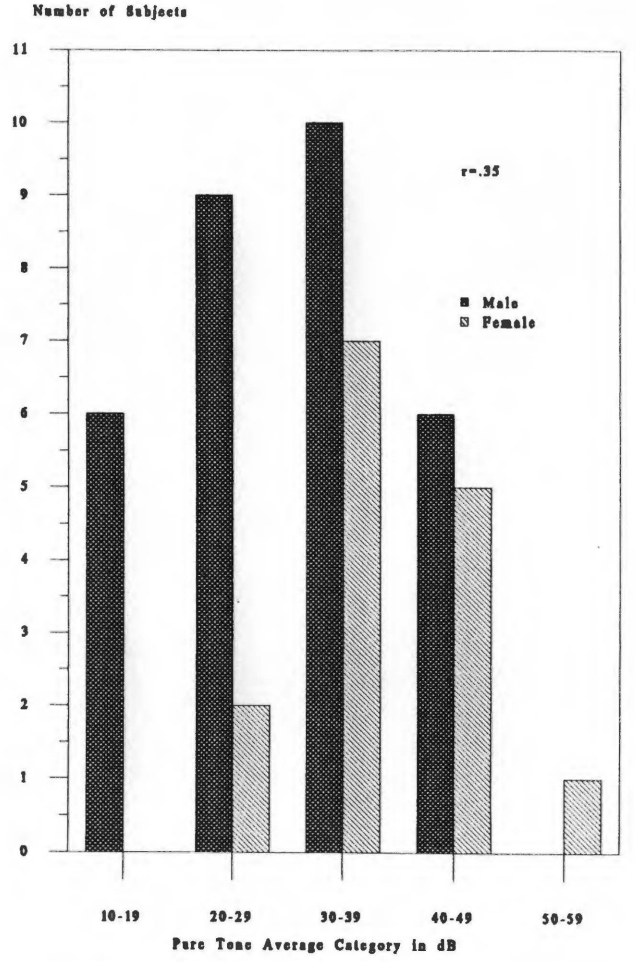


Figure 81. Number of male and female subjects in each of five pure tone average categories.

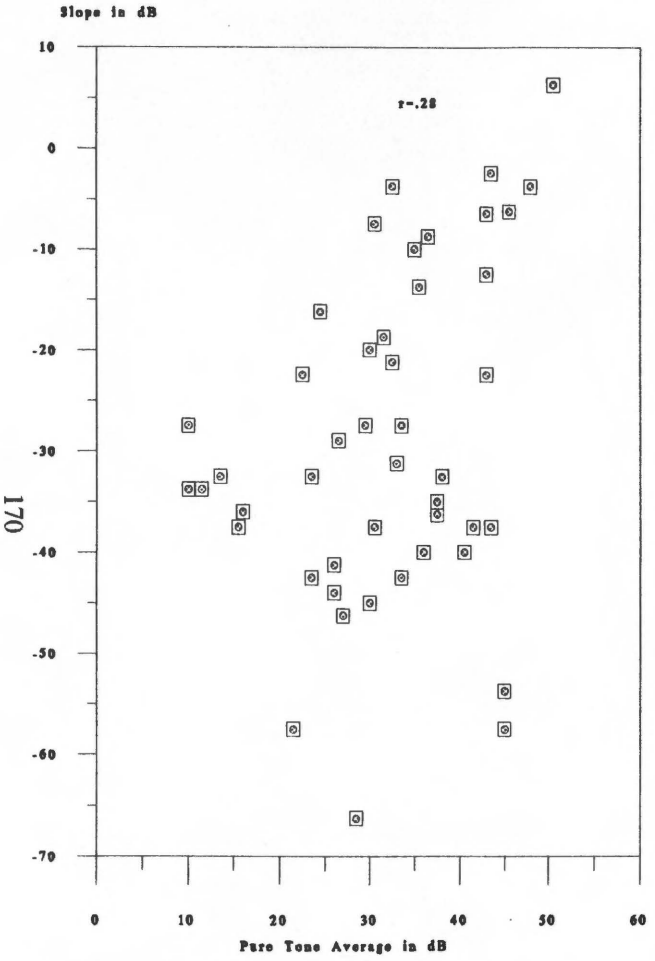


Figure 82. The relationship between pure tone average and slope.

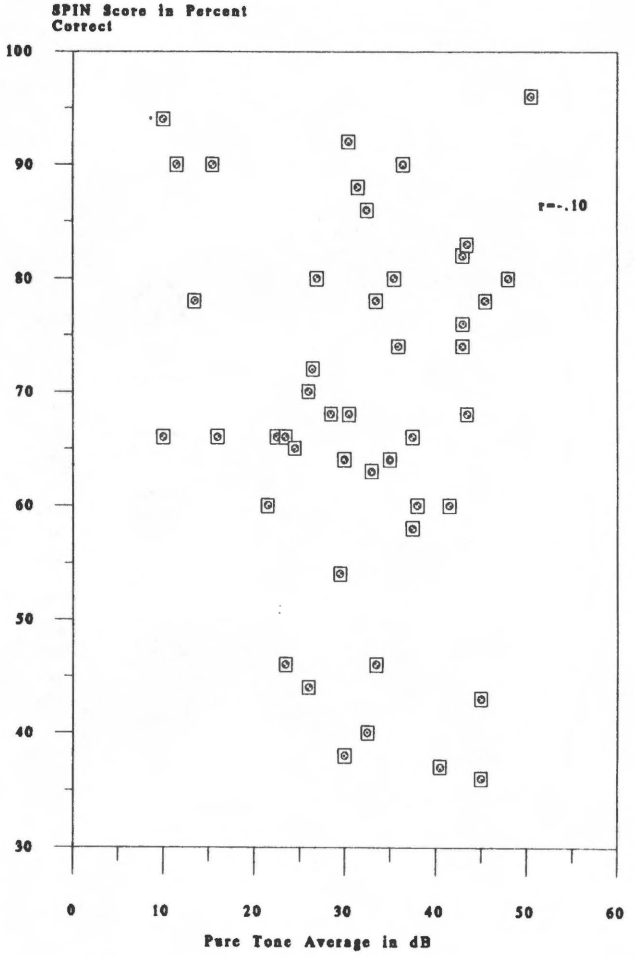


Figure 83. The relationship between pure tone average and Speech Perception in Noise test scores.

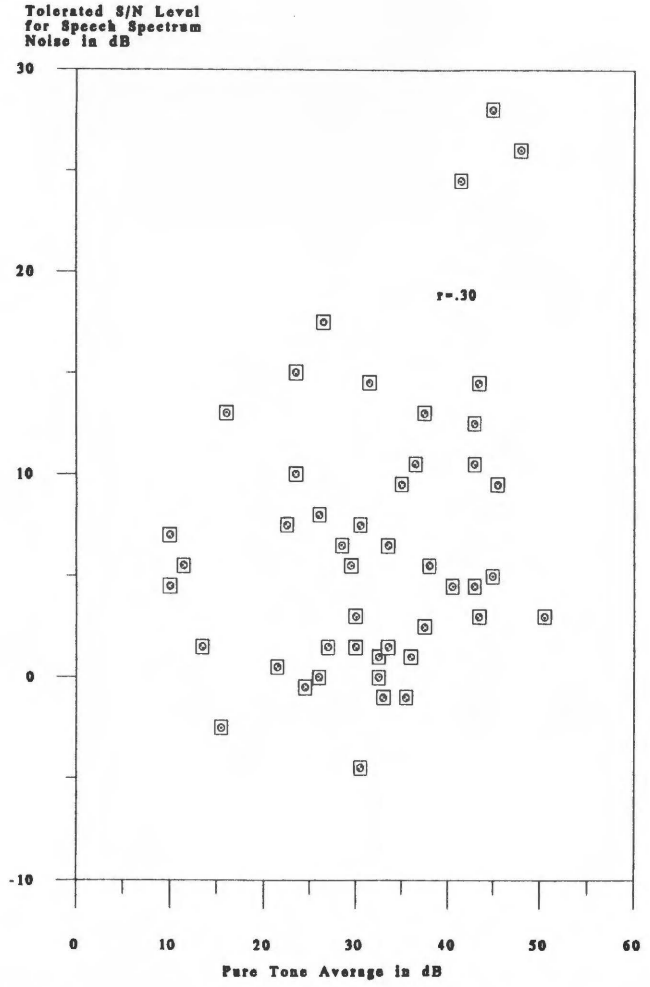


Figure 84. The relationship between pure tone average and tolerated signal-to-noise level for speech spectrum noise.

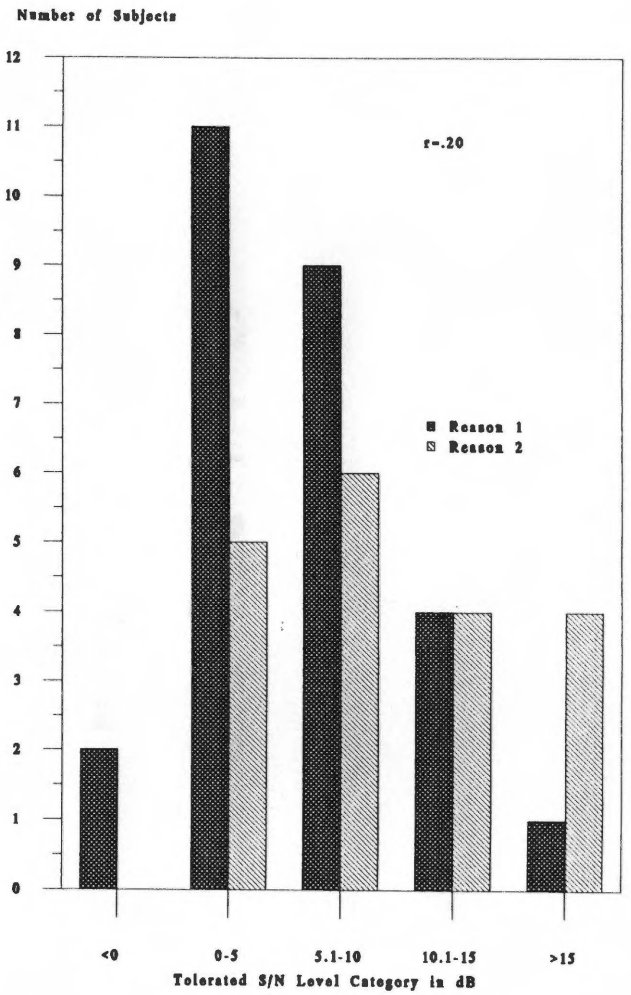


Figure 85. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for five tolerated signal-to-noise level categories for multitalker babble.

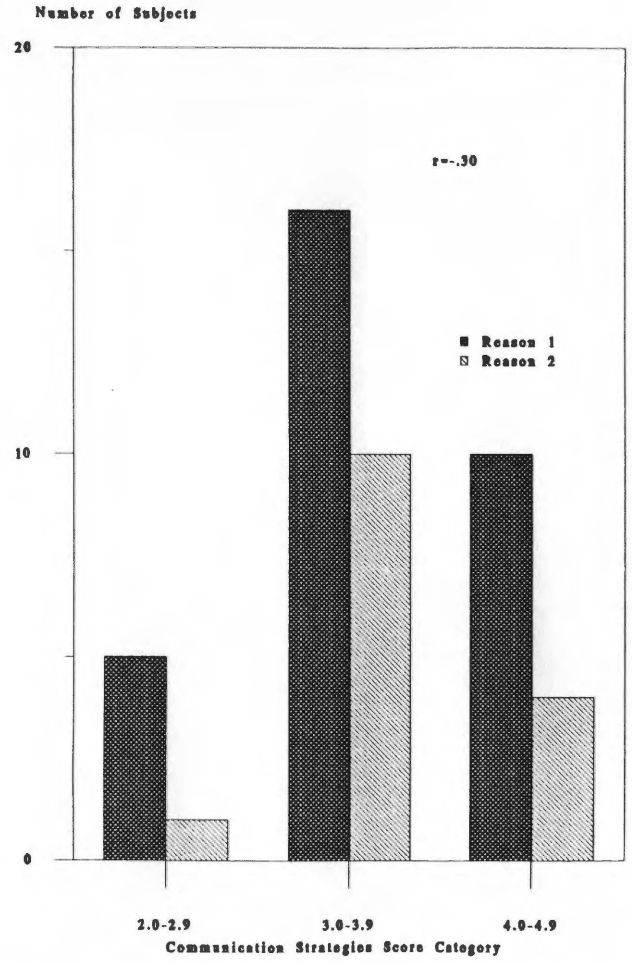


Figure 86. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for three Communication Strategies (from the Communication Profile for the Hearing Impaired) categories.

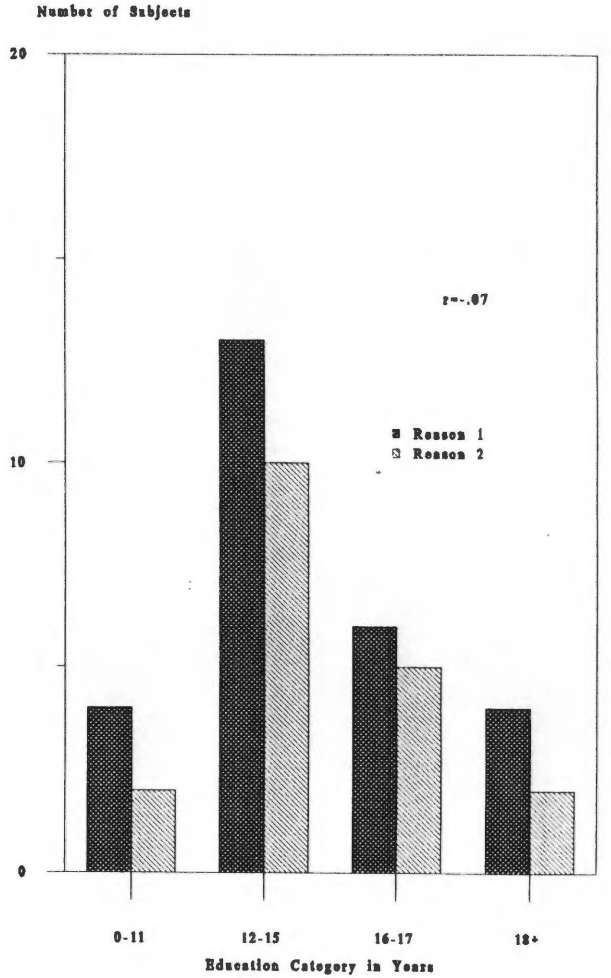


Figure 87. The number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for four education categories.

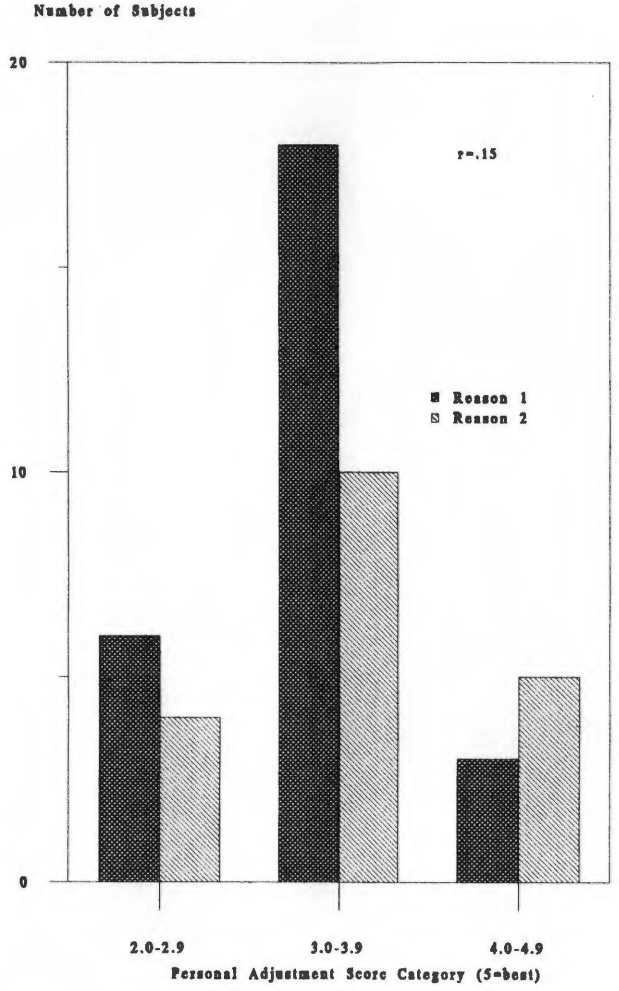


Figure 88. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for three categories of Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

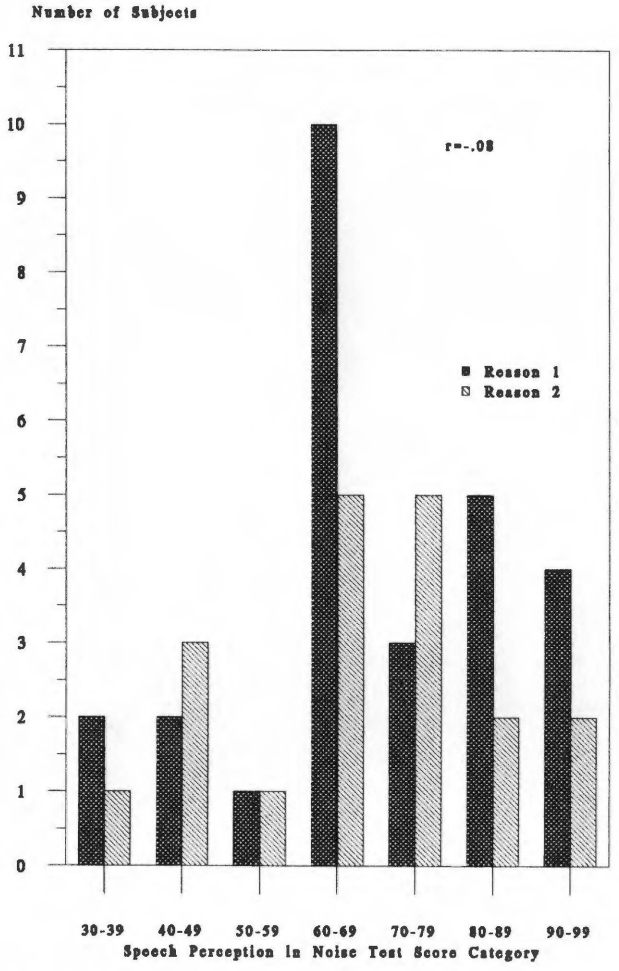


Figure 89. The number of subjects purchasing hearing aids because of 1-self-motivation and 2- encouragement from others for six SPIN test score categories.

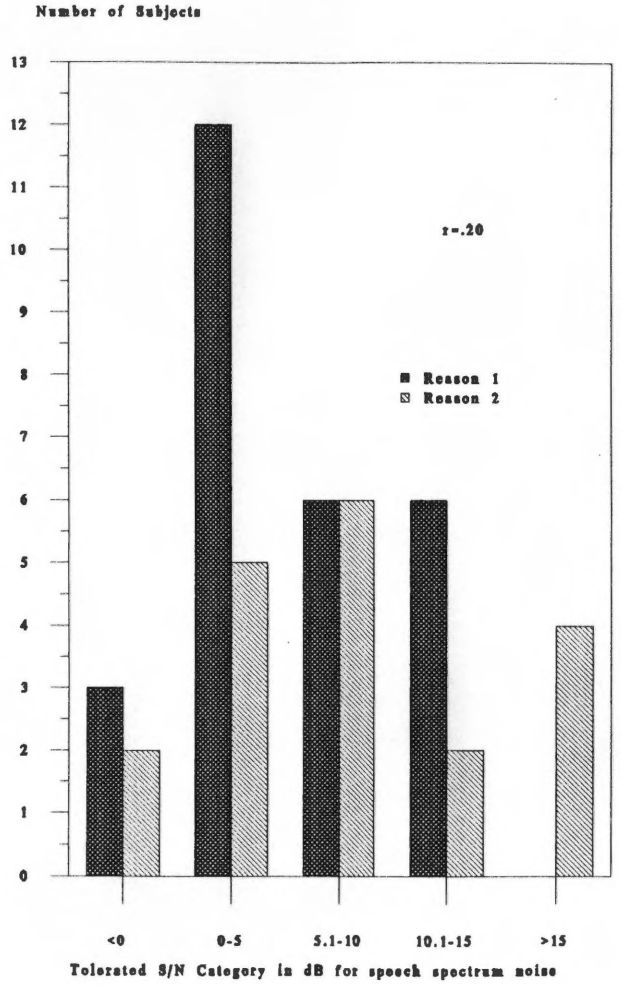


Figure 90. The number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for four categories of tolerated signal-to-noise levels for speech spectrum noise.

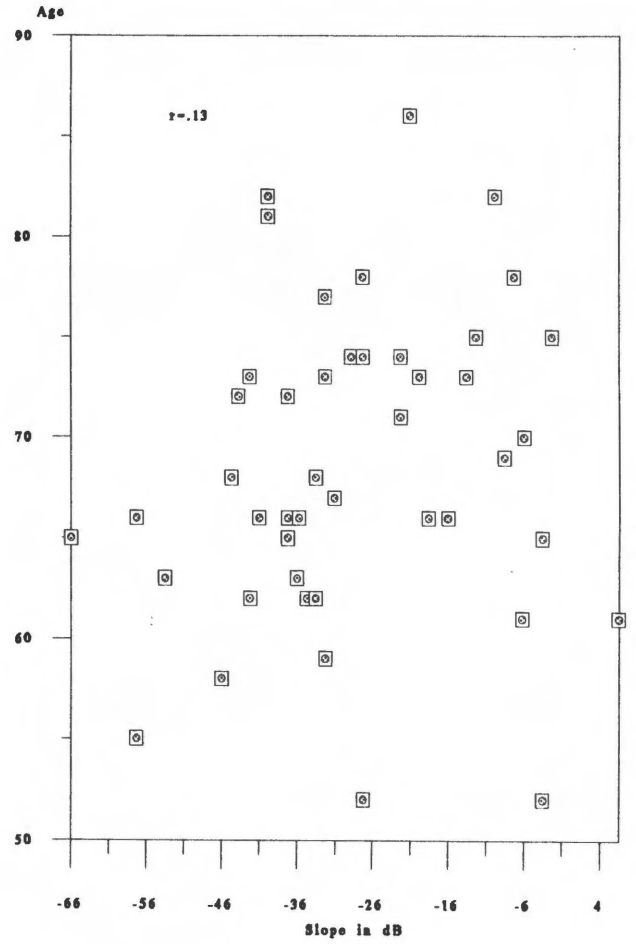


Figure 91. The relationship between slope of hearing loss and age.

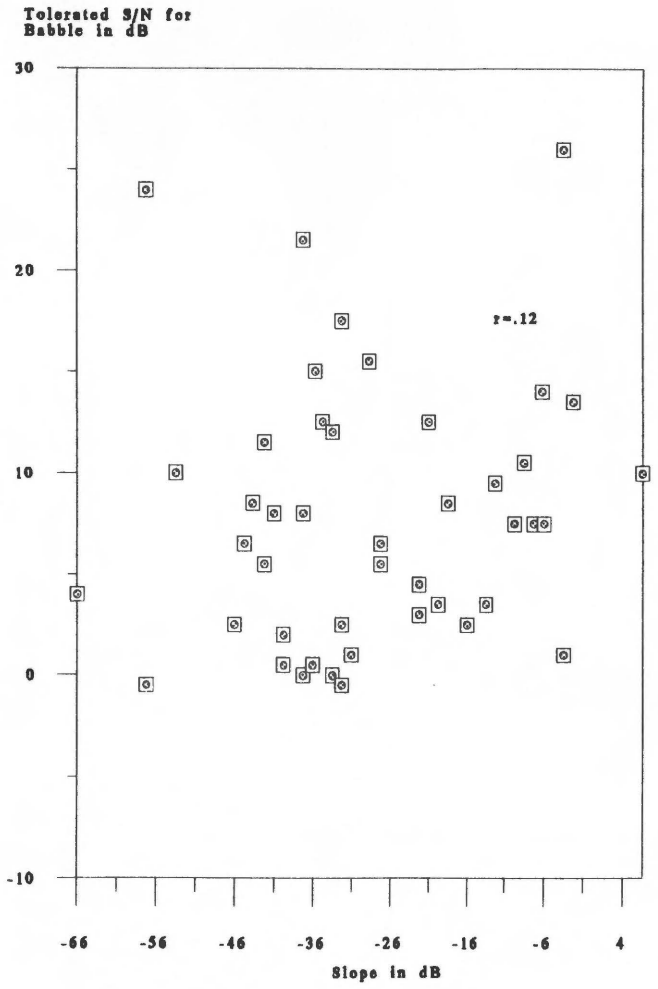


Figure 92. Relationship between slope of hearing loss and tolerated S/N level for babble.

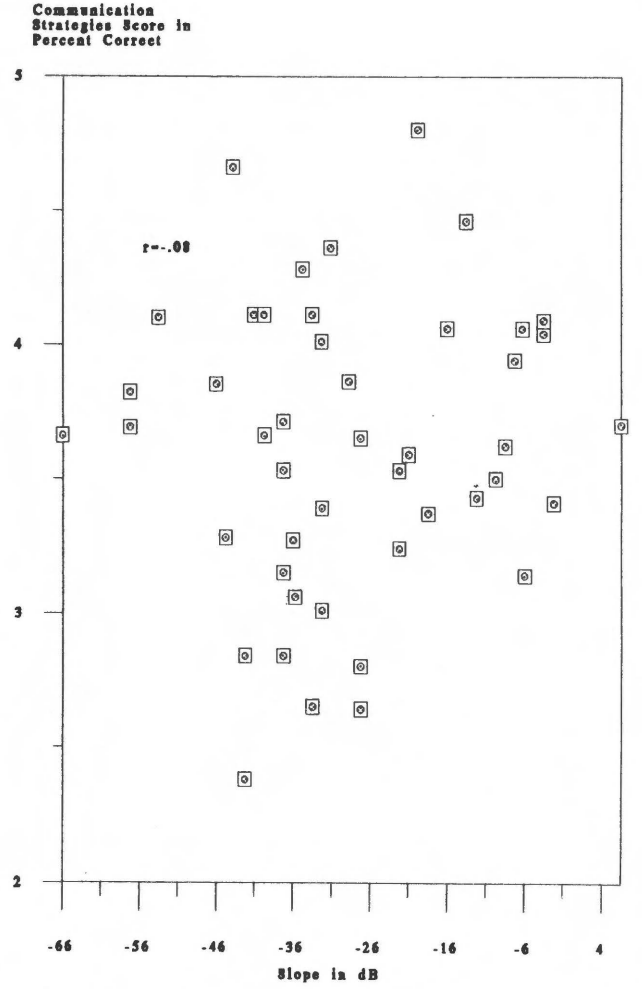


Figure 93. The relationship between slope of hearing loss and Communication Strategies scores from the Communication Profile for the Hearing Impaired.

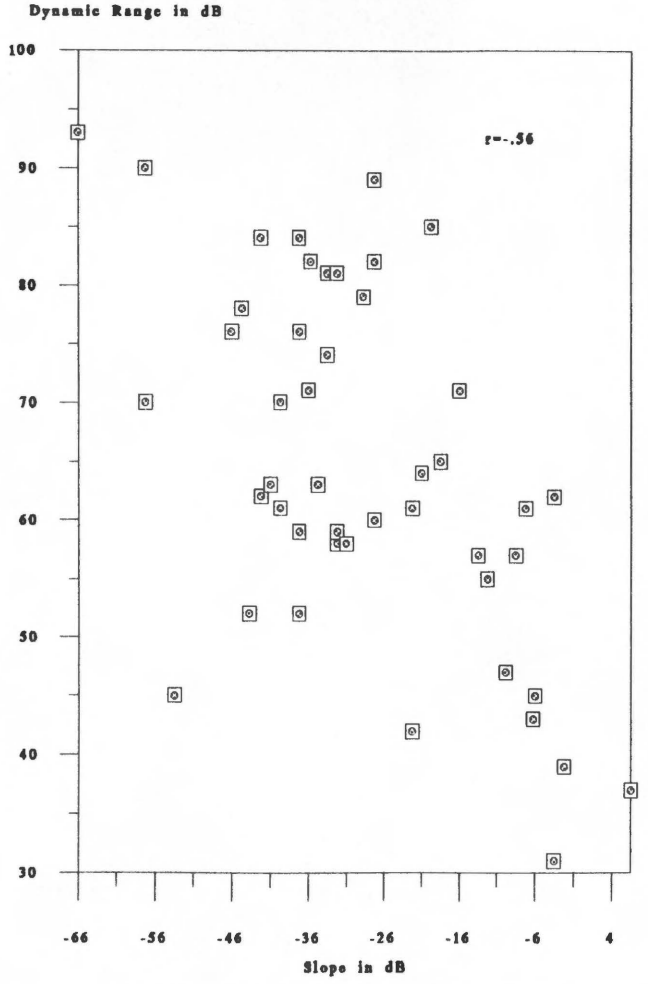


Figure 94. The relationship between slope of hearing loss and dynamic range.

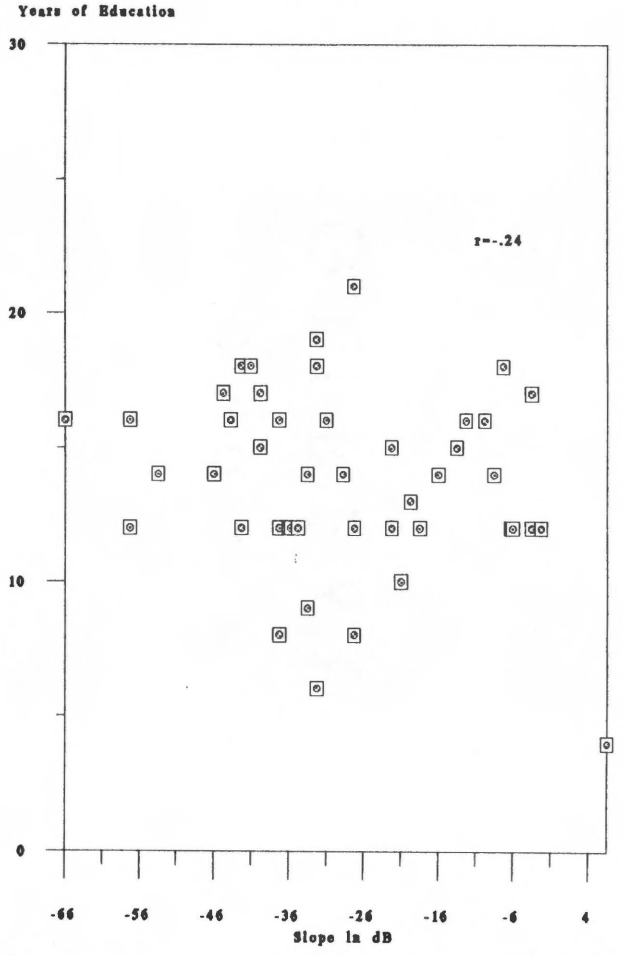


Figure 95. The relationship between slope of hearing loss and years of education.

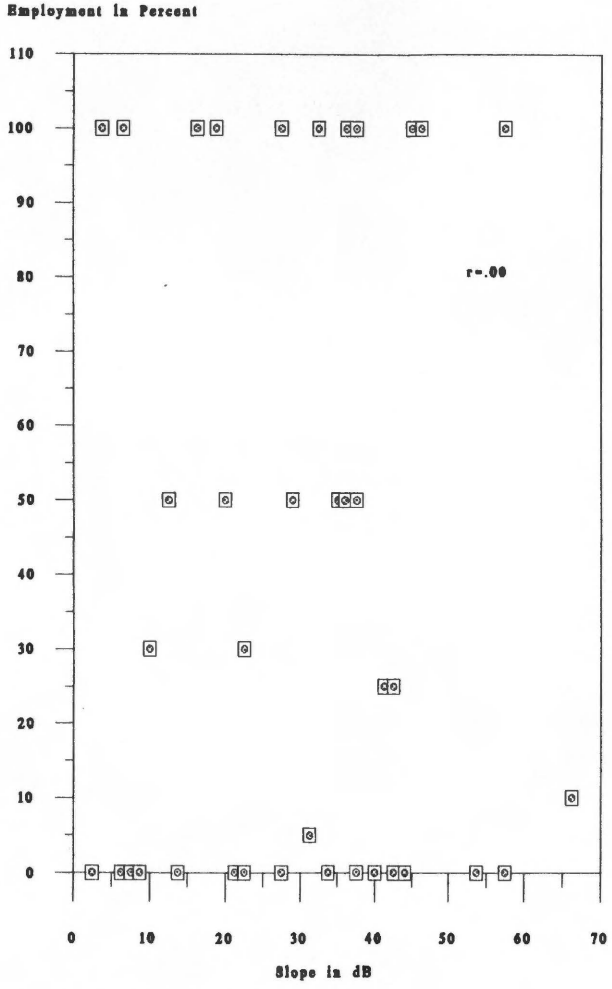


Figure 96. The relationship between slope of hearing loss and percent employment.

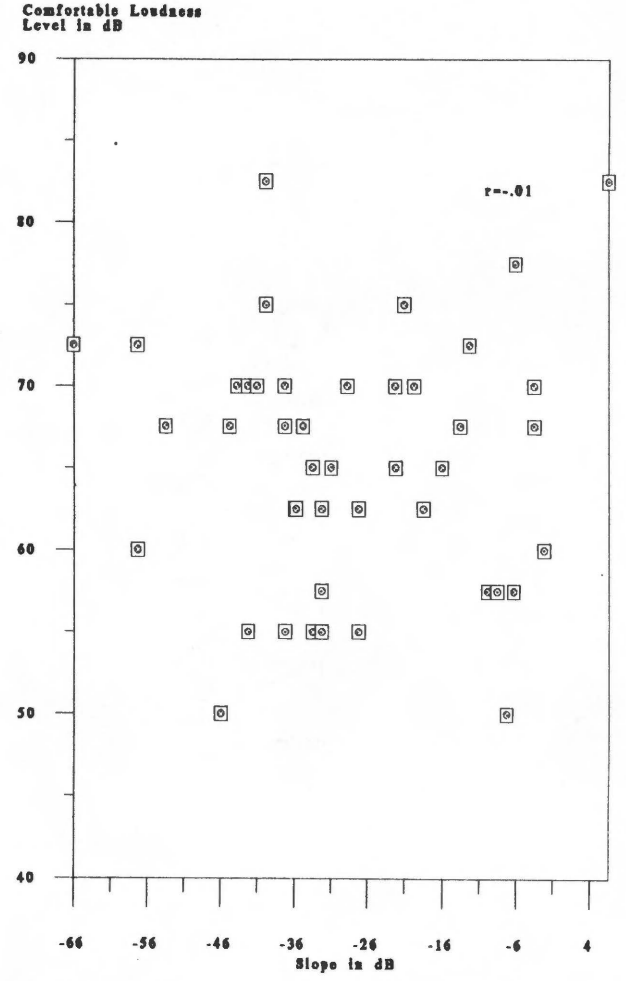


Figure 97. The relationship between slope of hearing loss and comfortable loudness level.

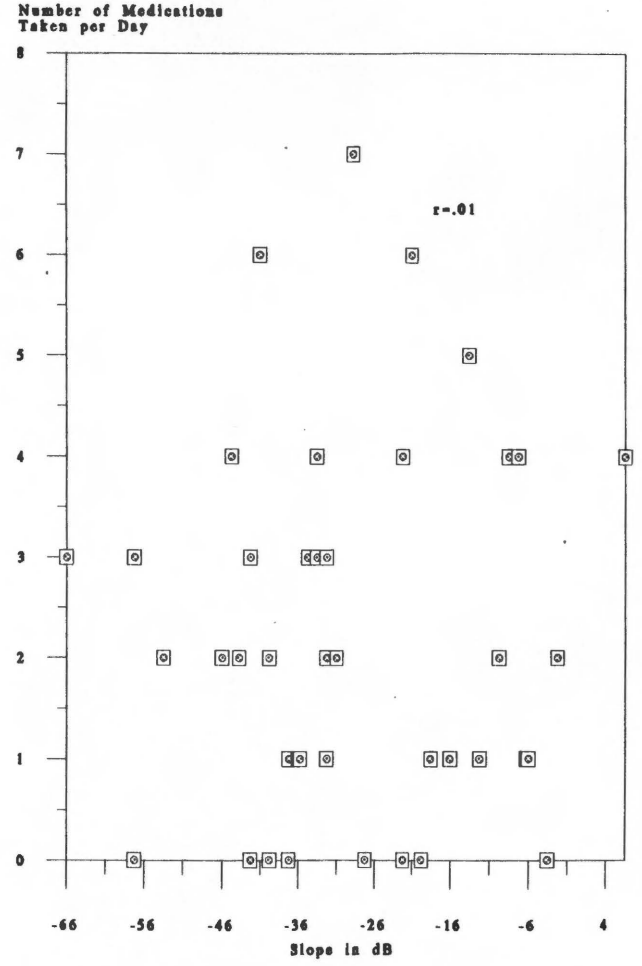


Figure 98. The relationship between slope of hearing loss and number of medications taken per day.

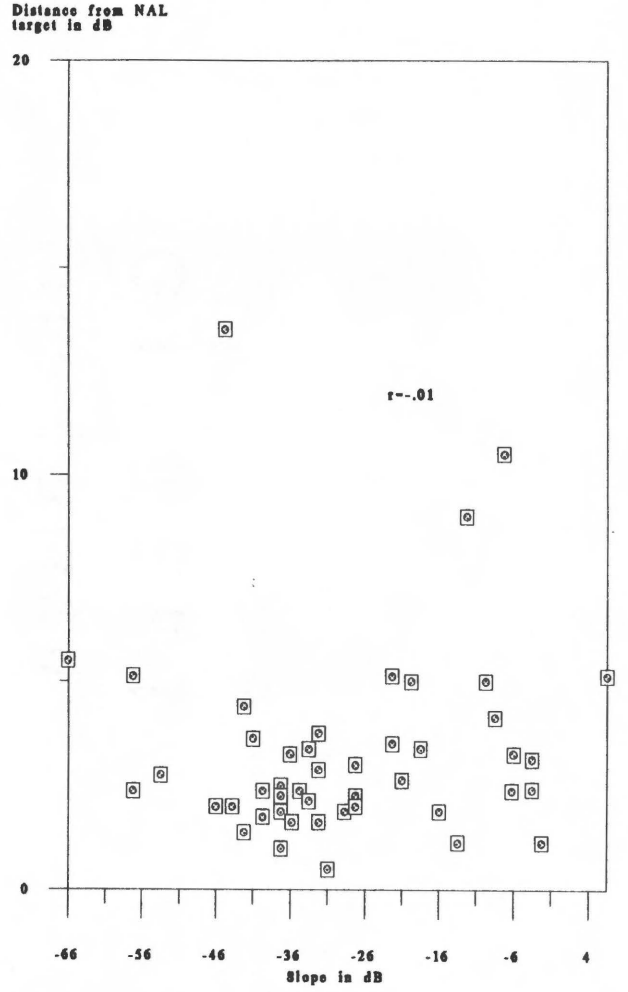


Figure 99. The relationship between slope of hearing loss and difference between NAL target gain and actual insertion gain.

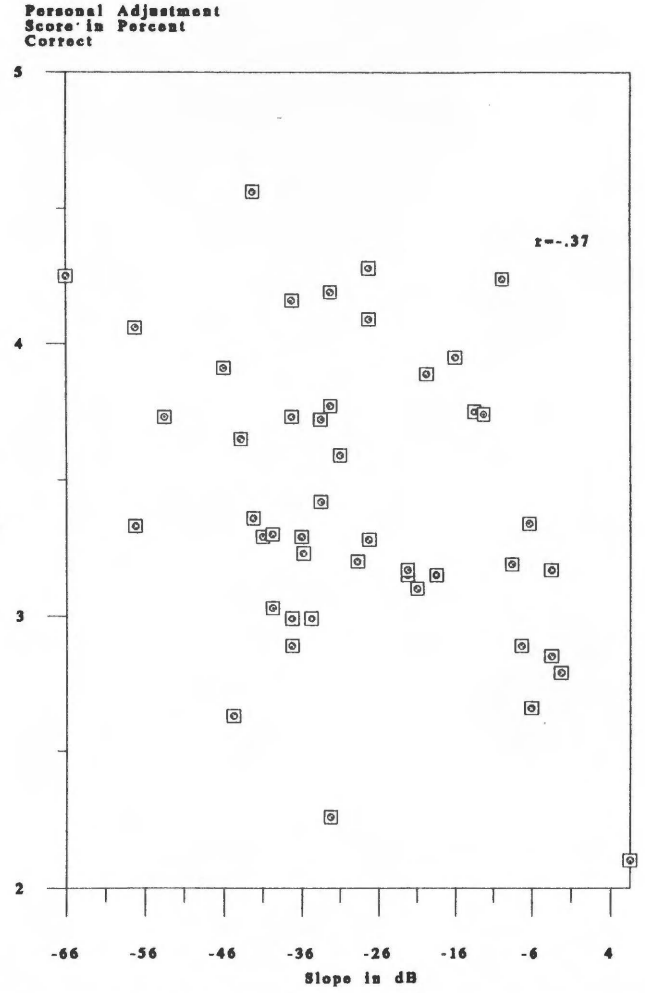


Figure 100. The relationship between slope of hearing loss and Personal Adjustment scores from the Communication Profile for the Hearing Impaired.

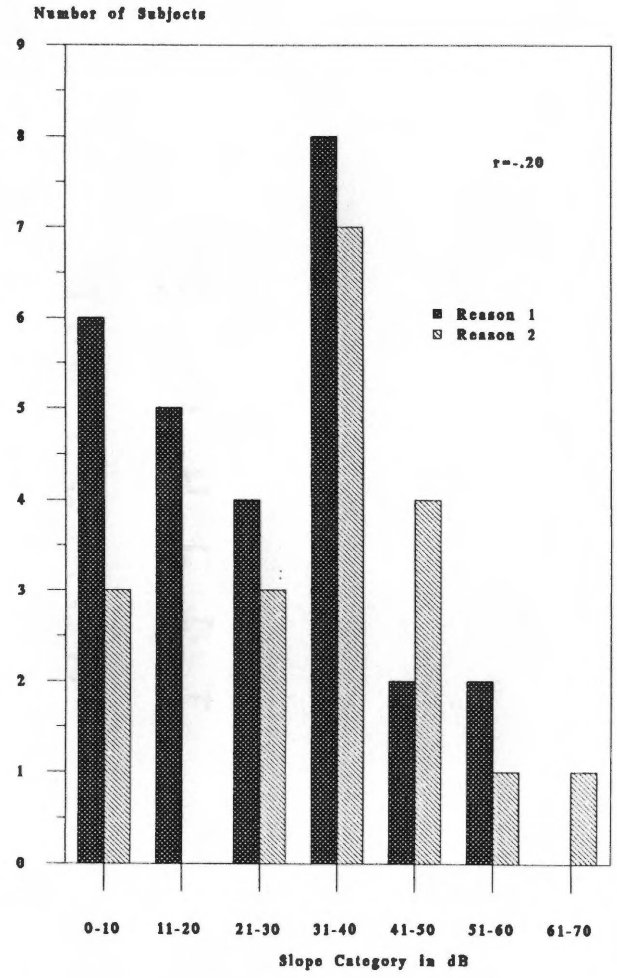


Figure 101. The number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for seven categories of hearing loss slope.

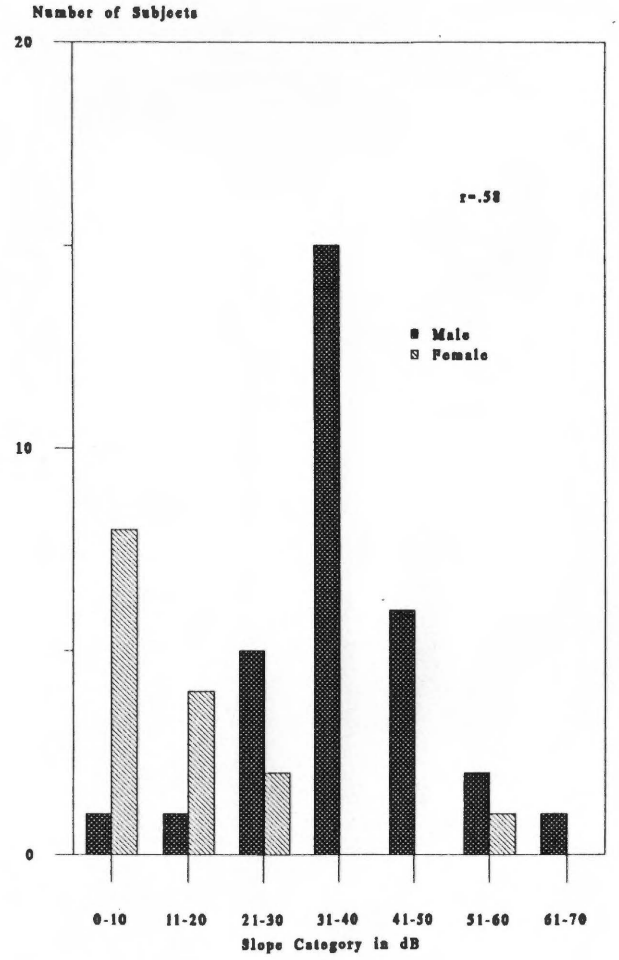


Figure 102. The number of male and female subjects in each of seven categories of hearing loss slope.

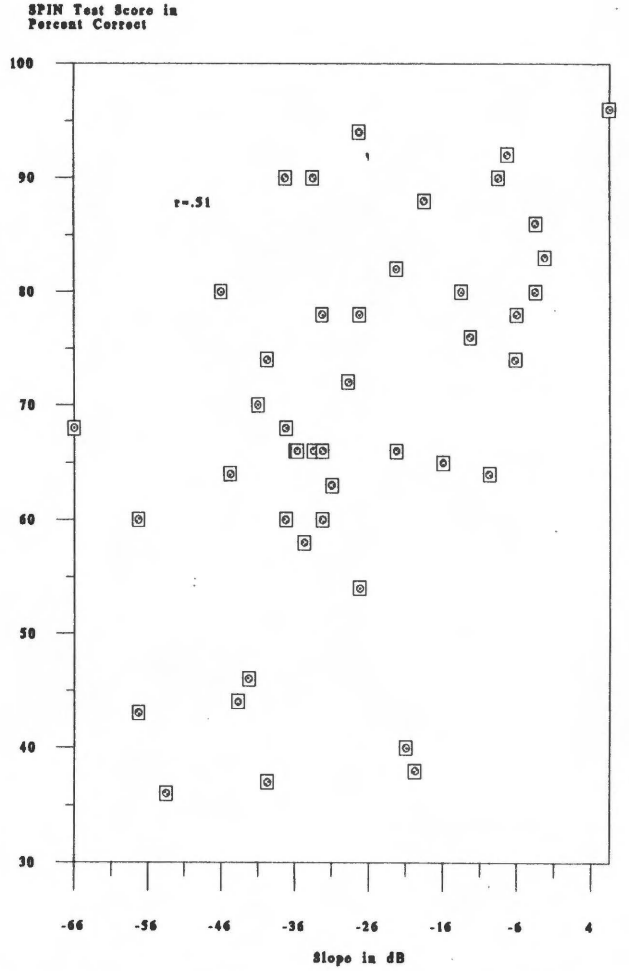


Figure 103. The relationship between slope of hearing loss and Speech Perception in Noise test scores.

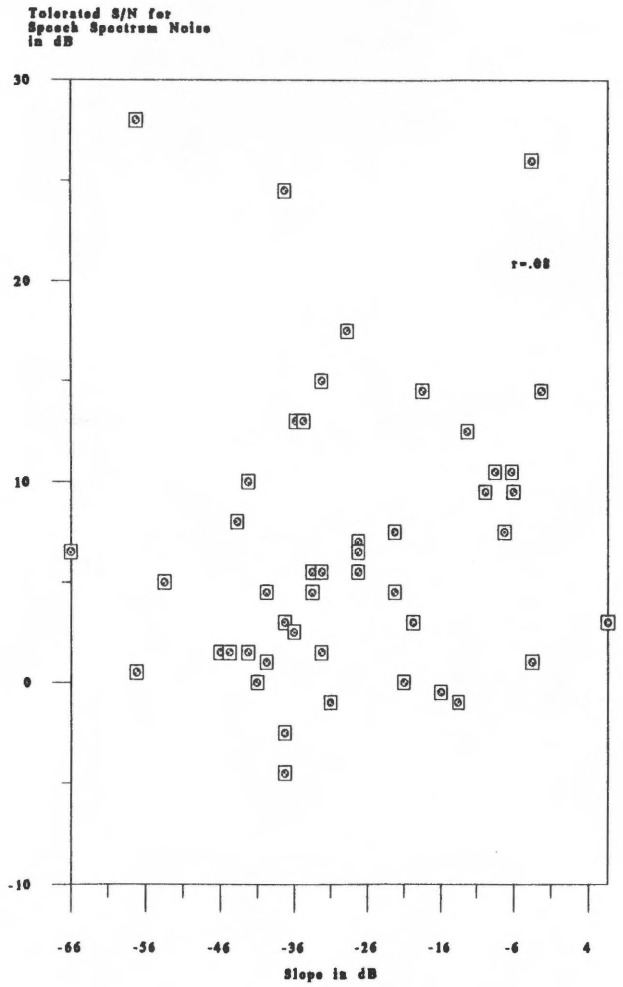


Figure 104. The relationship between slope of hearing loss and tolerated signal-to-noise level for speech spectrum noise.

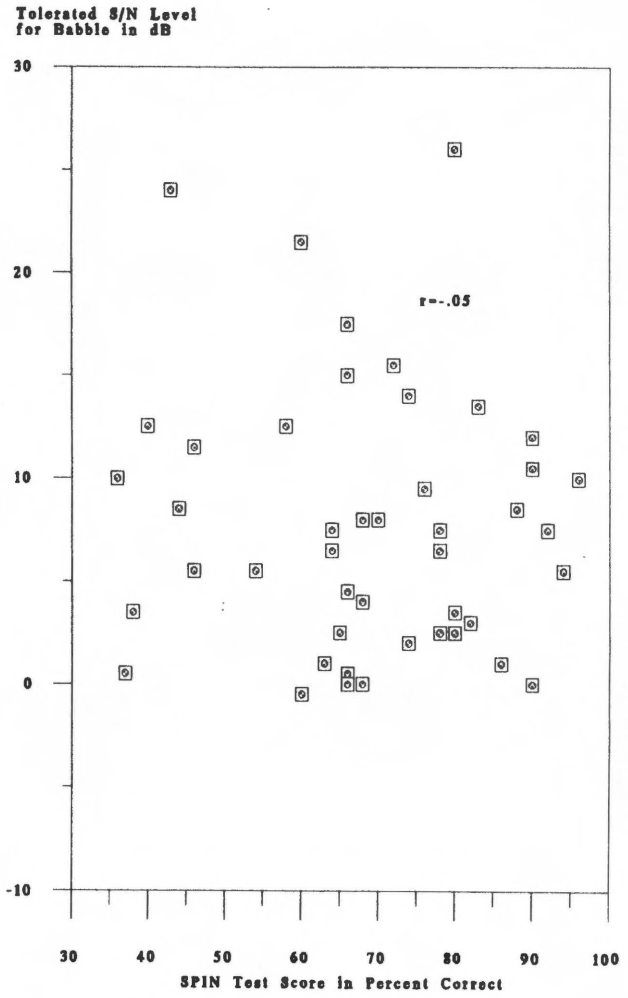


Figure 105. The relationship between SPIN test scores and tolerated signal-to-noise levels for babble.

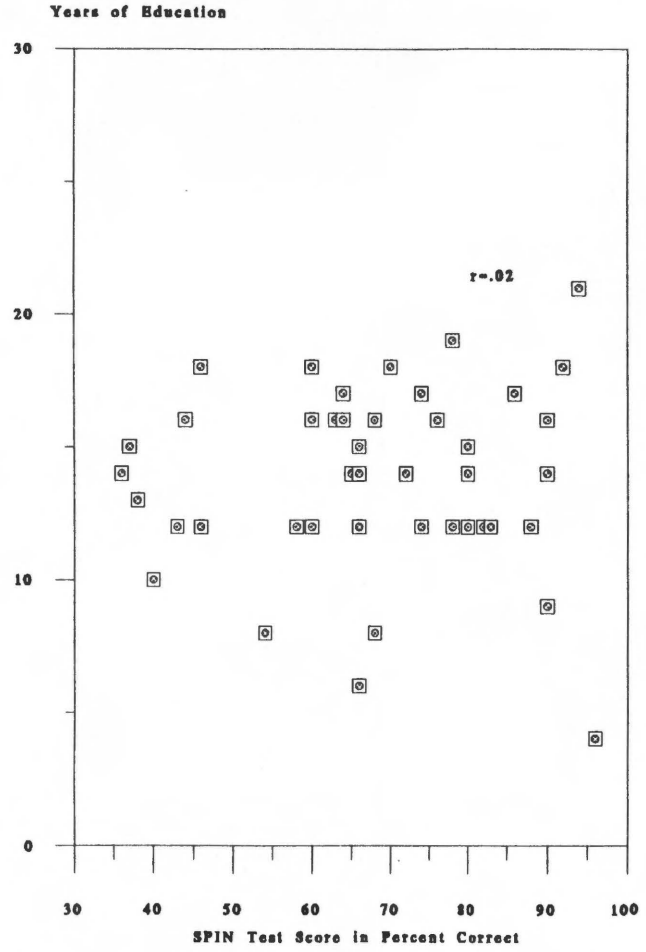


Figure 106. The relationship between Speech Perception in Noise test scores and years of education.

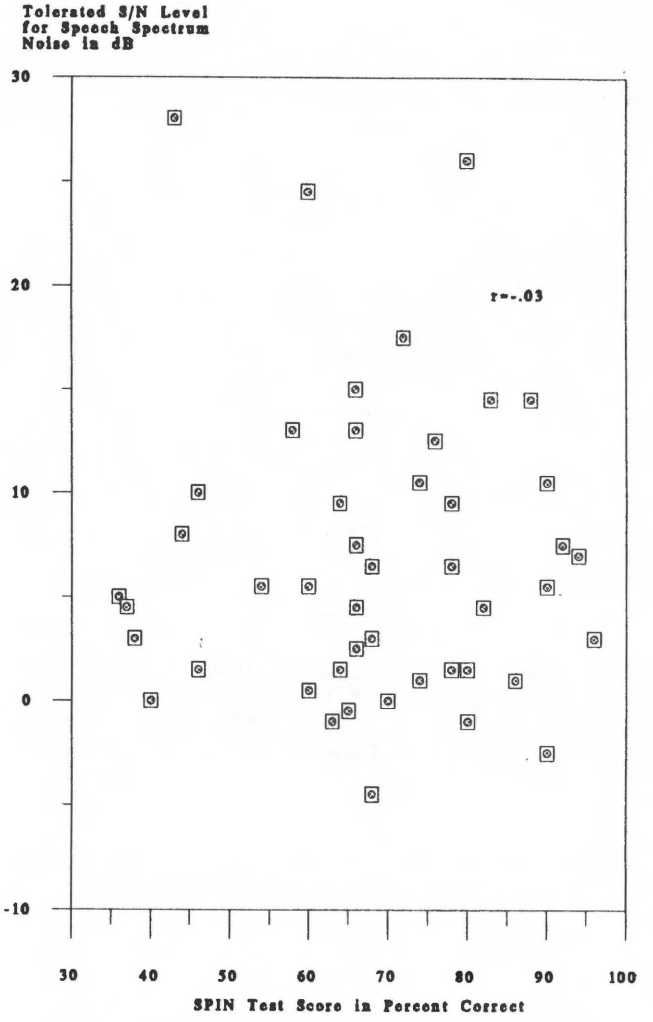


Figure 107. The relationship between Speech Perception in Noise test scores and tolerated signal-to-noise levels for speech spectrum noise.

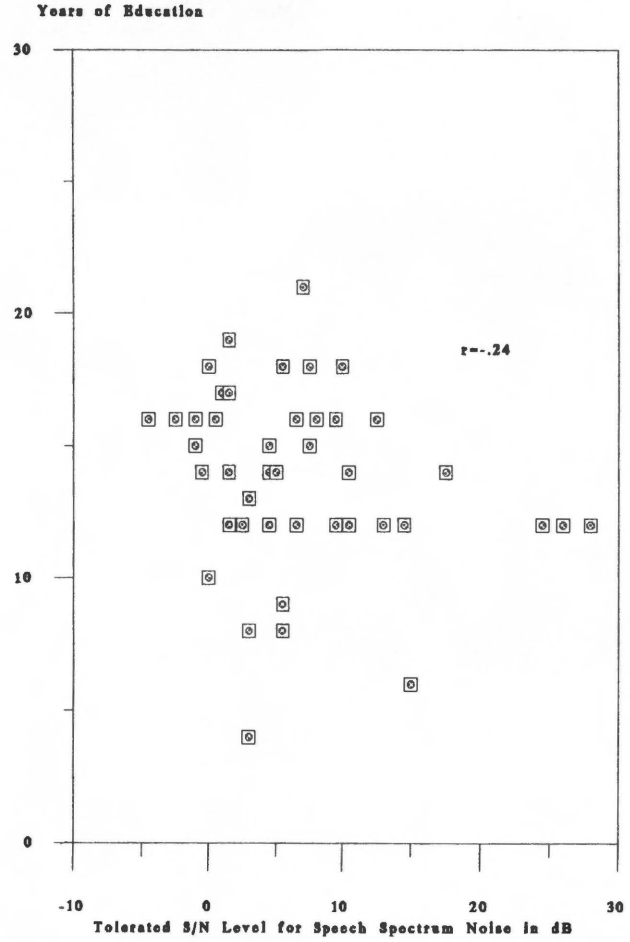


Figure 108. The relationship between tolerated signal-to-noise level for speech spectrum noise and years of education.

APPENDIX H

Graphs of relationships between predictive and response variables appearing together in regression equations

(Figures 109- 183)

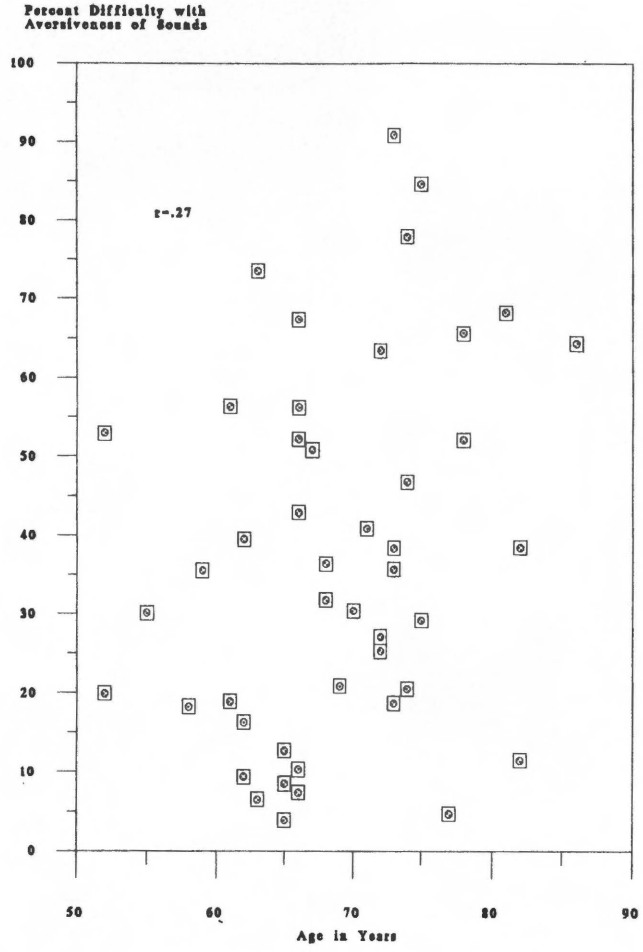


Figure 109. The relationship between age and Aversiveness of Sounds subscale scores from the Profile of Hearing Aid Performance.

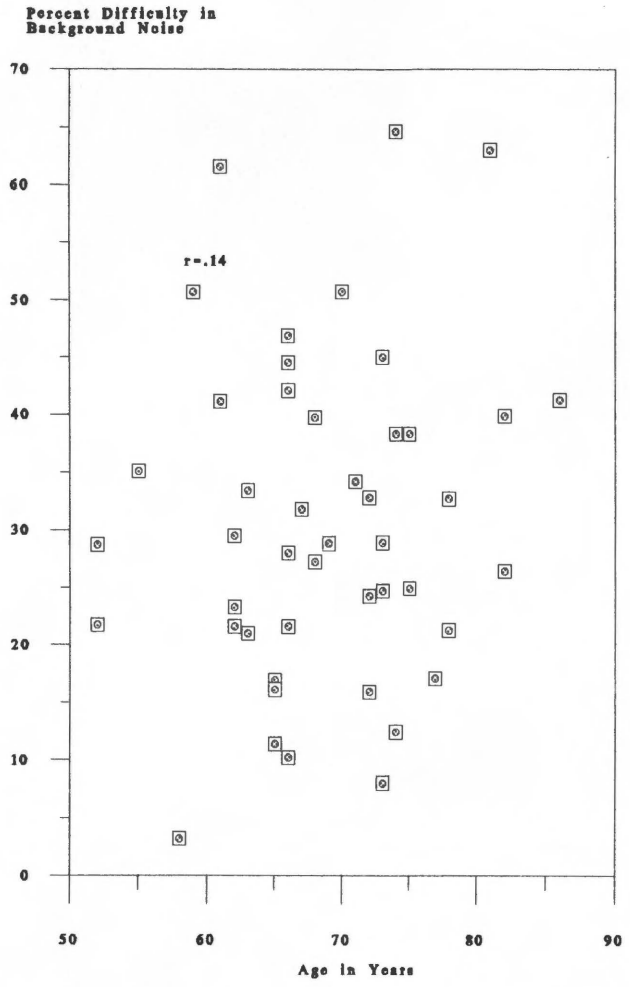


Figure 110. The relationship between age and Background Noise subscale scores of the Profile of Hearing Aid Performance.

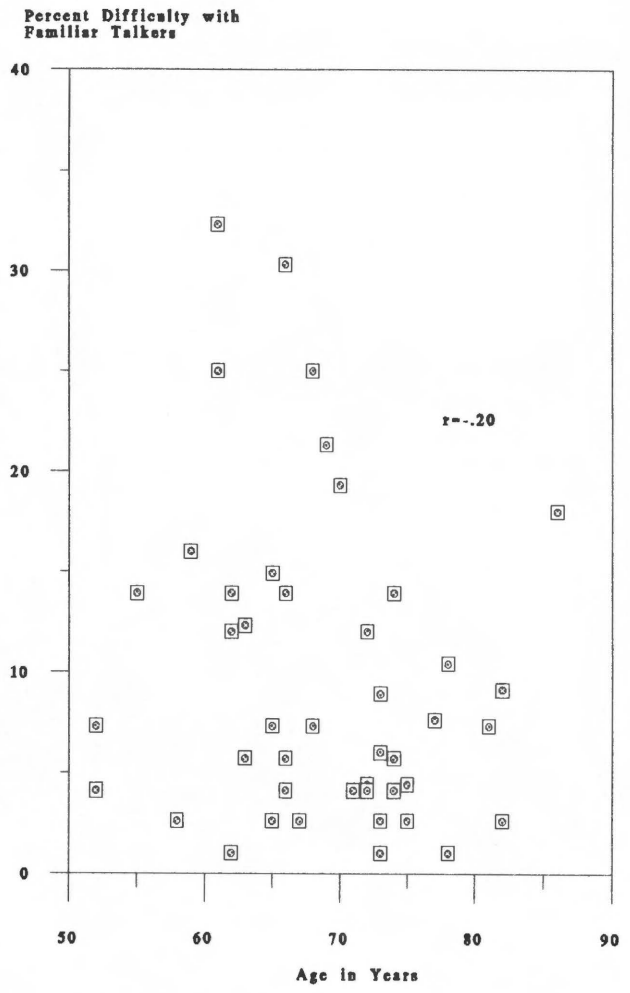


Figure 111. The relationship between age and the Familiar Talker subscale scores of the Profile of Hearing Aid Performance.

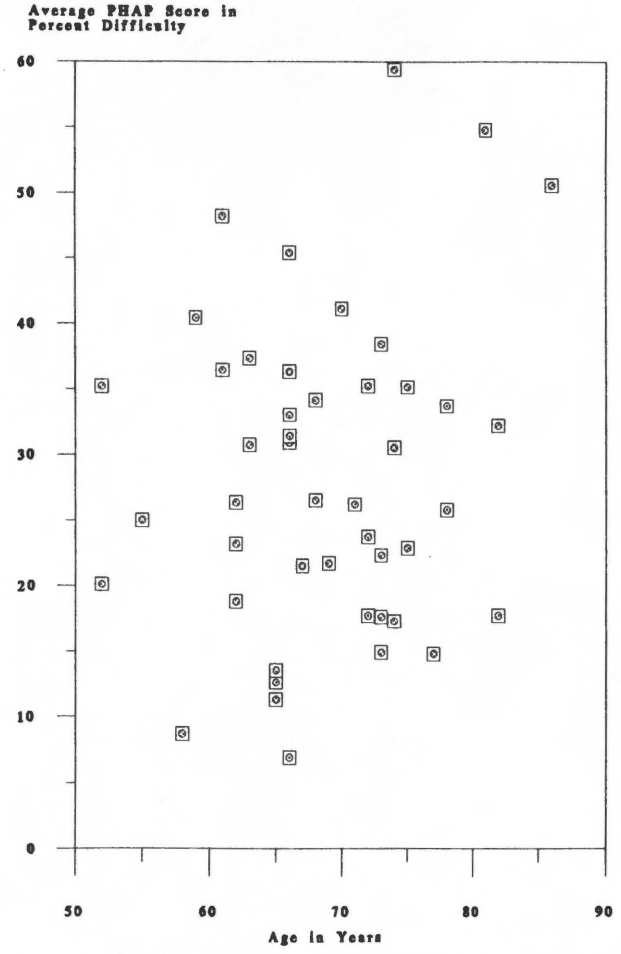


Figure 112. The relationship between age and average scores on the Profile of Hearing Aid Performance.

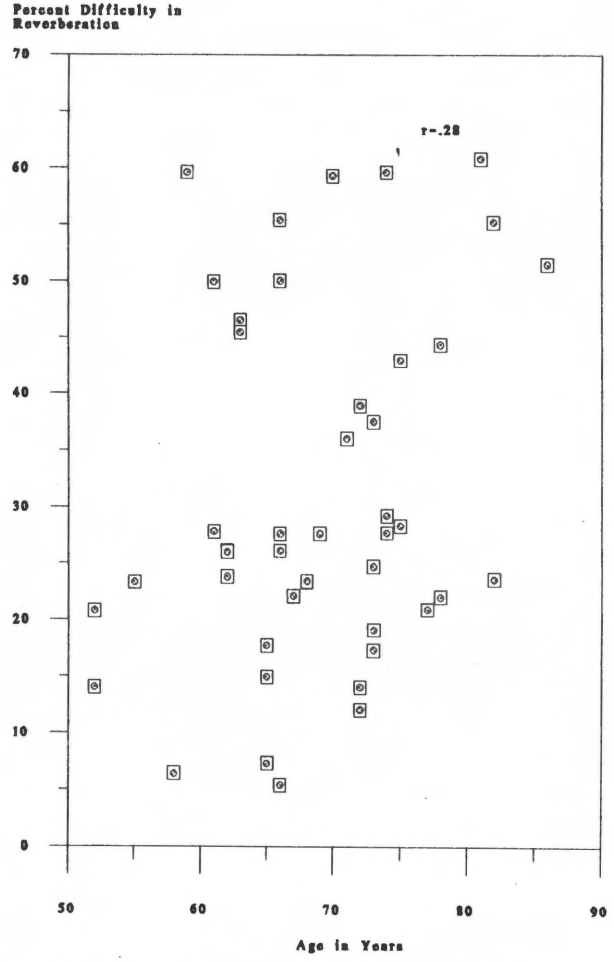


Figure 113. The relationship between age and Reverberation subscale scores of the Profile of Hearing Aid Performance.

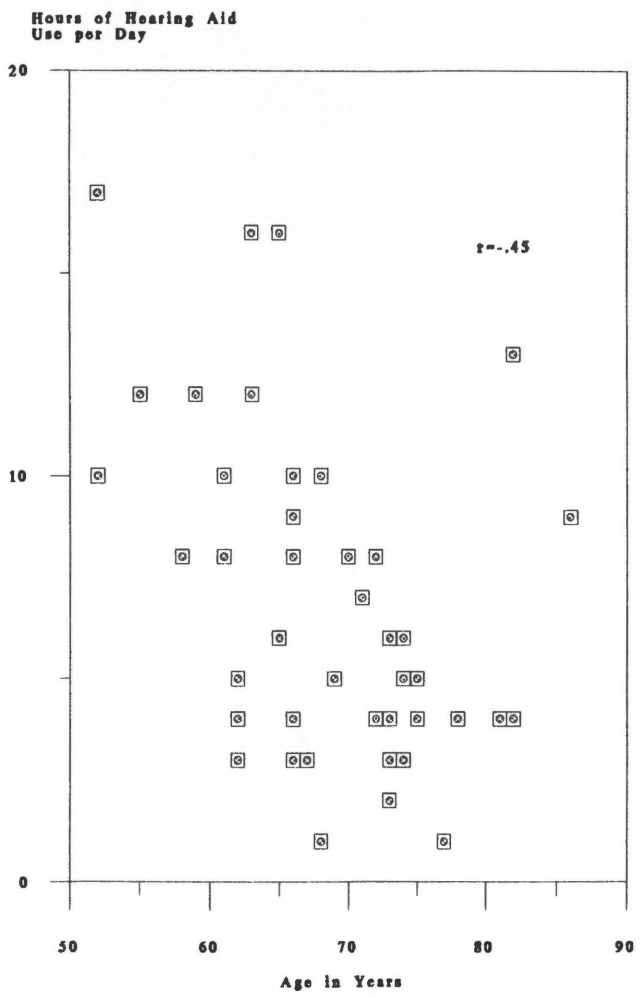


Figure 114. The relationship between age and hours of hearing aid use per day.

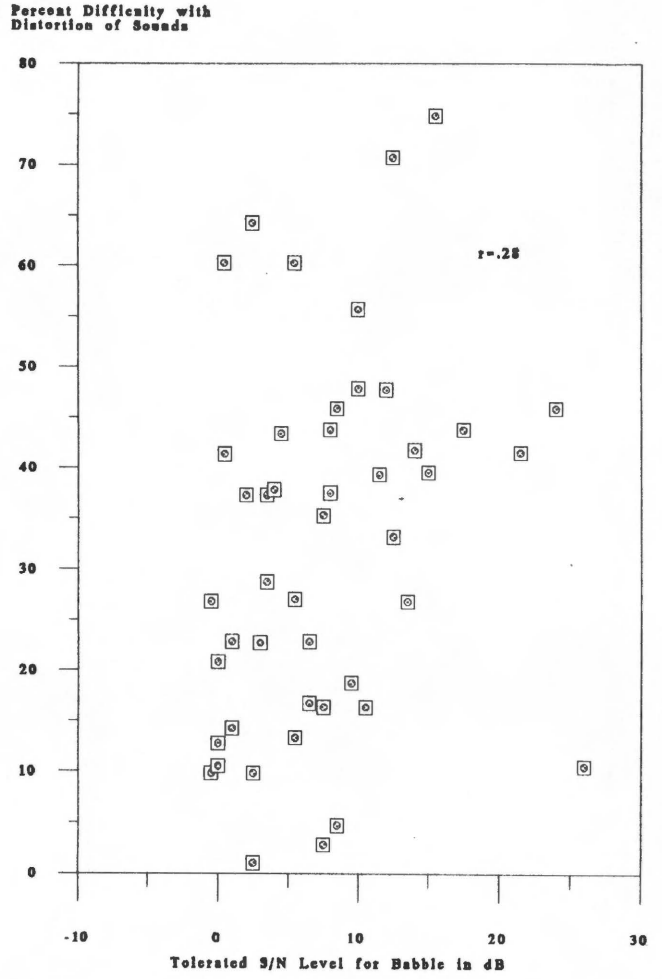


Figure 115. The relationship between tolerated signal-to-noise level for babble and Distortion of Sounds subscale scores from the Profile of Hearing Aid Performance.

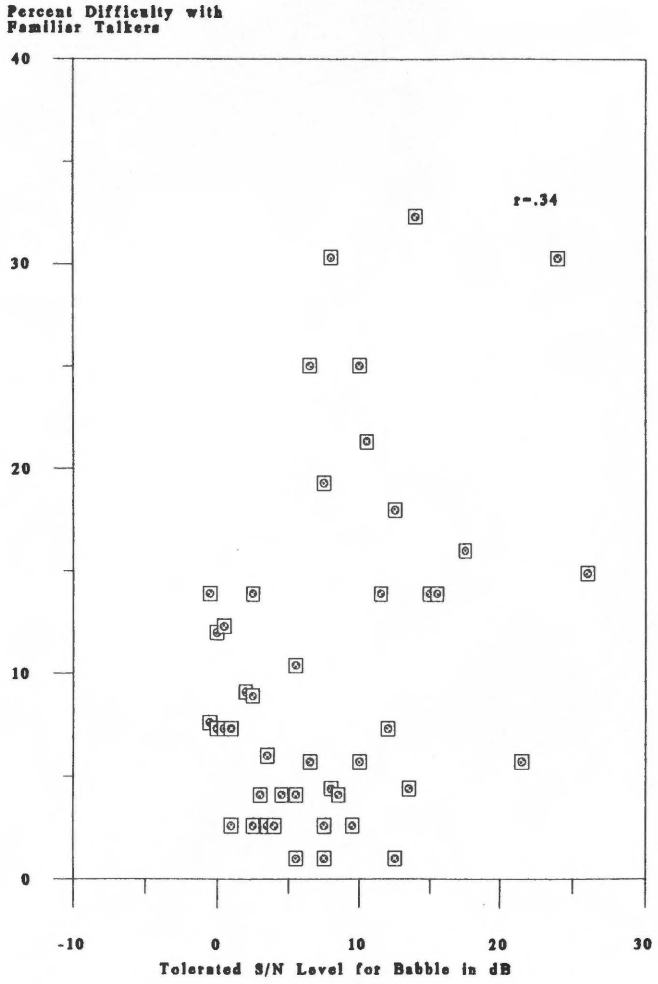


Figure 116. The relationship between tolerated signal-to-noise levels for babble and Familiar Talkers subscale scores from the Profile of Hearing Aid Performance.

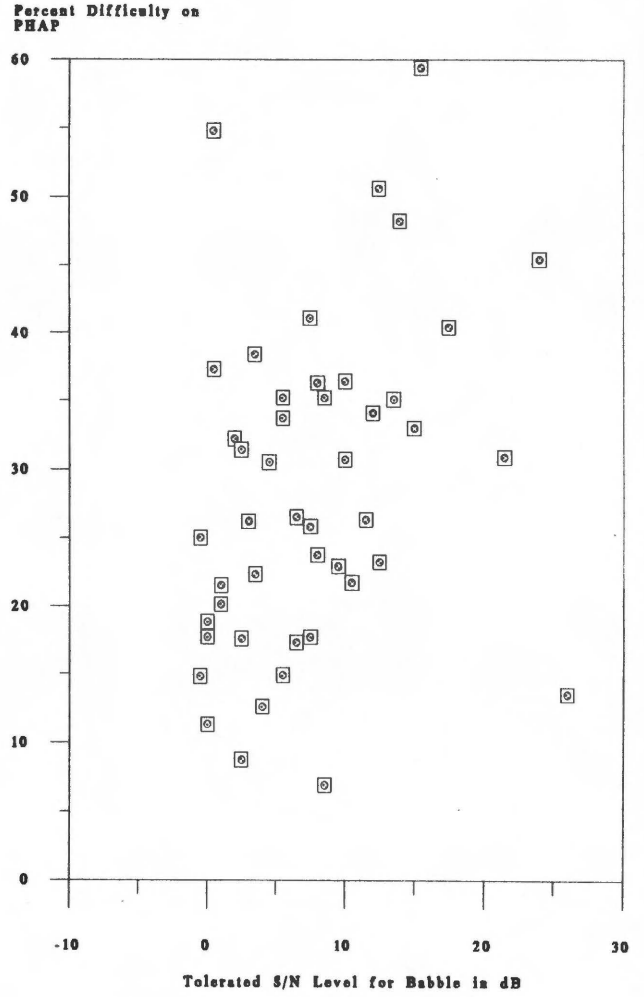


Figure 117. The relationship between tolerated signal-to-noise level for babble and average Profile of Hearing Aid Performance scores.

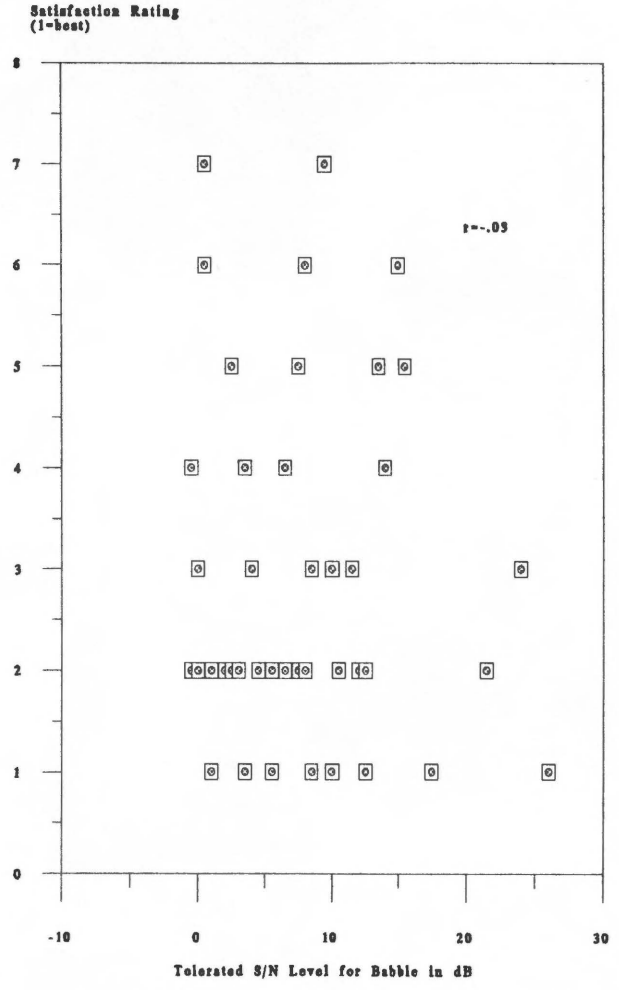


Figure 118. The relationship between tolerated signal-to-noise level for babble and hearing aid satisfaction ratings.

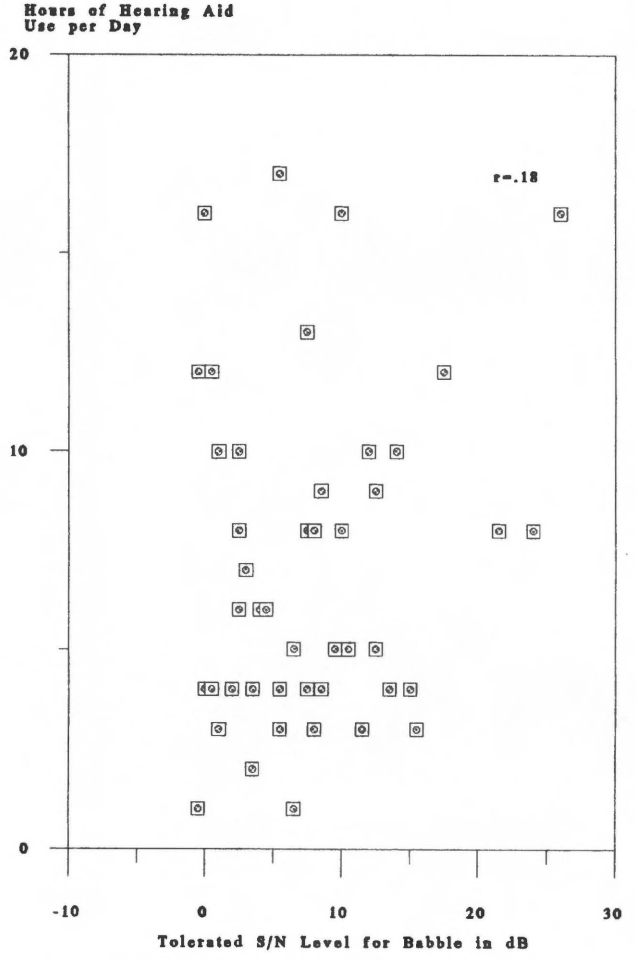


Figure 119. The relationship between tolerated signal-to-noise level for babble and hours of hearing aid use.

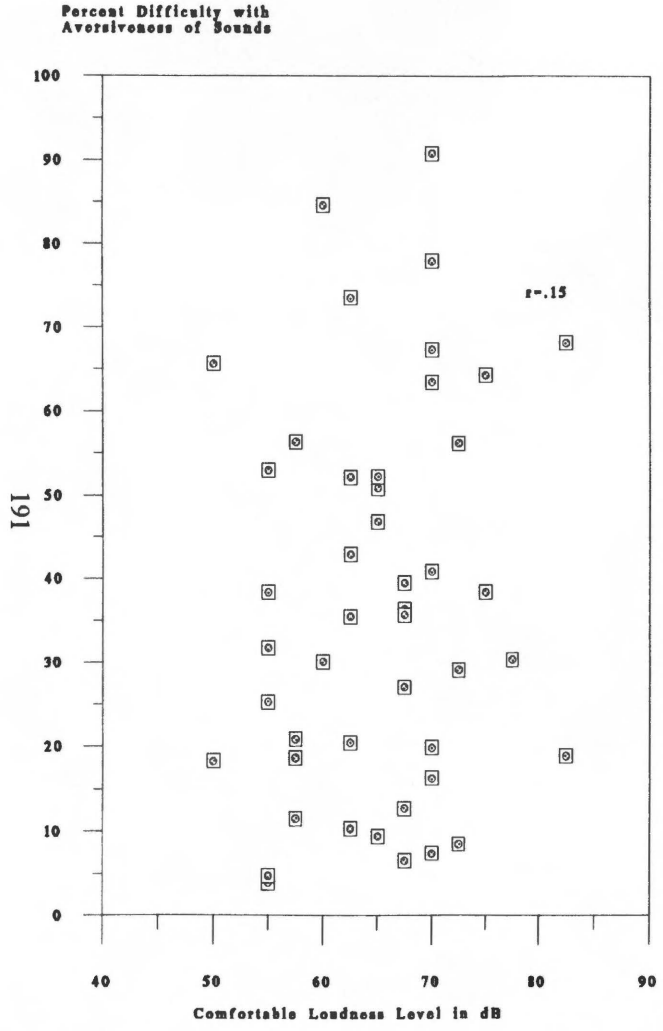


Figure 120. The relationship between comfortable loudnes level and the Aversiveness of Sounds subscale scores of the Profile of Hearing Aid Performance.

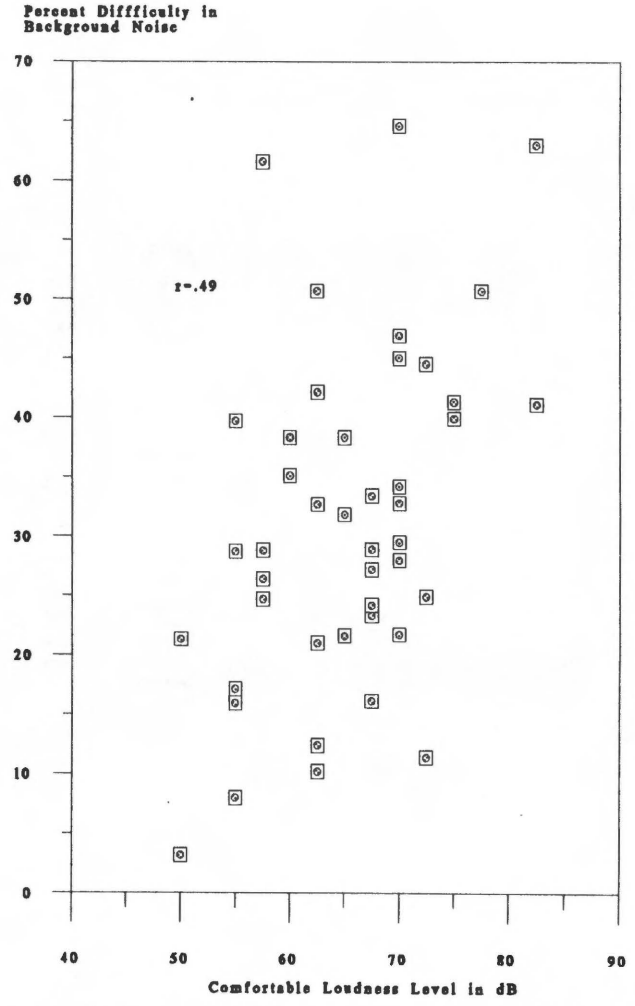


Figure 121. The relationship between comfortable loudness level and Background Noise subscale score of the Profile of Hearing Aid Performance.

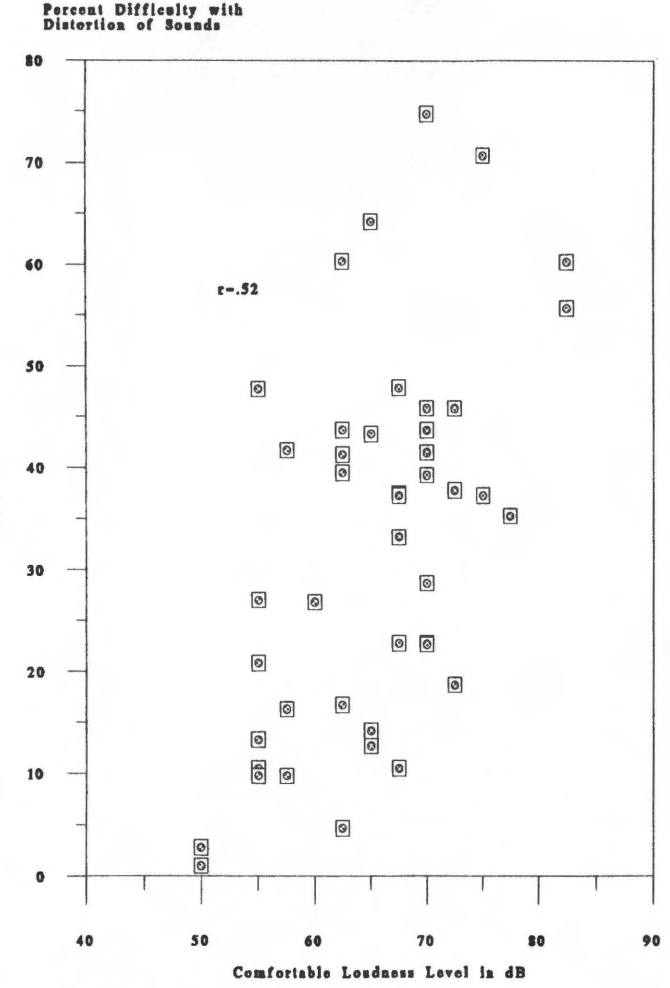


Figure 122. The relationship between comfortable loudness level and Distortion of Sounds subscale scores from the Profile of Hearing Aid Performance.

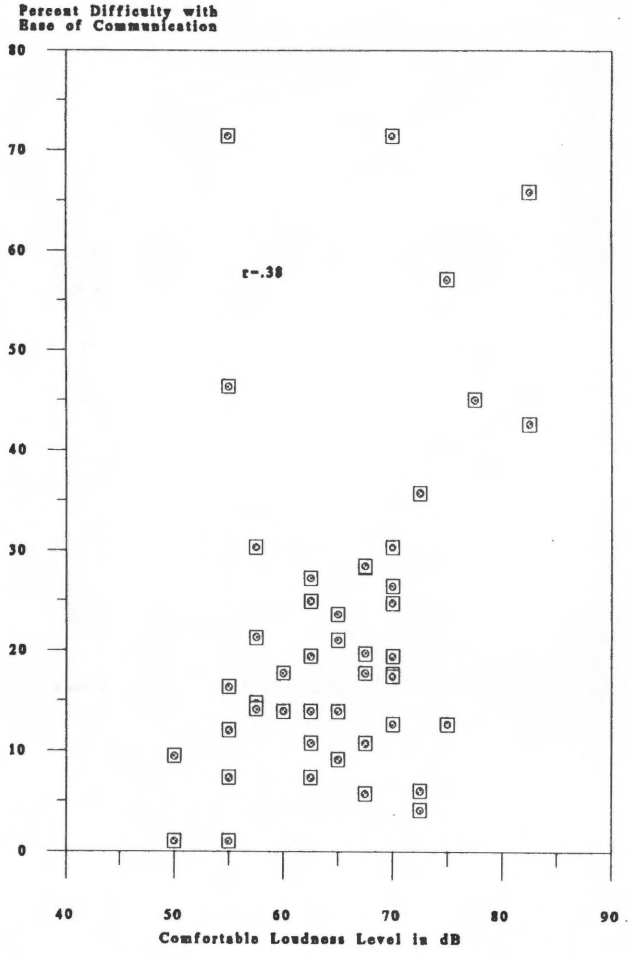


Figure 123. The relationship between comfortable loudness level and Ease of Communication subscale scores from the Profile of Hearing Aid Performance.

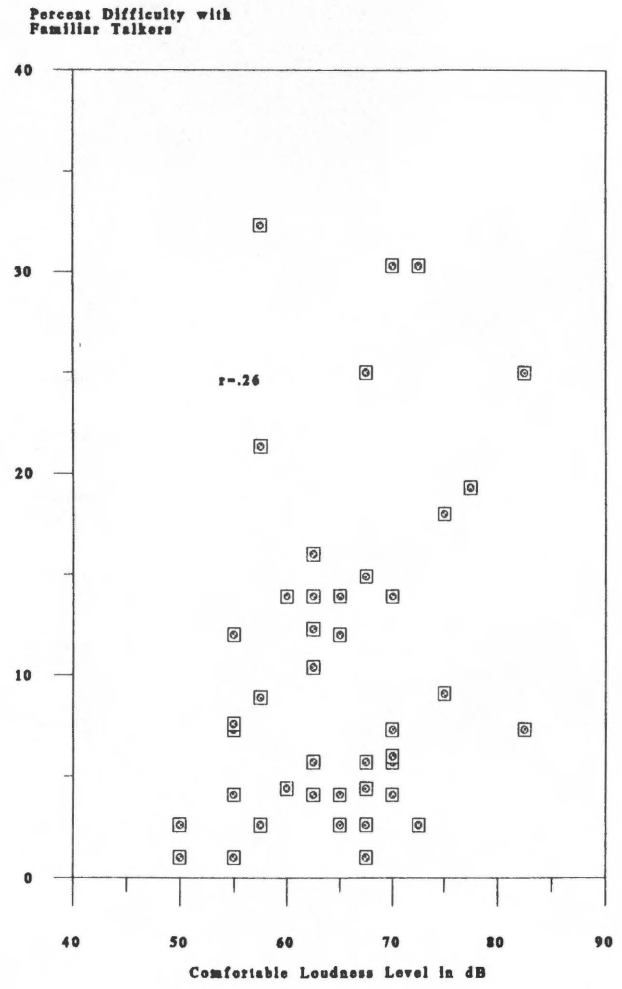


Figure 124. The relationship between comfortable loudness level and the Familiar Talkers subscale scores from the Profile of Hearing Aid Performance.

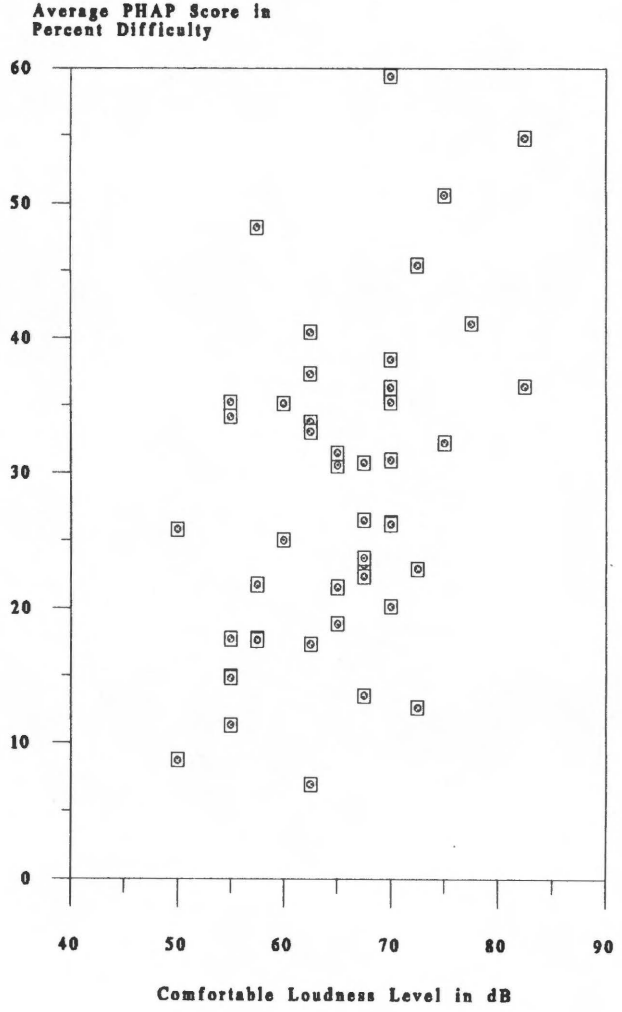


Figure 125. The relationship between comfortable loudness level and average Profile of Hearing Aid Performance scores.

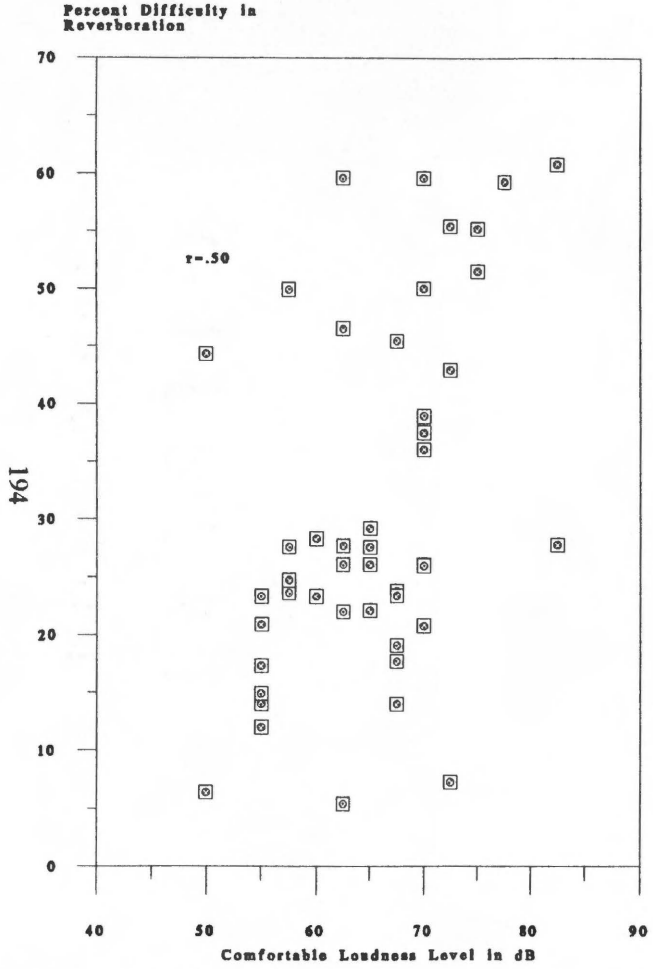


Figure 126. The relationship between comfortable loudness level and Reverberation subscale scores of the Profile of Hearing Aid Performance.

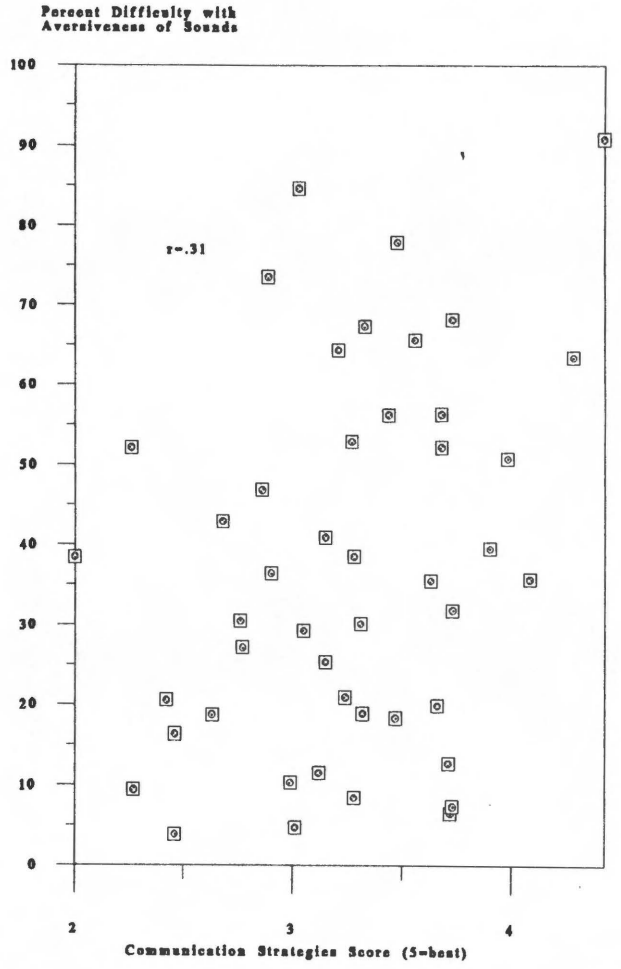


Figure 127. The relationship between Communication Strategies scores of the Communication Profile for the Hearing Impaired and Aversiveness of Sounds subscale scores of the PHAP.

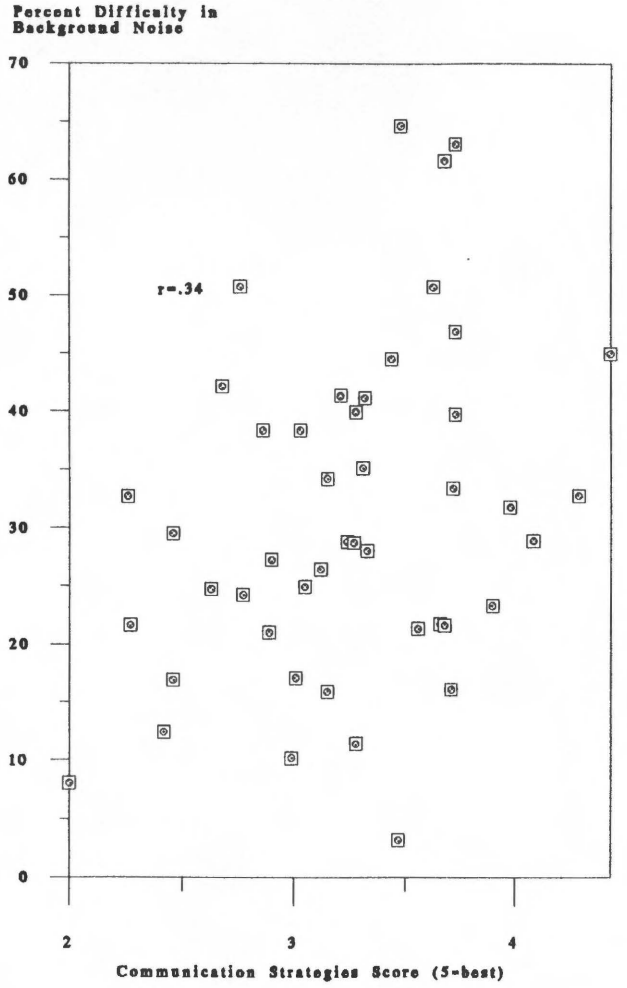


Figure 128. The relationship between Communication Strategies scores and the Background Noise subscale of the PHAP.

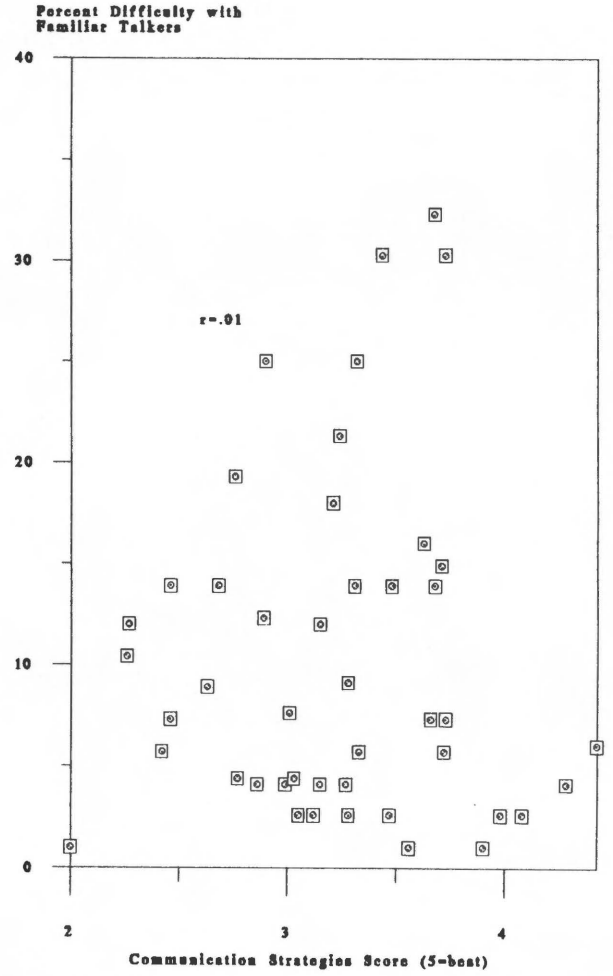


Figure 129. The relationship between Communication Strategies scores from the Communication Profile for the Hearing Impaired and Familiar Talkers subscale scores from the PHAP.

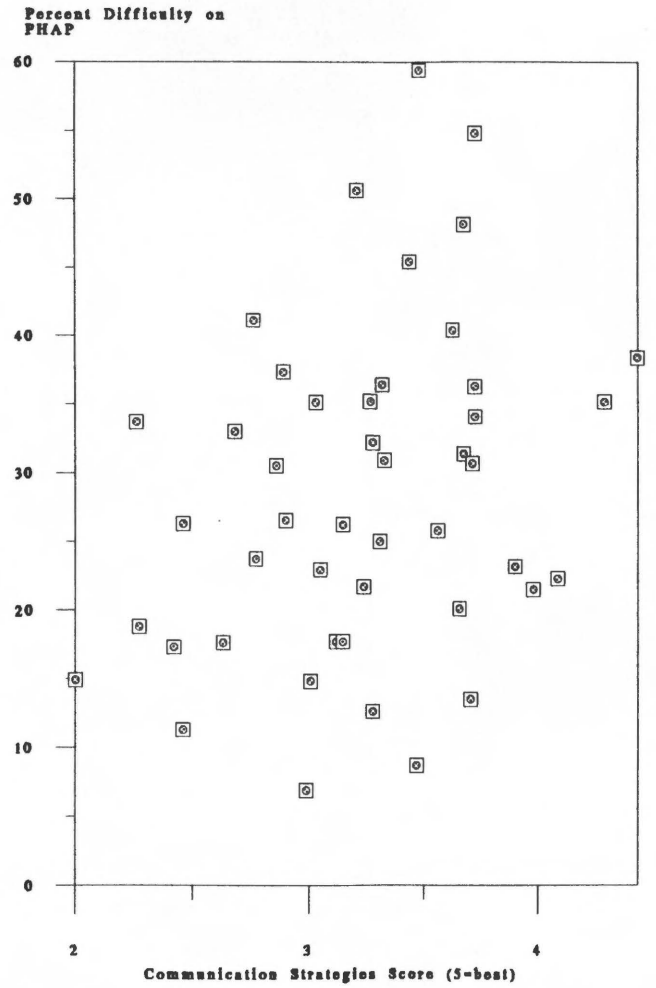


Figure 130. The relationship between Communication Strategies scores from the CPHI and average Profile of Hearing Aid Performance scores.

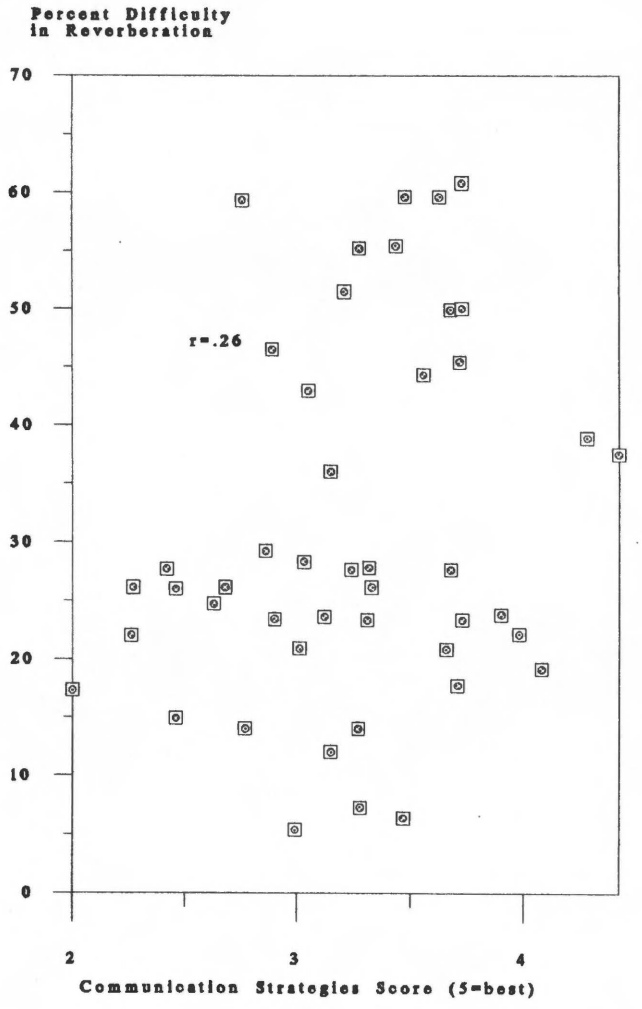


Figure 131. The relationship between Communication Strategies scores from the CPHI and Reverberation subscale scores from the PHAP.

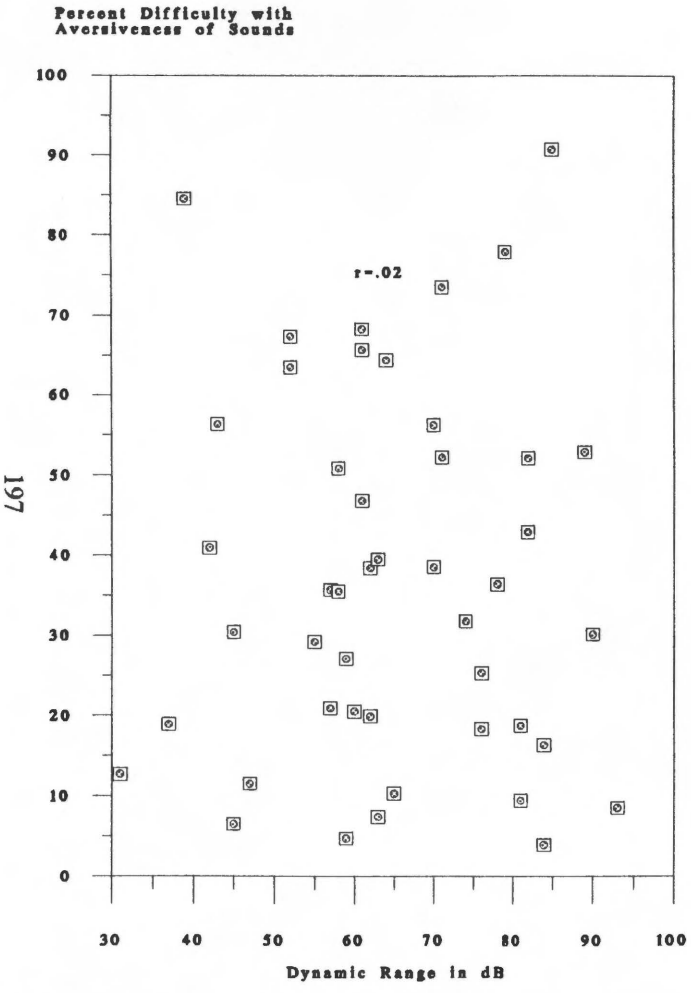


Figure 132. The relationship between dynamic range and Aversiveness of Sounds subscale scores of the Profile of Hearing Aid Performance.

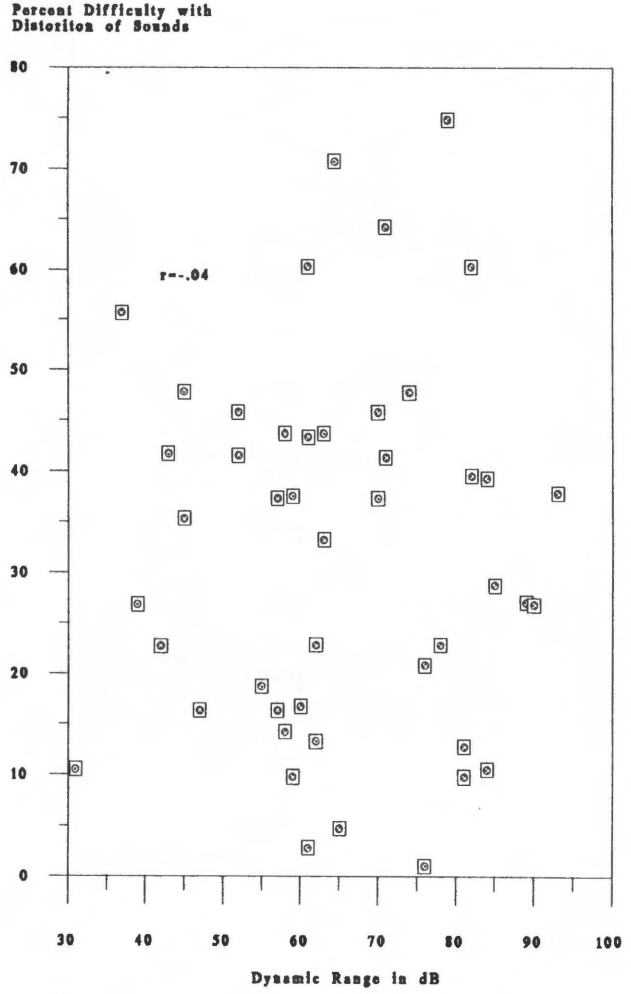


Figure 133. The relationship between dynamic range and Distortion of Sounds subscale scores from the Profile of Hearing Aid Performance.

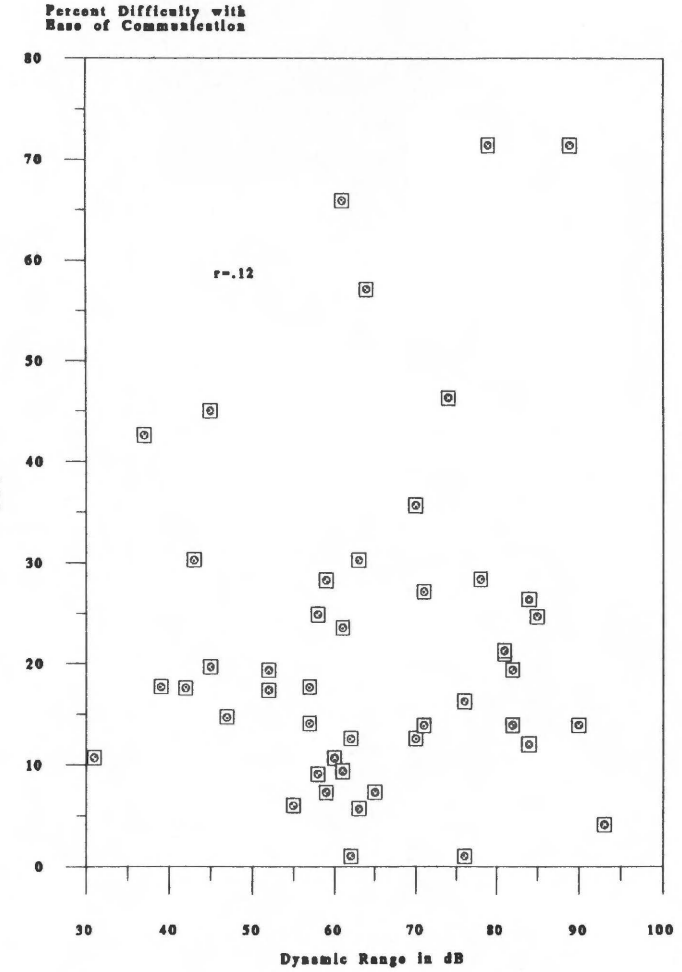


Figure 134. The relationship between dynamic range and Ease of Communication subscale scores from the Profile of Hearing Aid Performance.

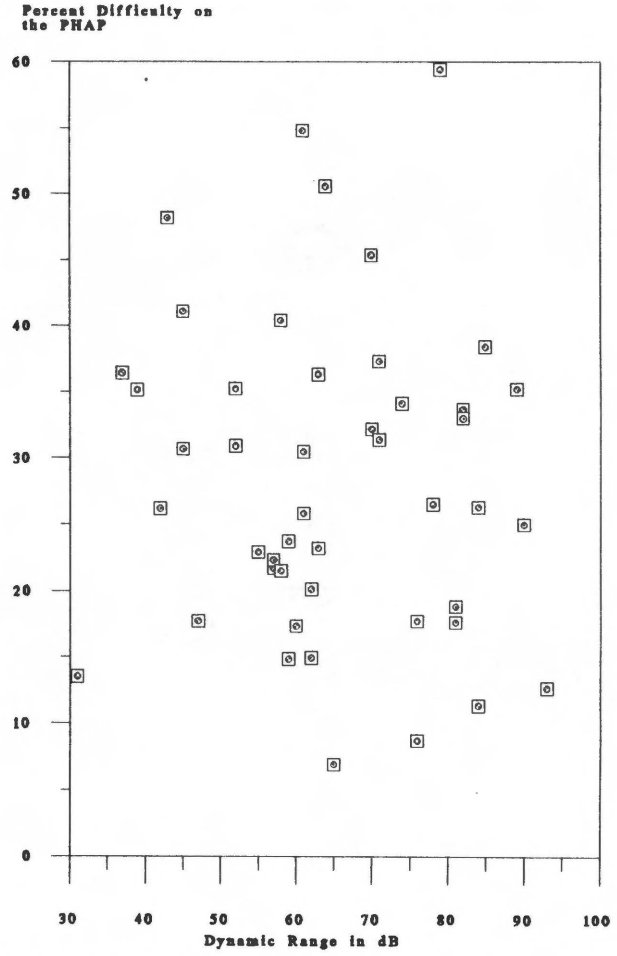


Figure 135. The relationship between dynamic range and average Profile of Hearing Aid Performance scores.

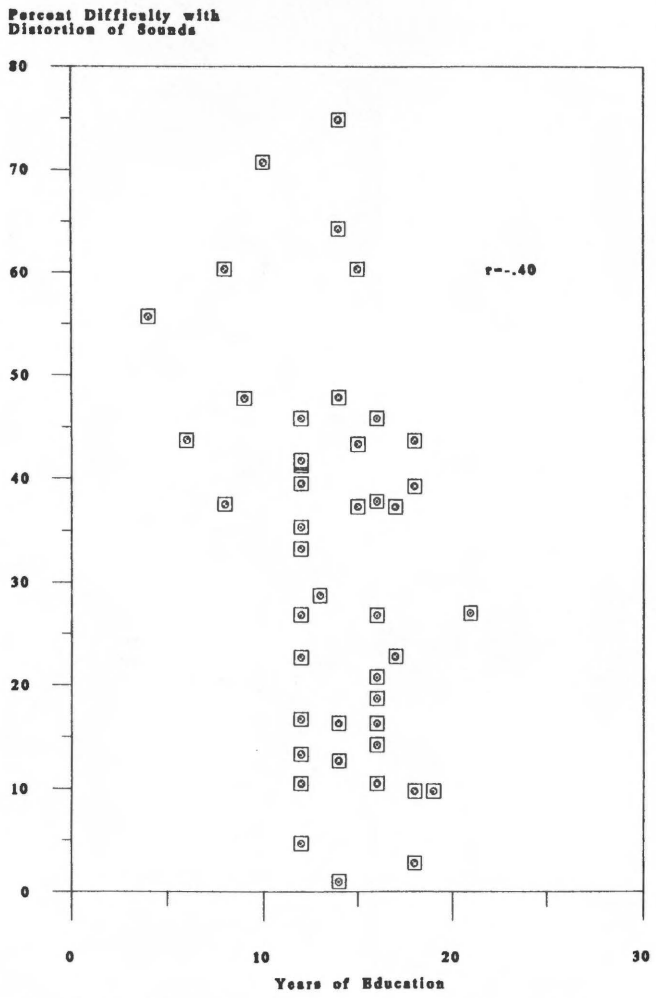


Figure 136. The relationship between years of education and Distortion of Sounds subscale scores from the PHAP.

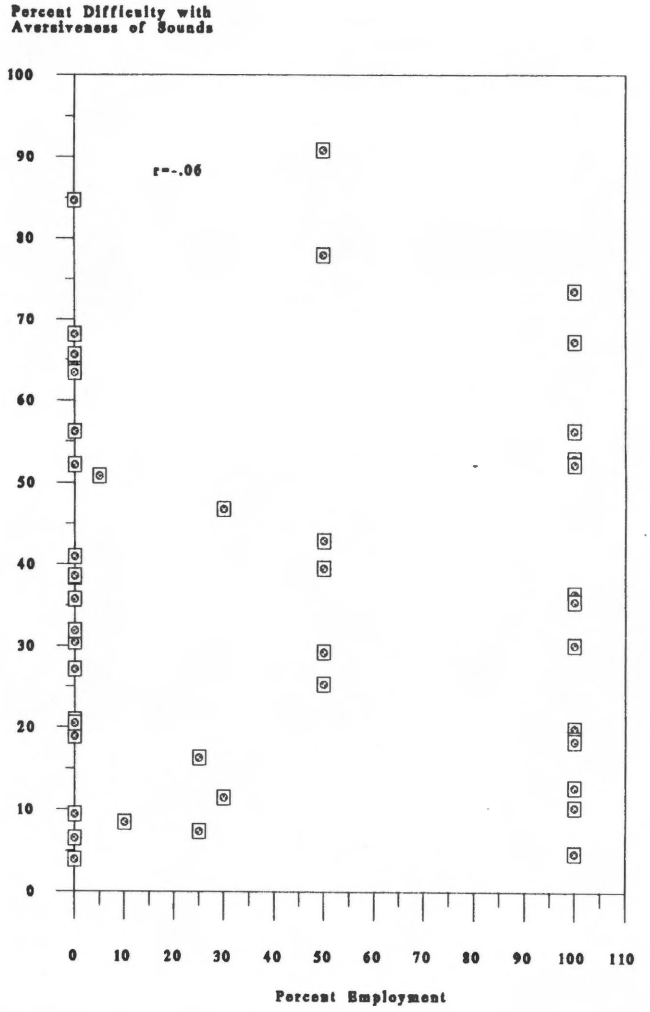


Figure 137. The relationship between employment and Aversiveness of Sounds Subscale scores from the PHAP.

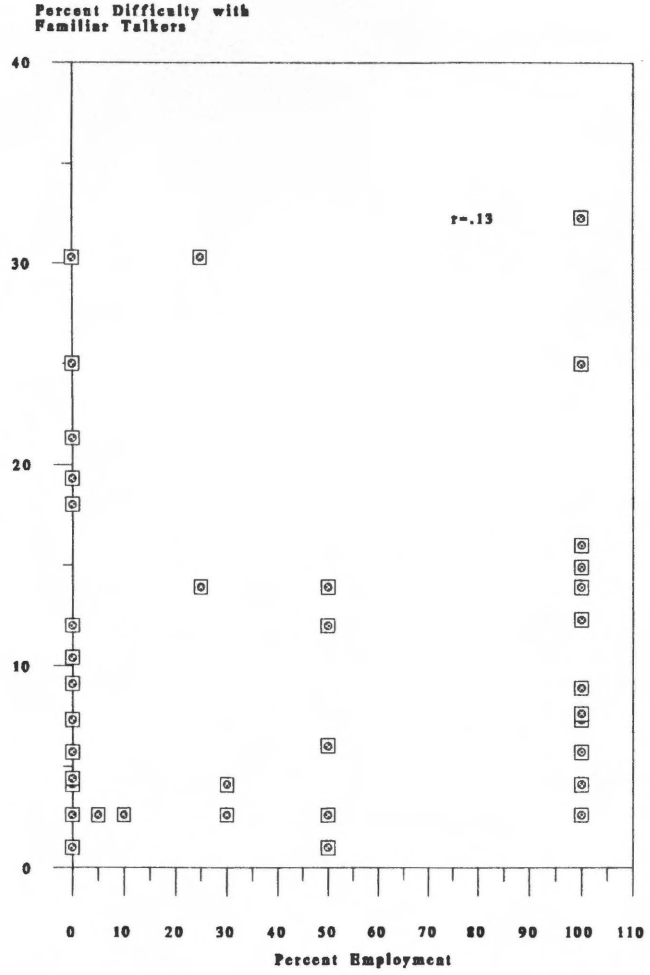


Figure 138. The relationship between employment and Familiar Talkers subscale scores from the PHAP.

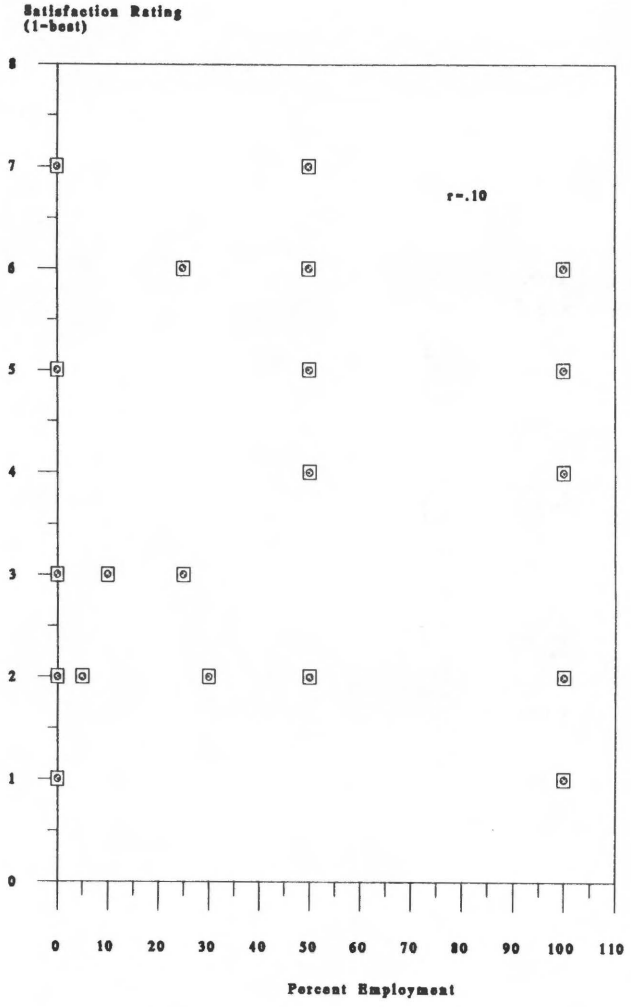


Figure 139. The relationship between employment and satisfaction rating.

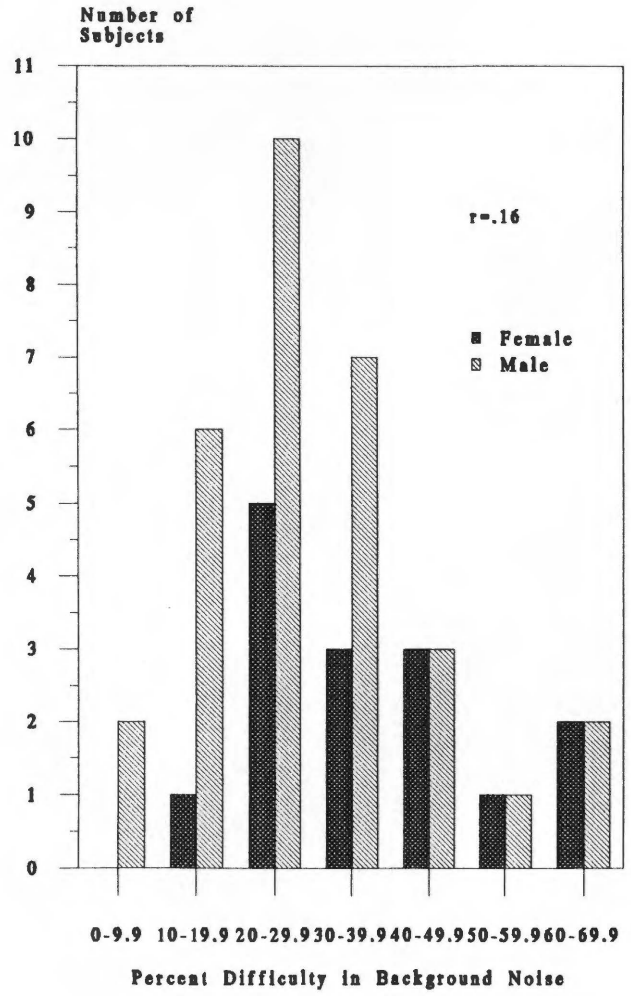


Figure 140. Background noise subscale scores from the PHAP for male and female subjects.

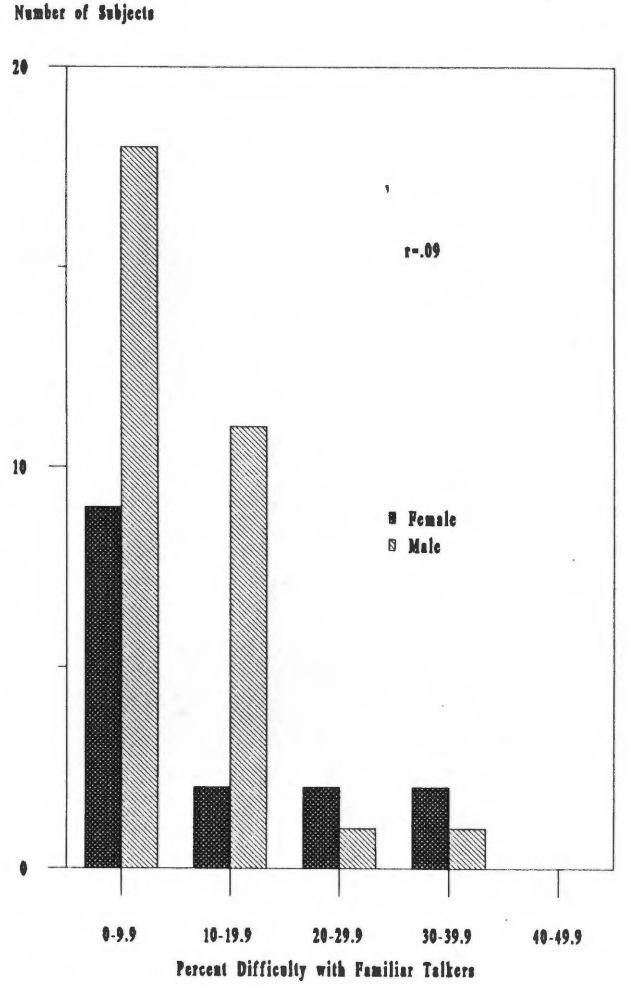


Figure 141. Familiar Talkers subscale scores from the PHAP for male and female subjects.

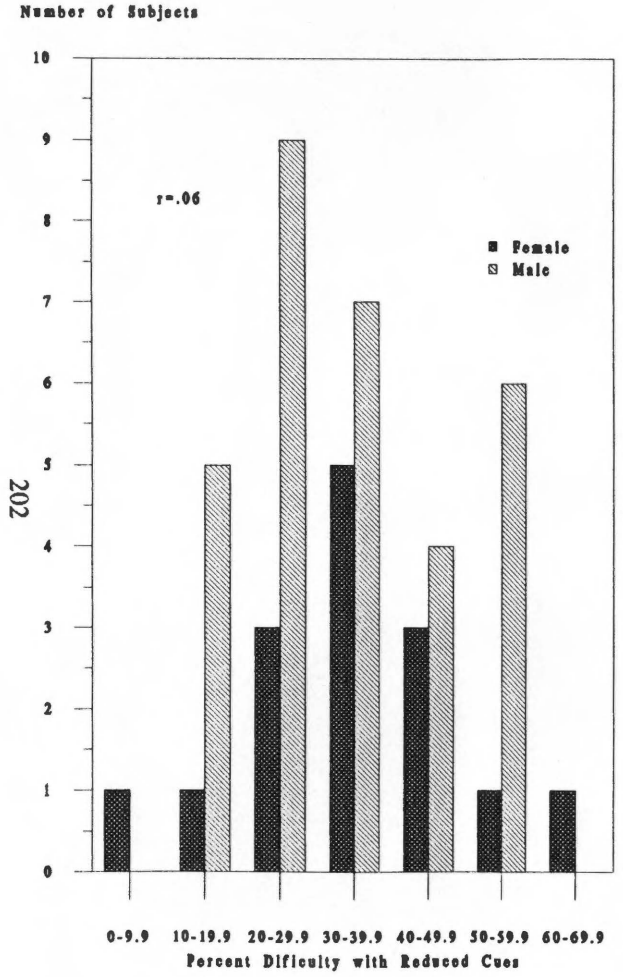


Figure 142. Reduced Cues subscale scores from the PHAP for male and female subjects.

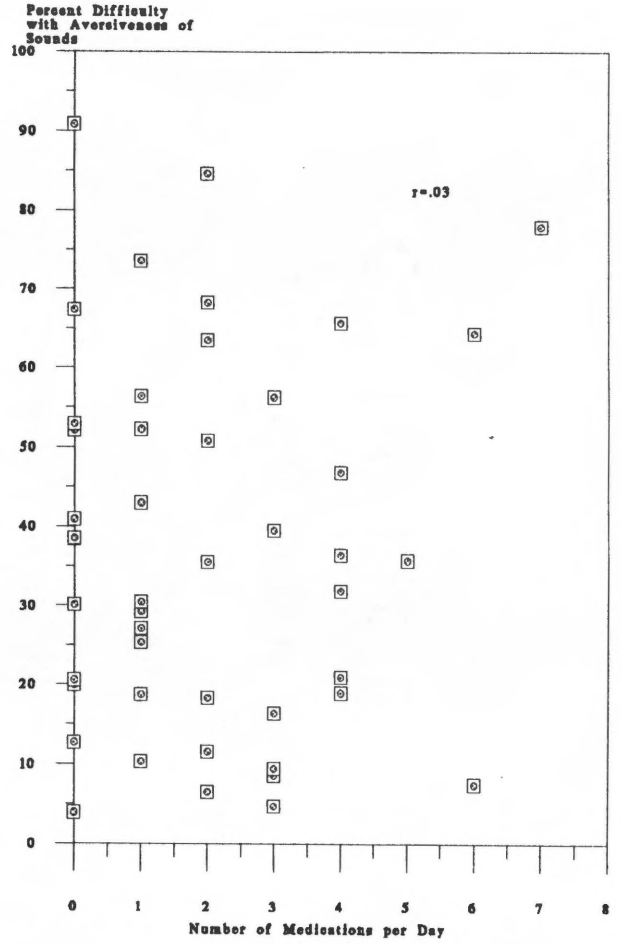


Figure 143. The relationship between number of medications taken per day and Aversiveness of Sounds subscale scores from the PHAP.

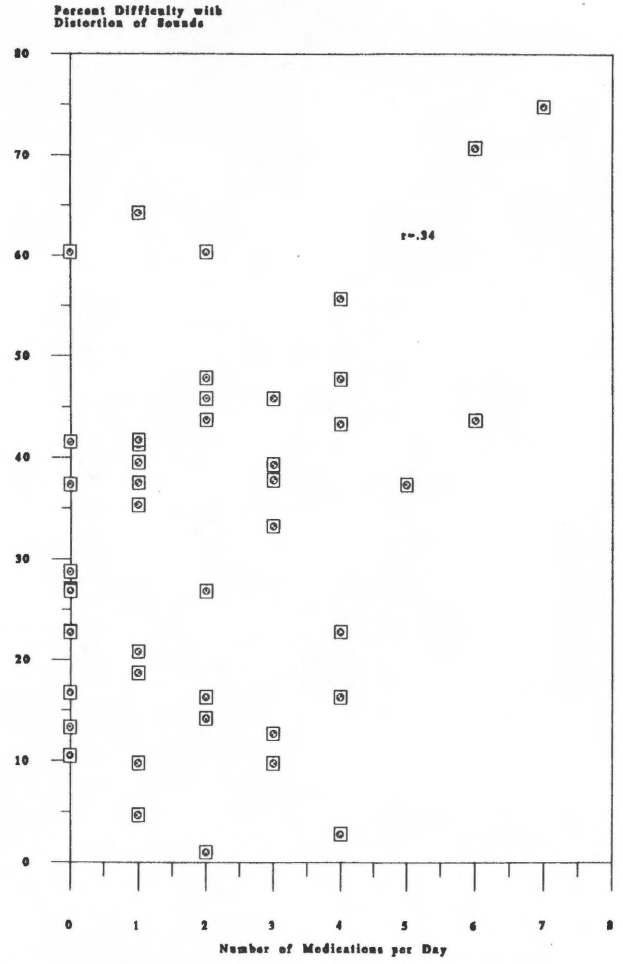


Figure 144. The relationship between number of medications taken per day and Distortion of Sounds subscale scores from the PHAP.

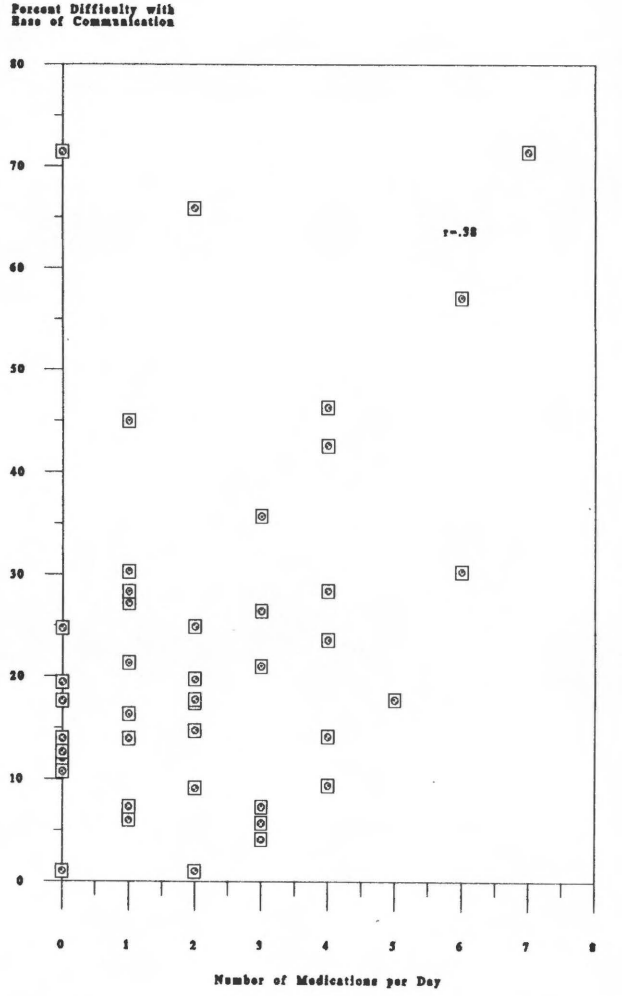


Figure 145. The relationship between number of medications taken per day and Ease of Communication subscale scores from the PHAP.

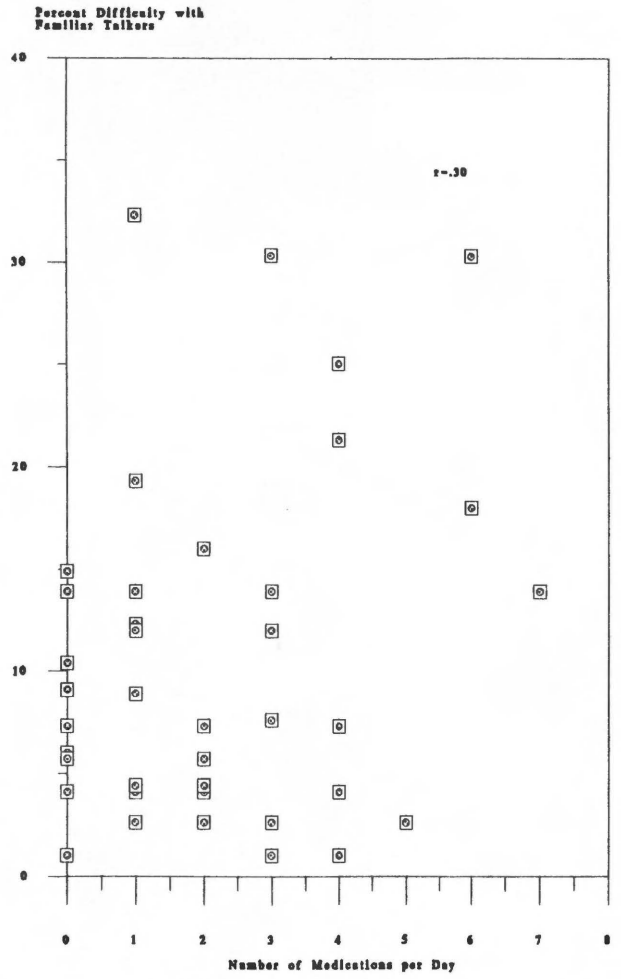


Figure 146. The relationship between number of medications taken per day and Familiar Talkers subscale scores from the PHAP.

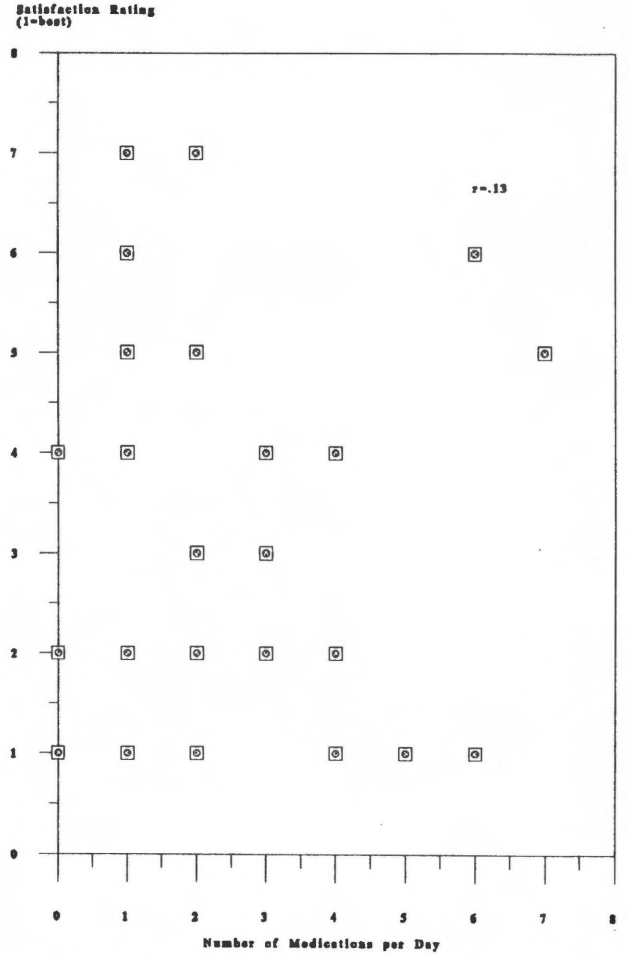


Figure 147. The relationship between number of medications taken per day and satisfaction ratings.

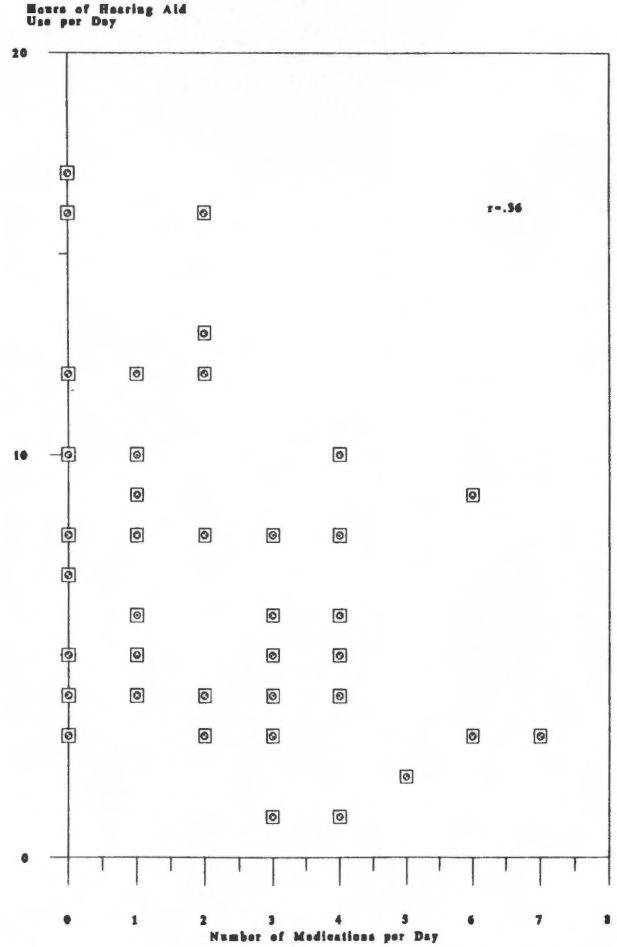


Figure 148. The relationship between number of medications per day and hours of hearing aid use.

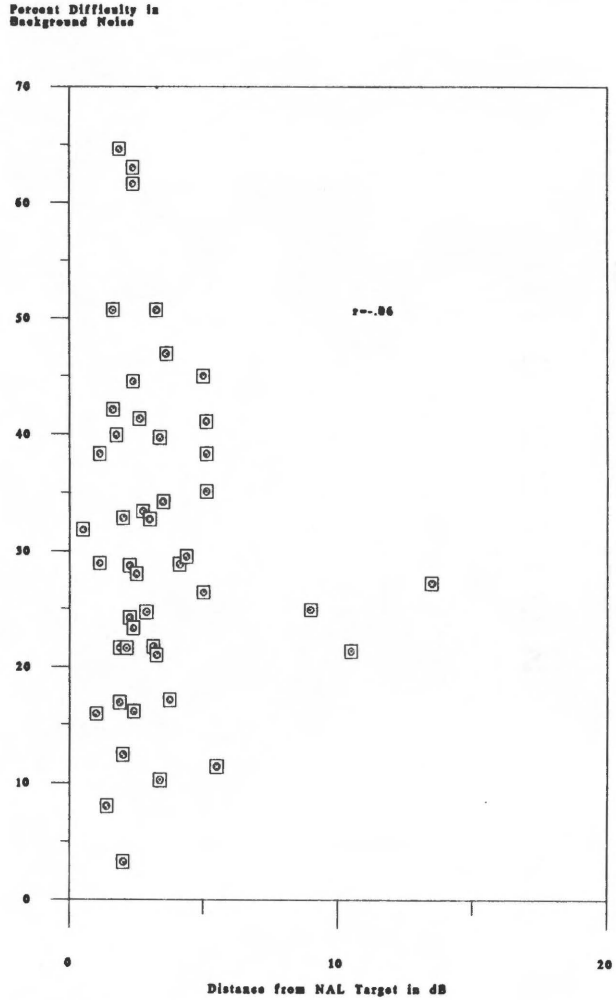


Figure 149. The relationship between distance from NAL target gain and Background Noise subscale scores from the PHAP.

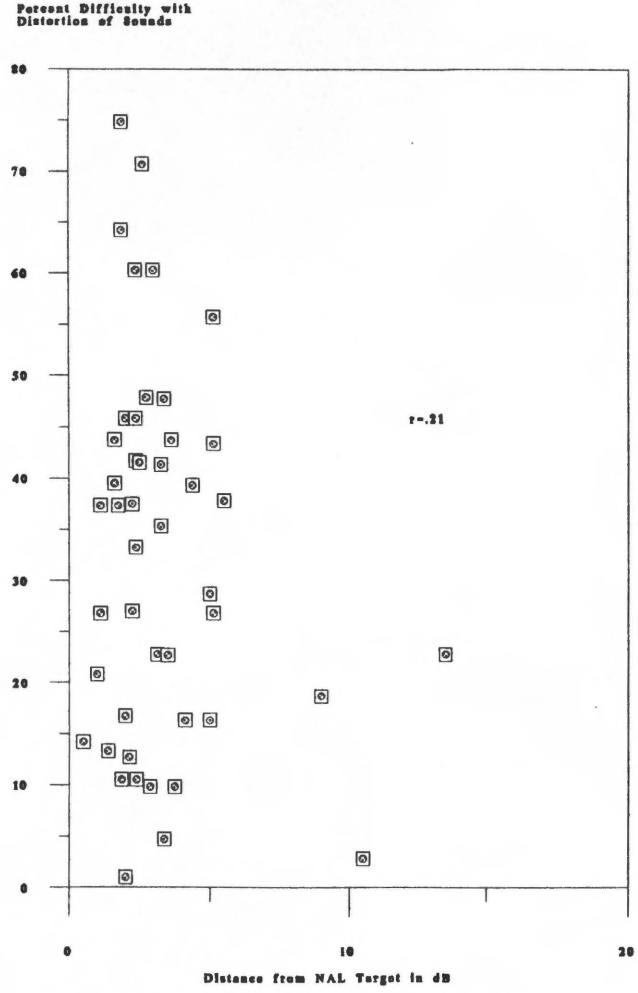


Figure 150. The relationship between distance from NAL target gain and Distortion of Sounds subscale scores from the PHAP.

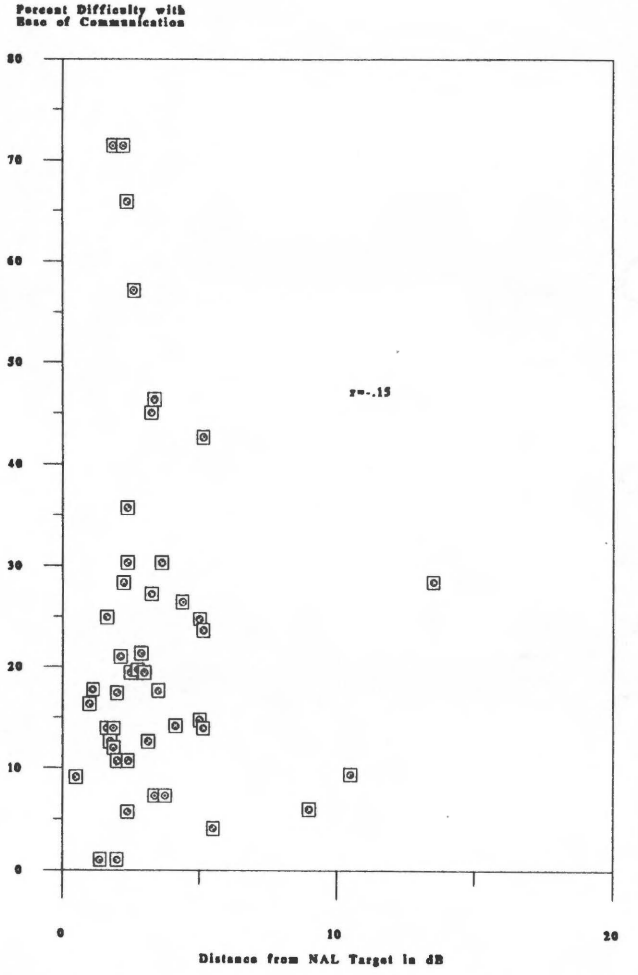


Figure 151. The relationship between distance from NAL target gain and Ease of Communication subscale scores from the PHAP.

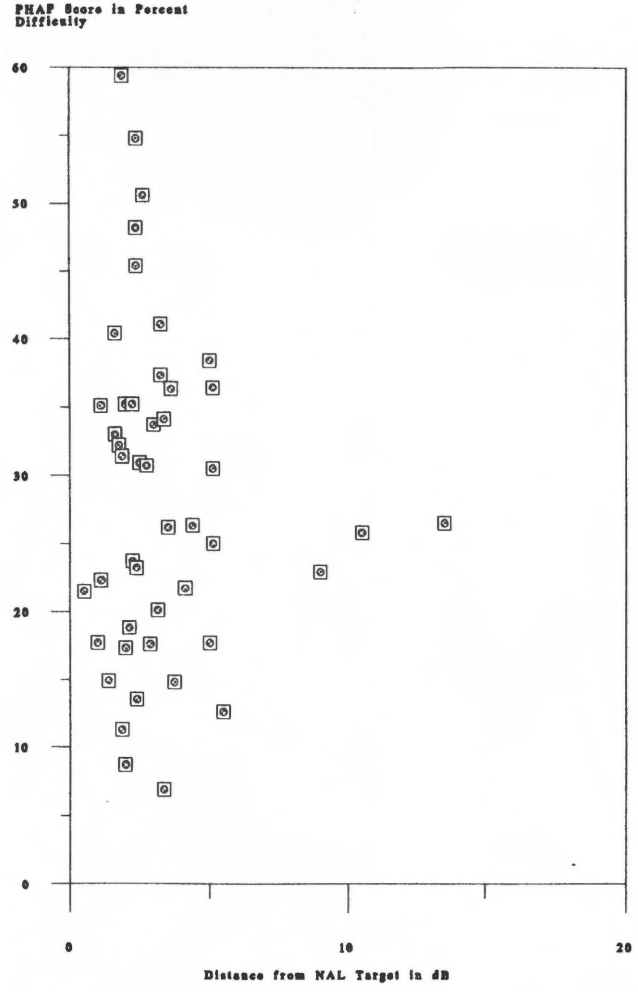


Figure 152. The relationship between distance from NAL target gain and average PHAP scores.

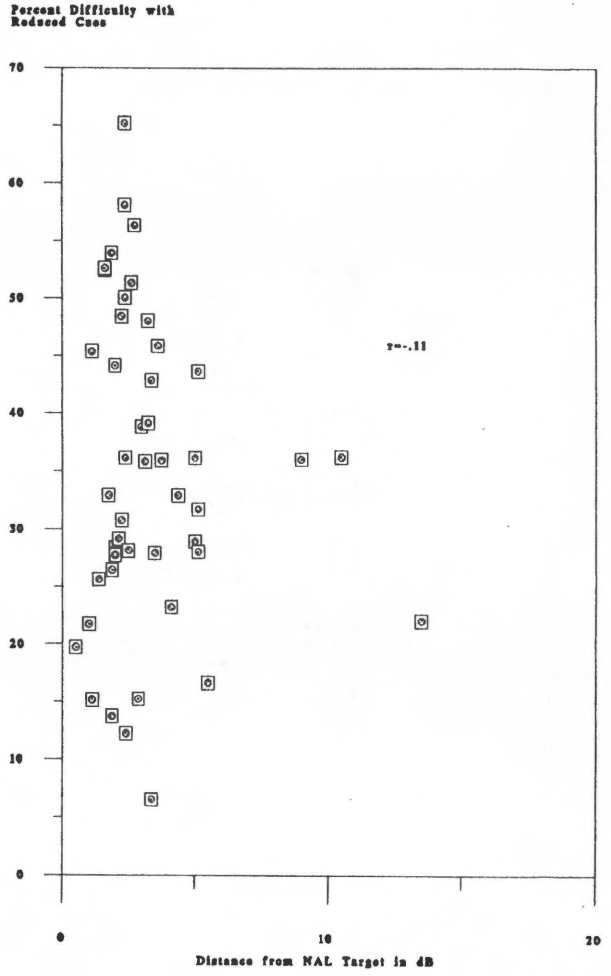


Figure 153. The relationship between distance from NAL target gain and Reduced Cues subscale scores from the PHAP.

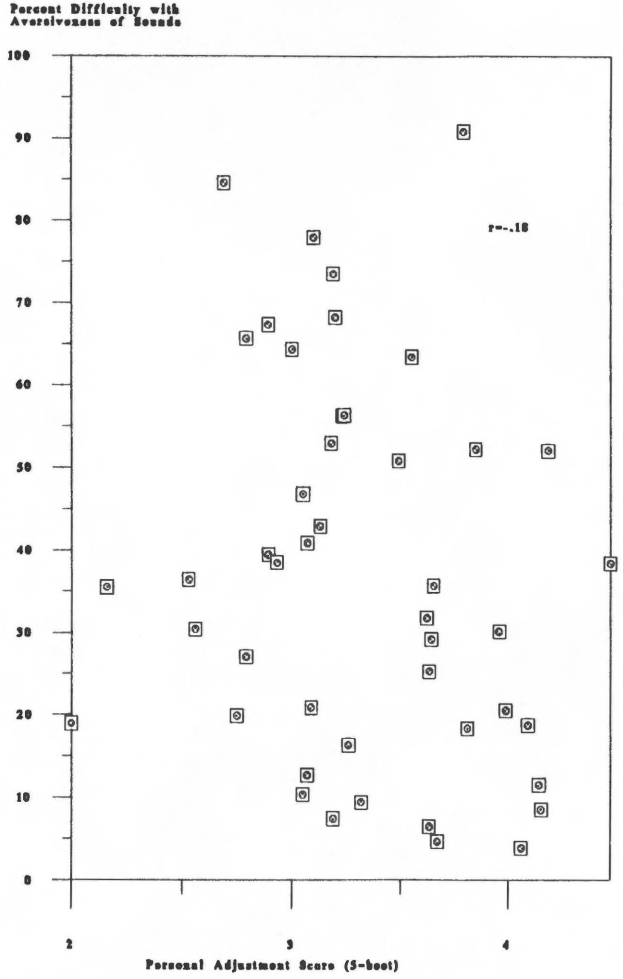


Figure 154. The relationship between Personal Adjustment scores and Aversiveness of Sounds subscale scores from the PHAP.

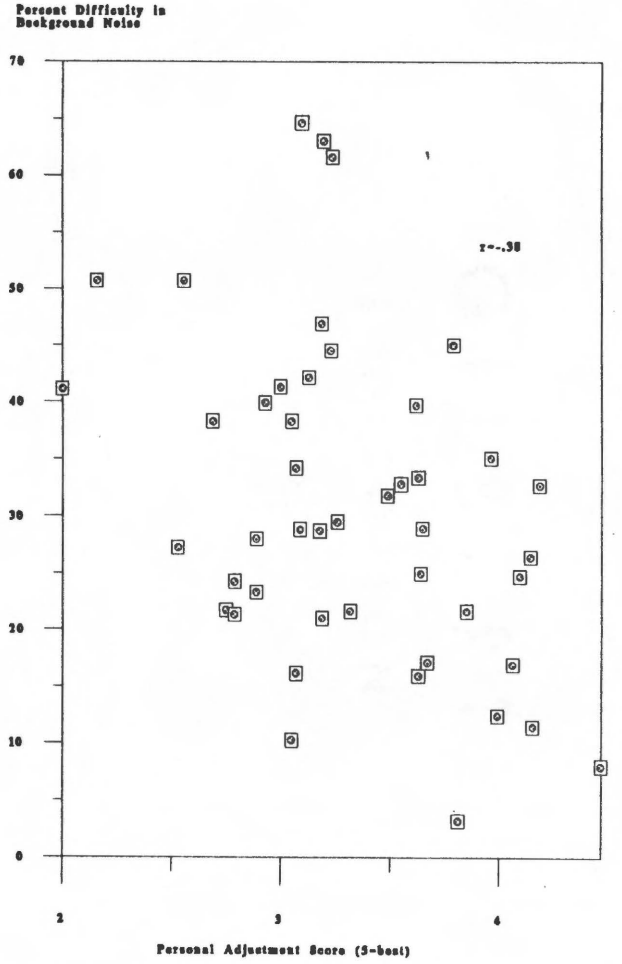


Figure 155. The relationship between Personal Adjustment scores and Background Noise subscale scores from the PHAP.

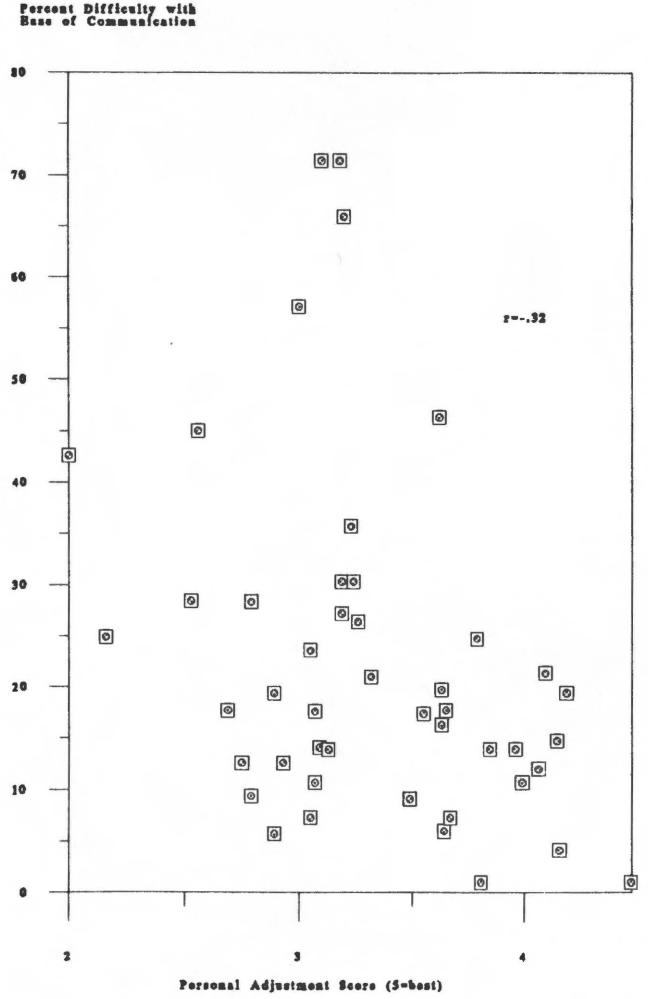


Figure 156. The relationship between Personal Adjustment scores from the CPHI and Ease of Communication scores from the PHAP.

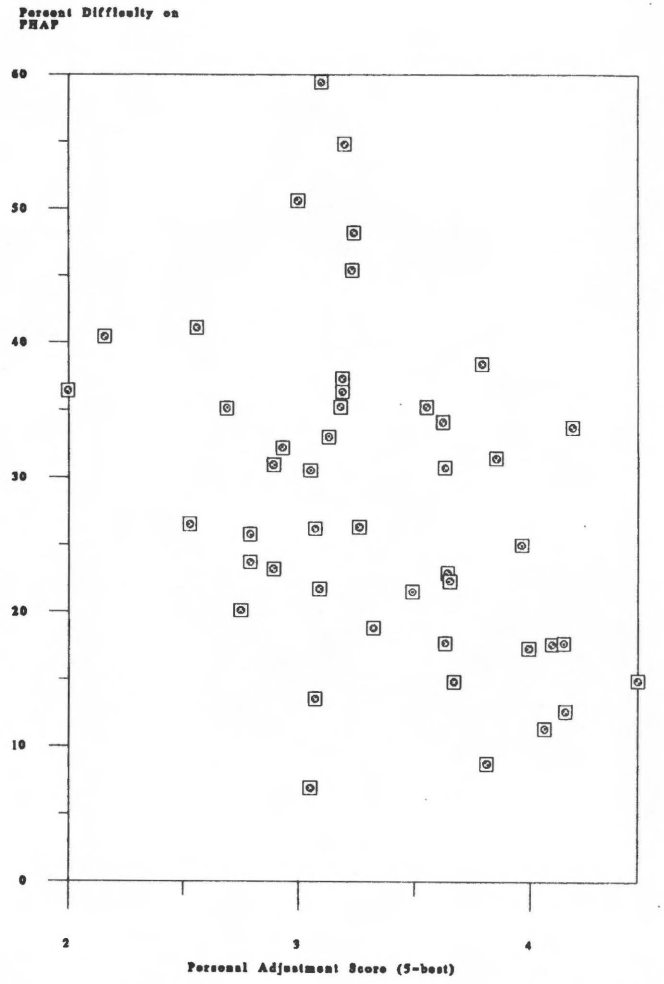


Figure 157. The relationship between Personal Adjustment scores of the CPHI and average PHAP scores.

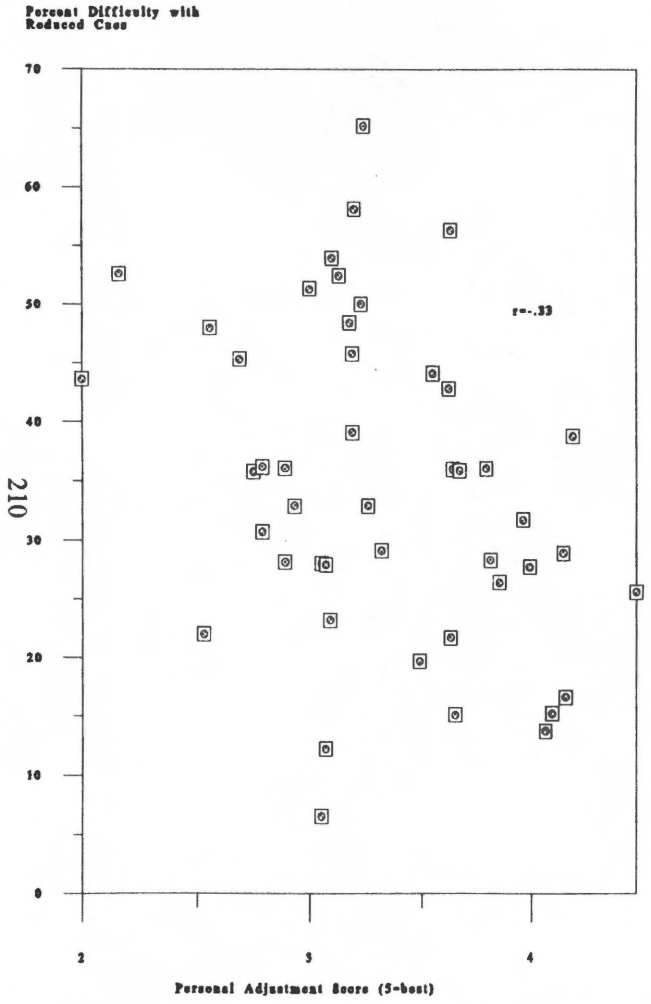


Figure 158. The relationship between Personal Adjustment scores from the CPHI and Reduced Cues subscale scores from the PHAP.

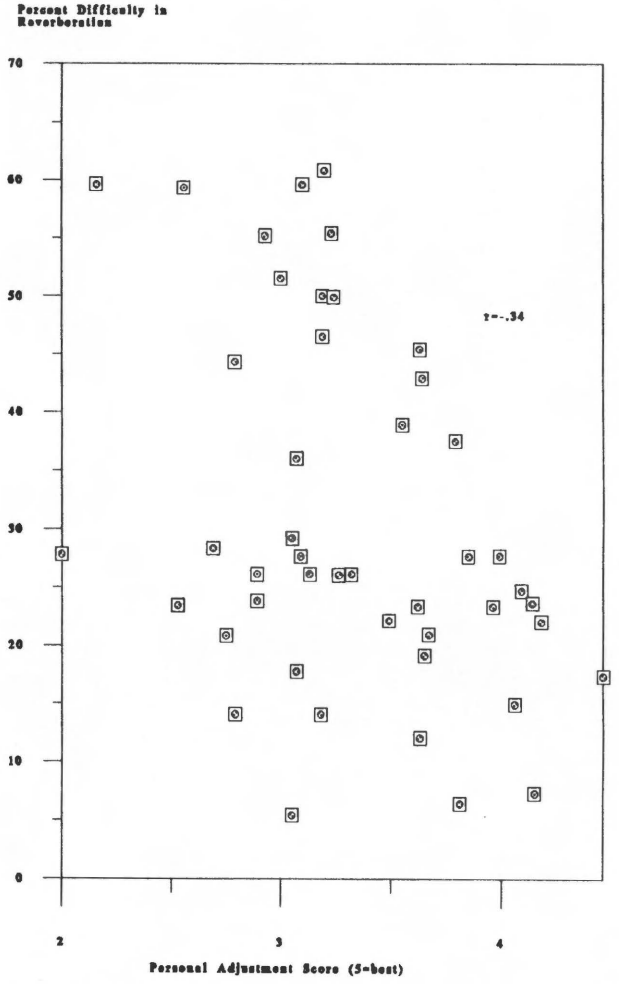


Figure 159. The relationship between Personal Adjustment scores from the CPHI and Reverberation subscale scores from the PHAP.

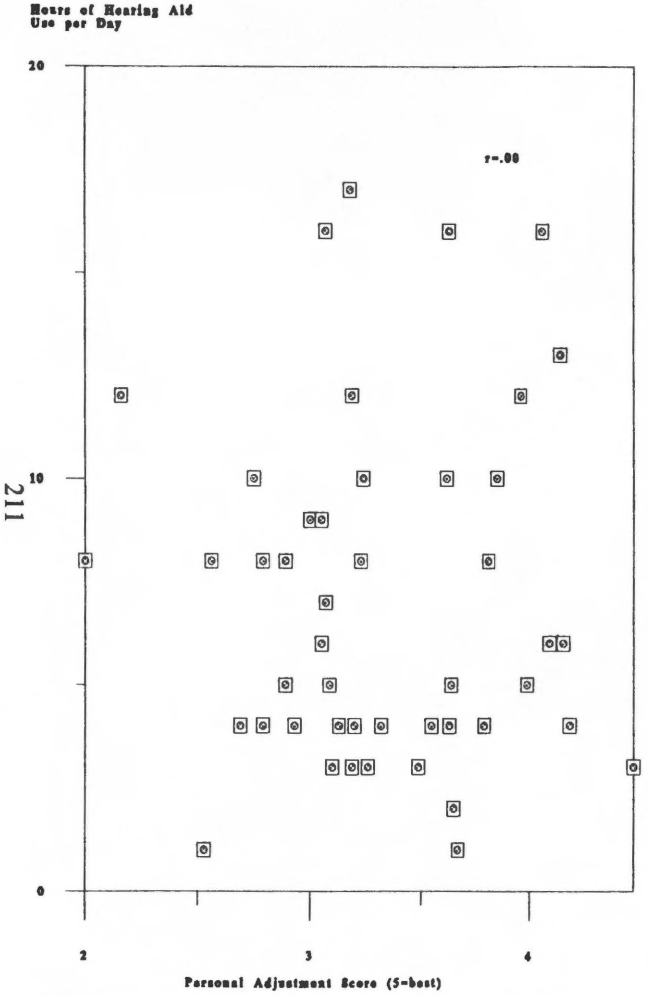


Figure 160. The relationship between Personal Adjustment scores from the CPHI and hours of hearing aid use per day.

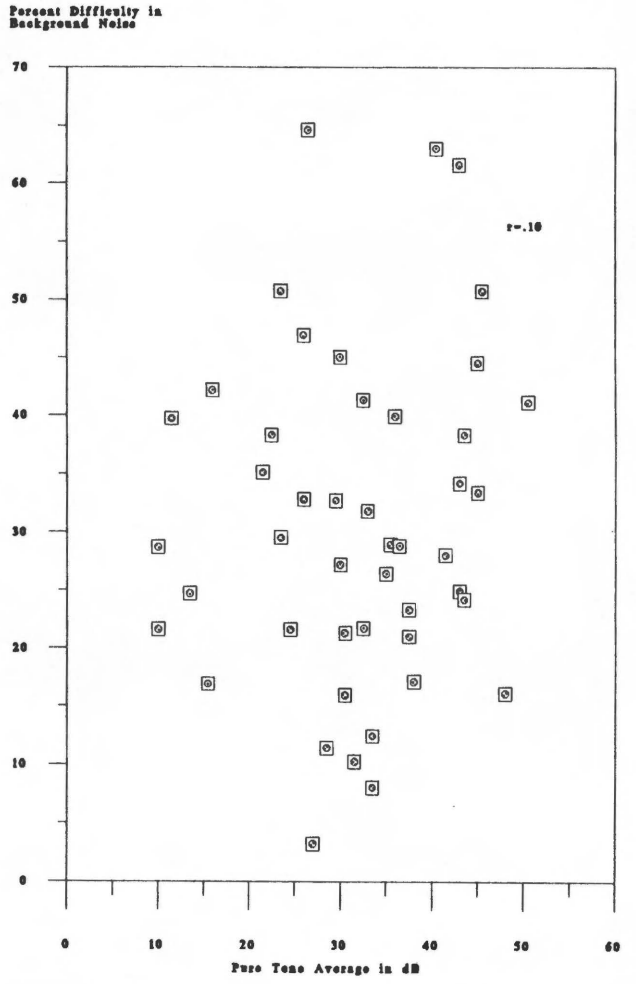


Figure 161. The relationship between pure tone average and Background Noise subscale scores from the PHAP.

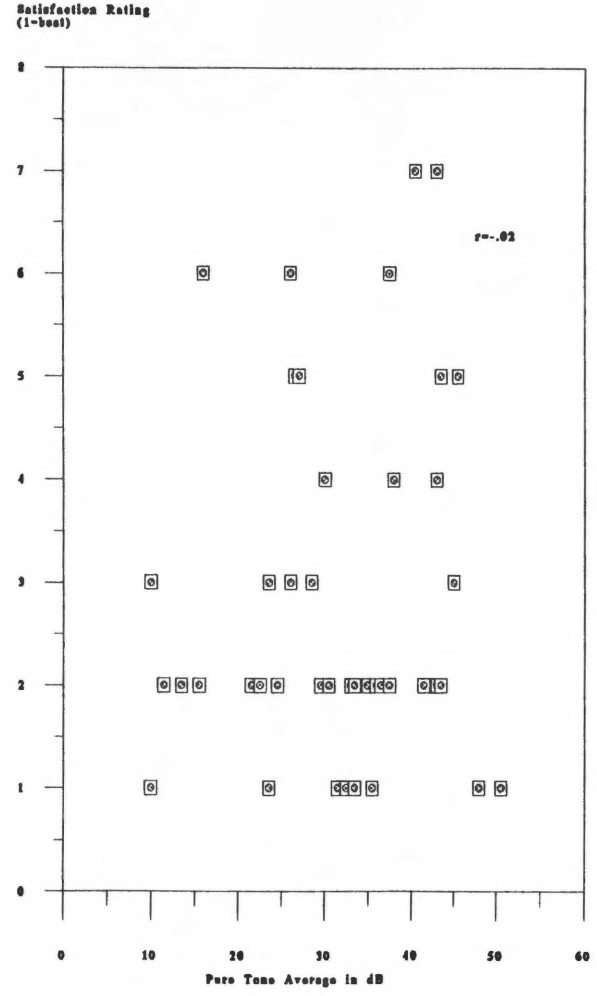


Figure 162. The relationship between pure tone average and hearing aid satisfaction ratings.

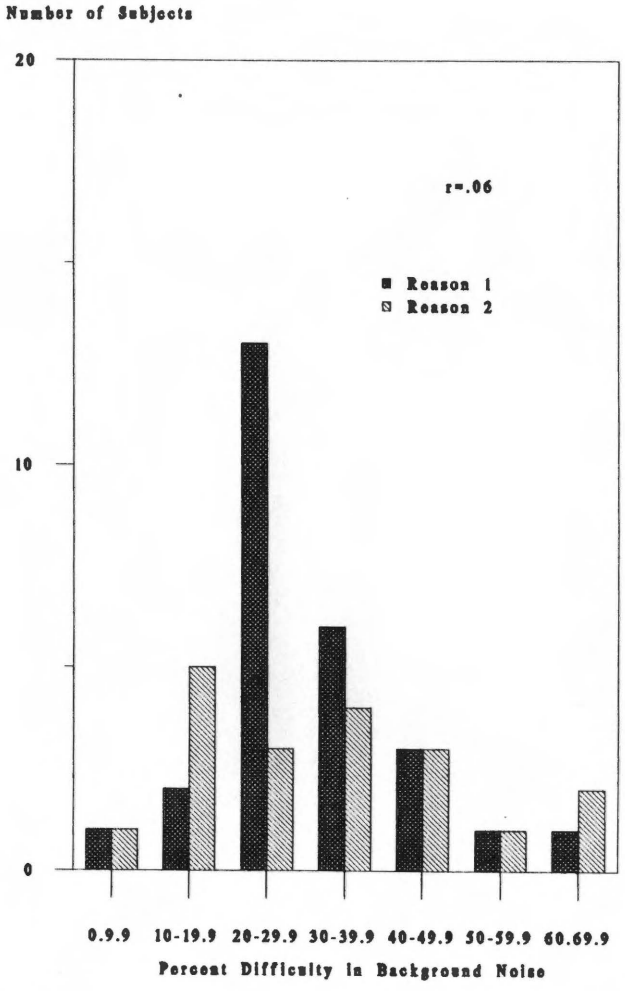


Figure 163. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for seven categories of Background Noise scores.

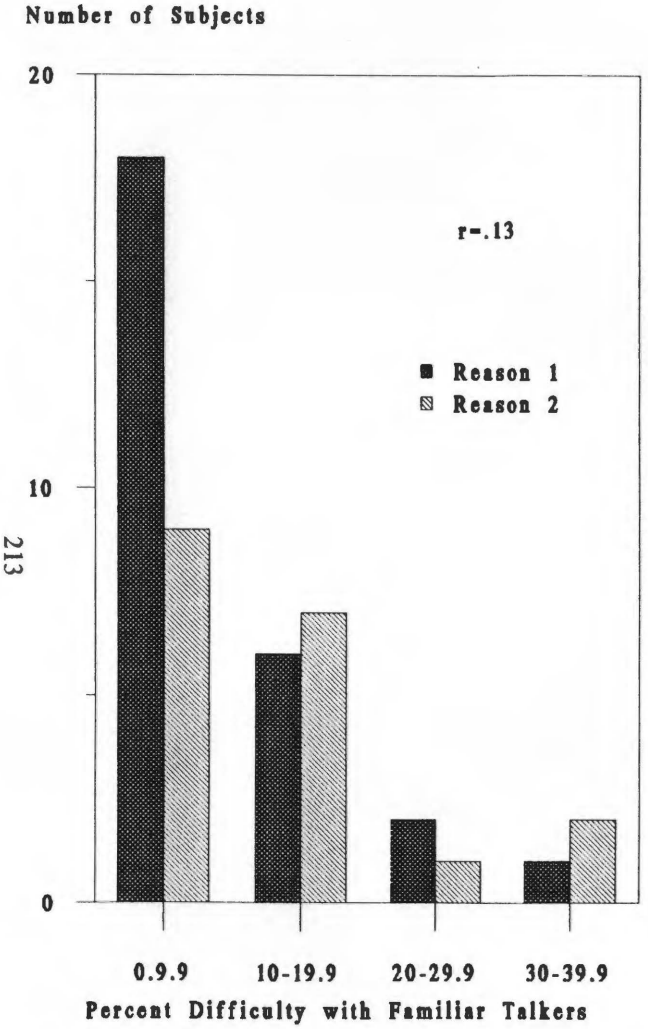


Figure 164. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for four categories of Familiar Talkers scores from the PHAP.

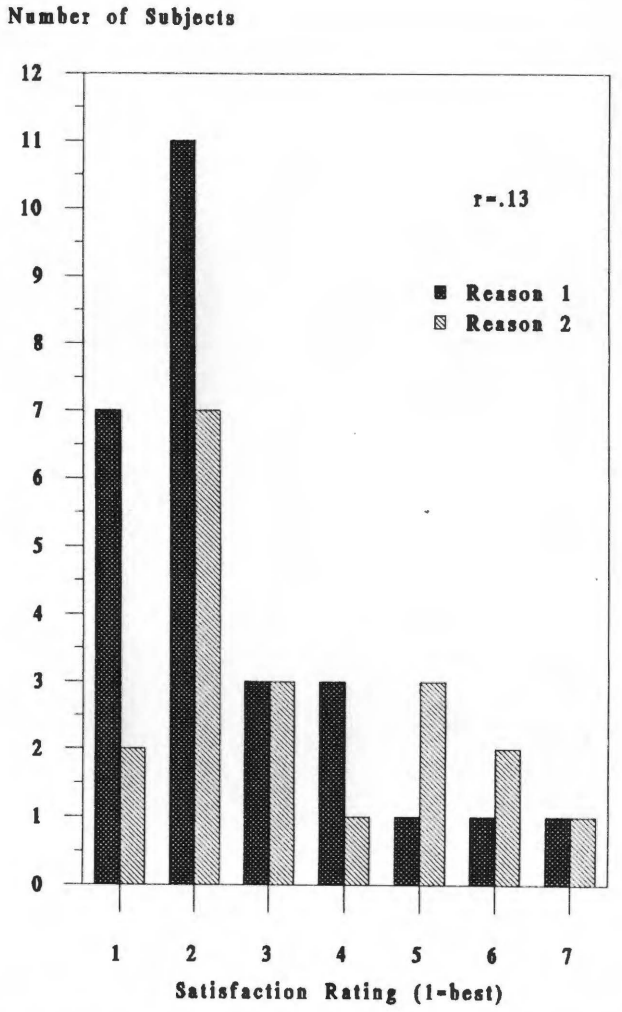


Figure 165. The number of subjects in each satisfaction rating category purchasing hearing aids because of 1-self-motivation and 2-encouragement from others.

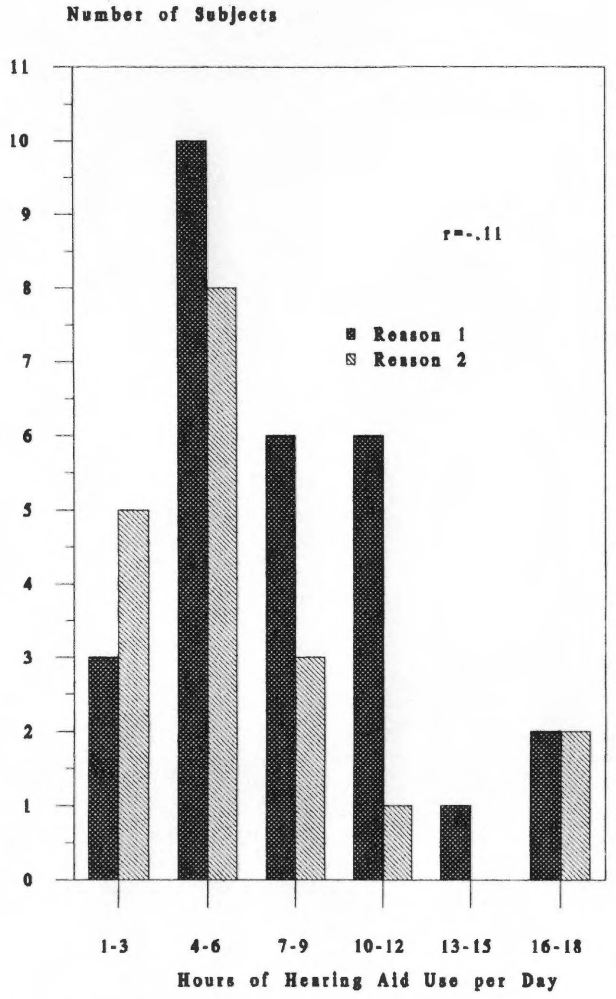


Figure 166. Number of subjects purchasing hearing aids because of 1-self-motivation and 2-encouragement from others for six categories of hearing aid usage.

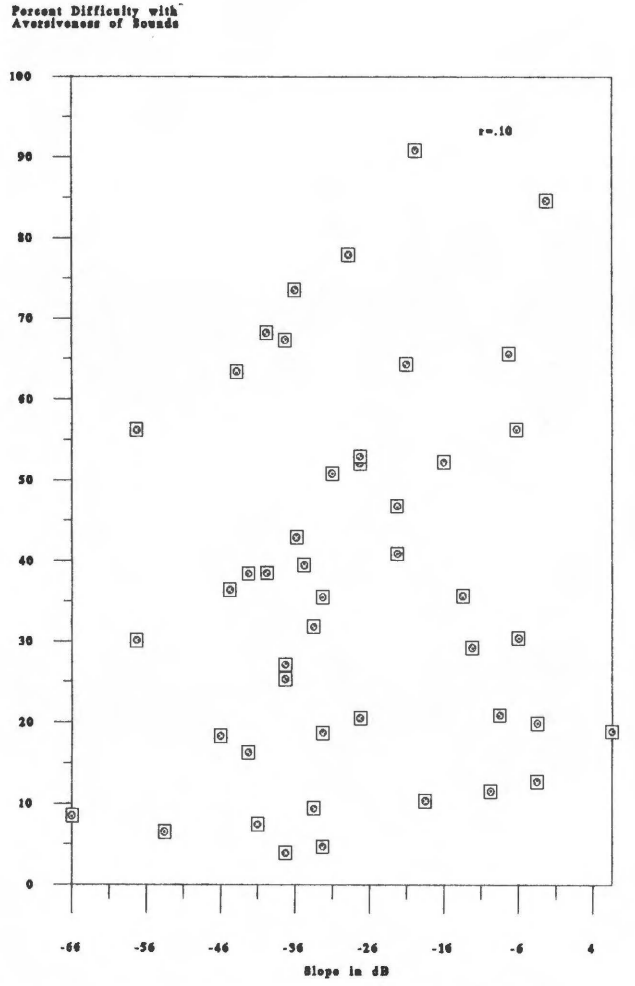


Figure 167. The relationship between slope and Aversiveness of Sounds subscale scores of the PHAP.

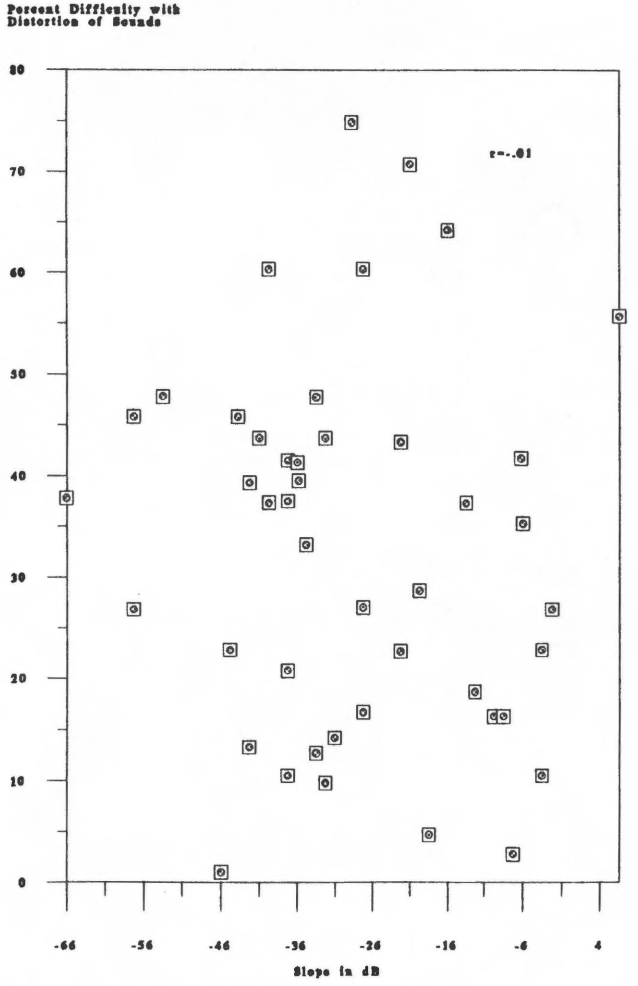


Figure 168. The relationship between slope and Distortion of Sounds subscale scores from the PHAP.

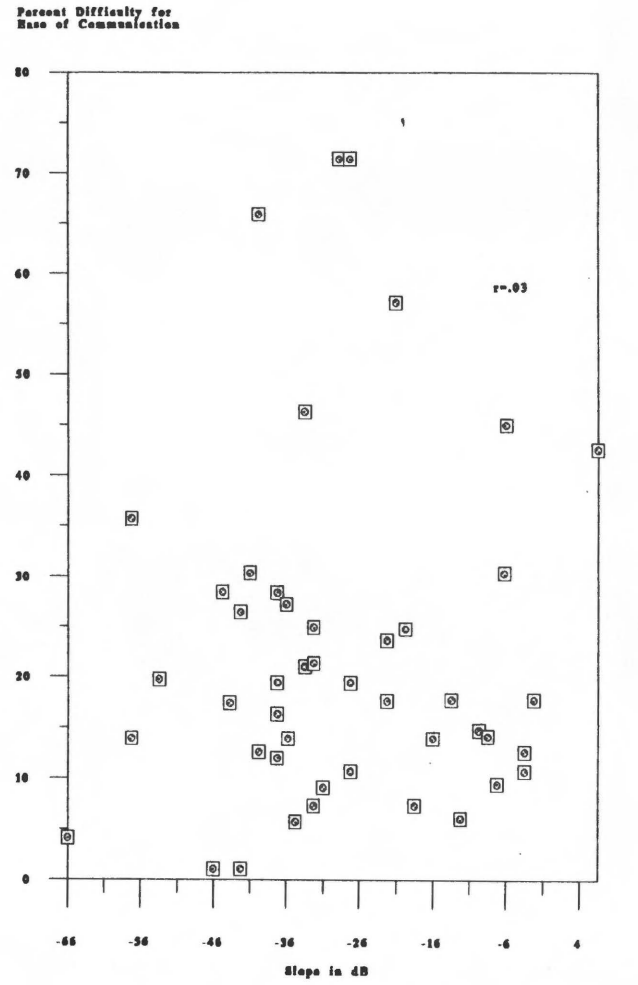


Figure 169. The relationship between slope of hearing loss and Ease of Communication subscale scores of the PHAP.

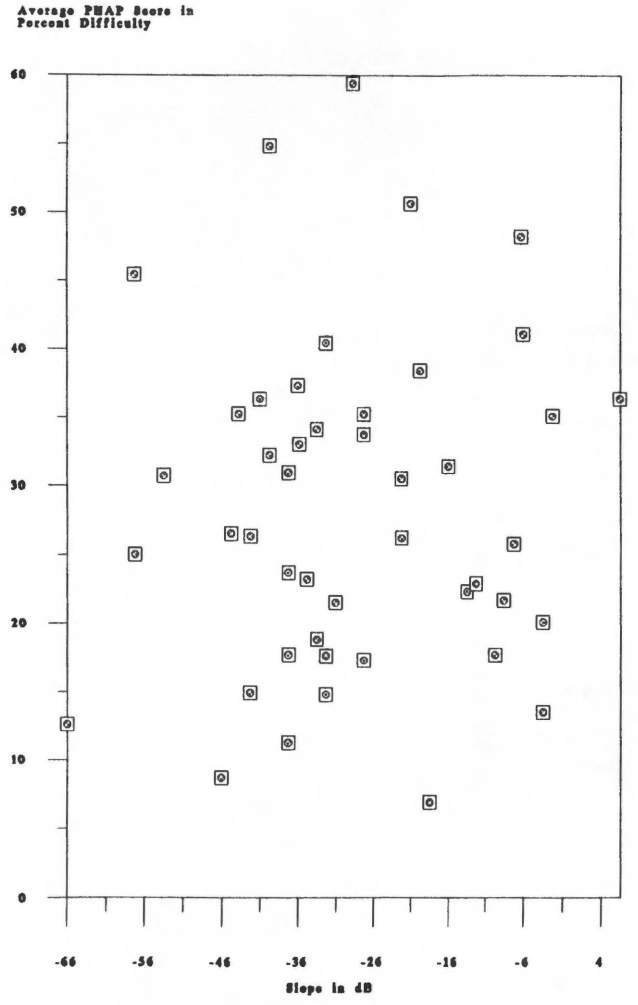


Figure 170. The relationship between slope of hearing loss and average PHAP scores.

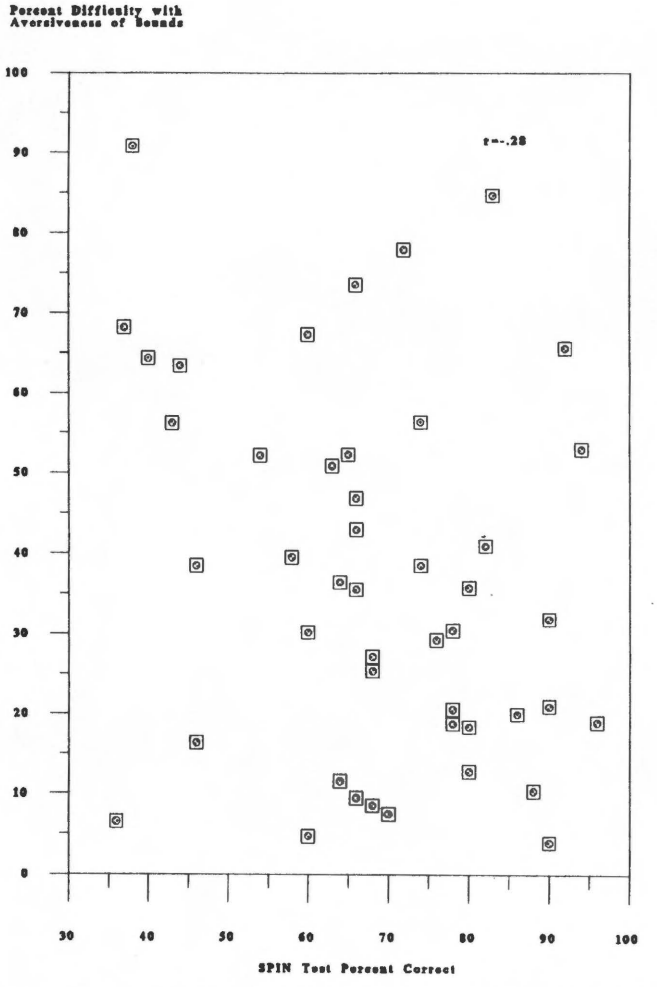


Figure 171. The relationship between SPIN scores and Aversiveness of Sounds subscale scores from the PHAP.

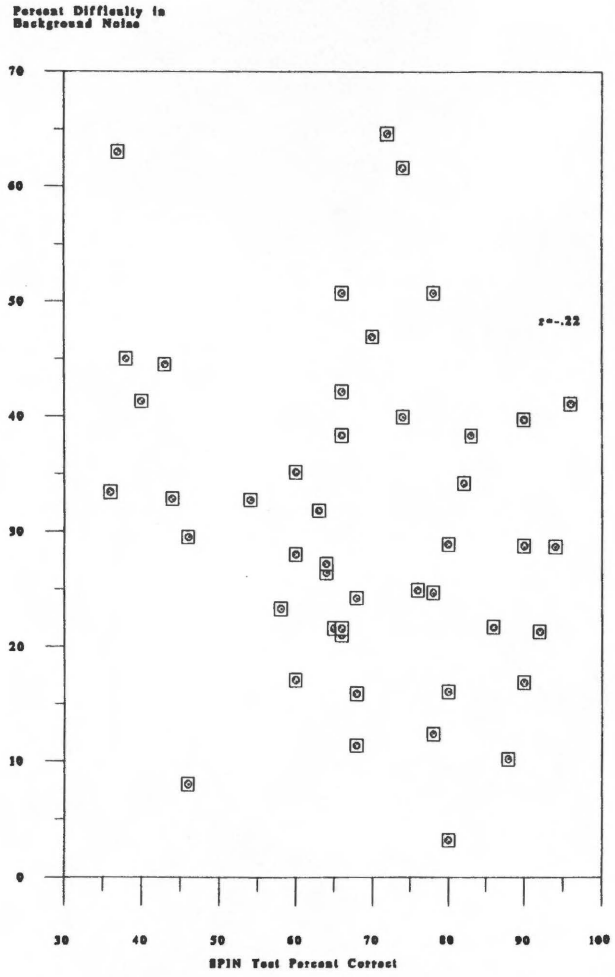


Figure 172. The relationship between SPIN test scores and Background Noise subscale scores from the PHAP.

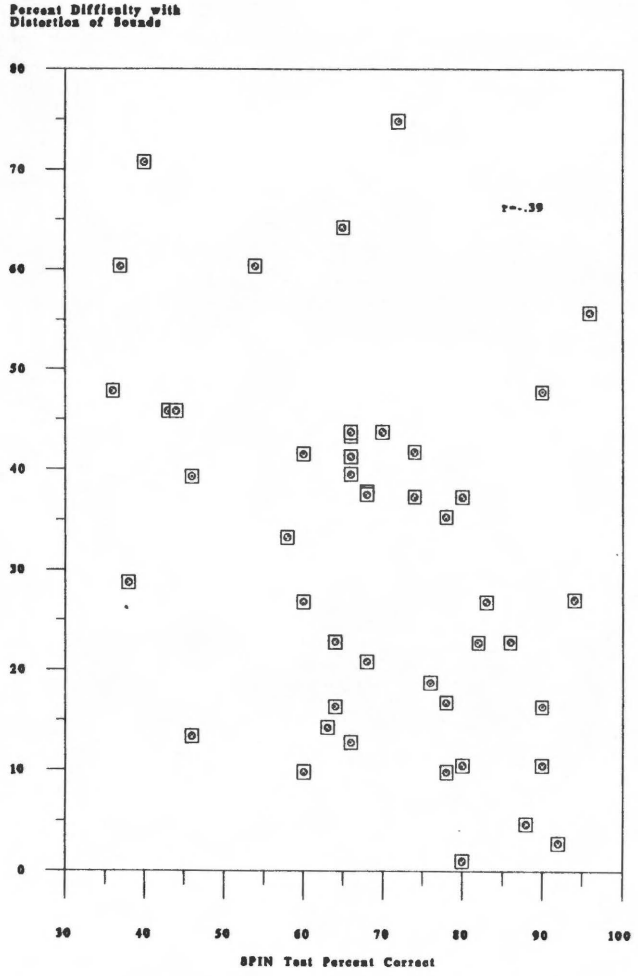


Figure 173. The relationship between SPIN test scores and Distortion of Sounds subscale scores from the PHAP.

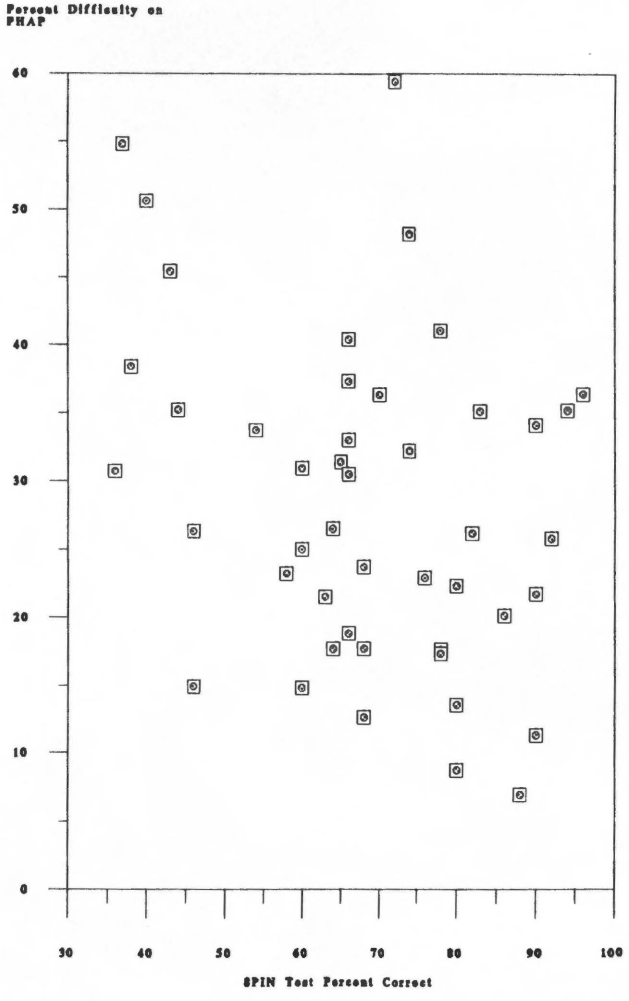


Figure 174. The relationship between SPIN test scores and average PHAP scores.

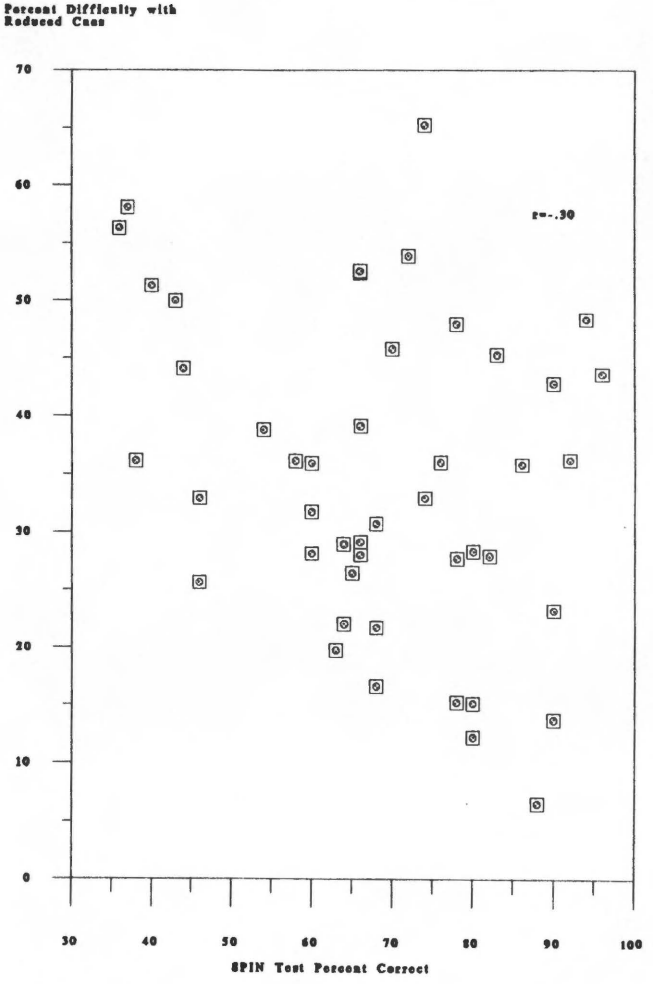


Figure 175. The relationship between SPIN test scores and Reduced Cues subscale scores from the PHAP.

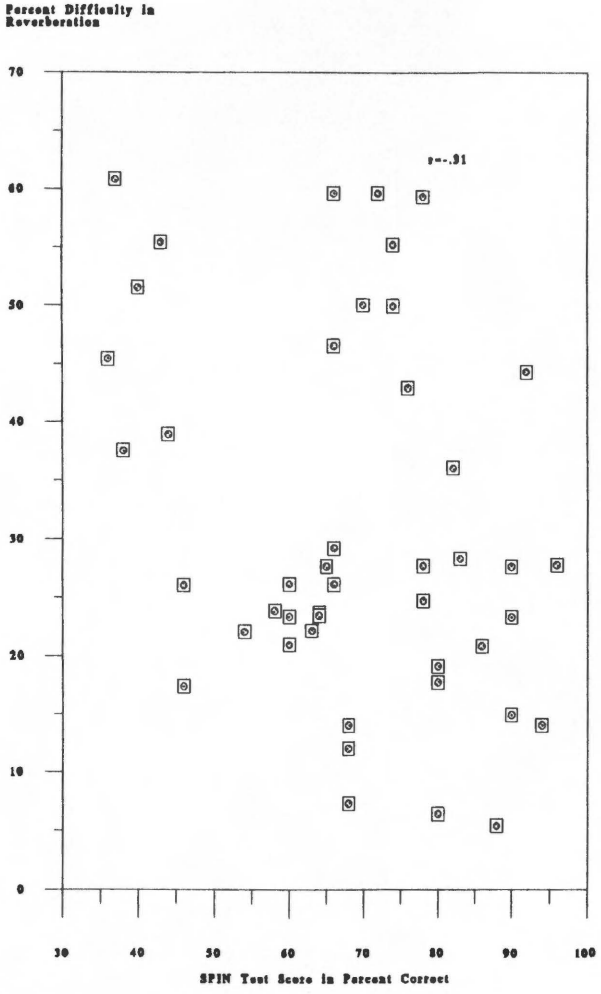


Figure 176. Relationship between SPIN test scores and Reverberation subscale scores from the PHAP.

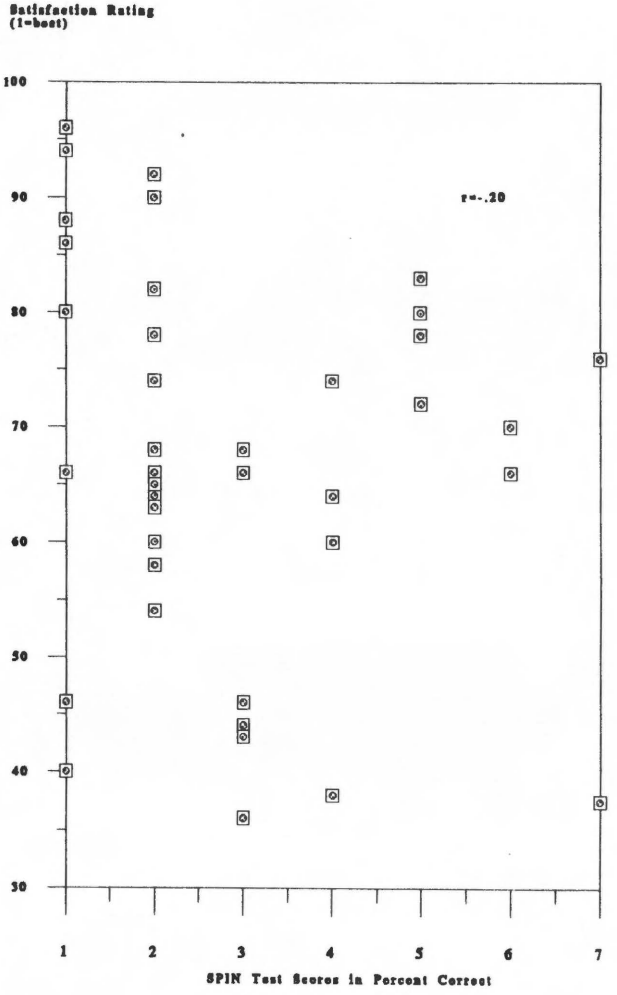


Figure 177. The relationship between SPIN test scores and hearing aid satisfaction ratings.

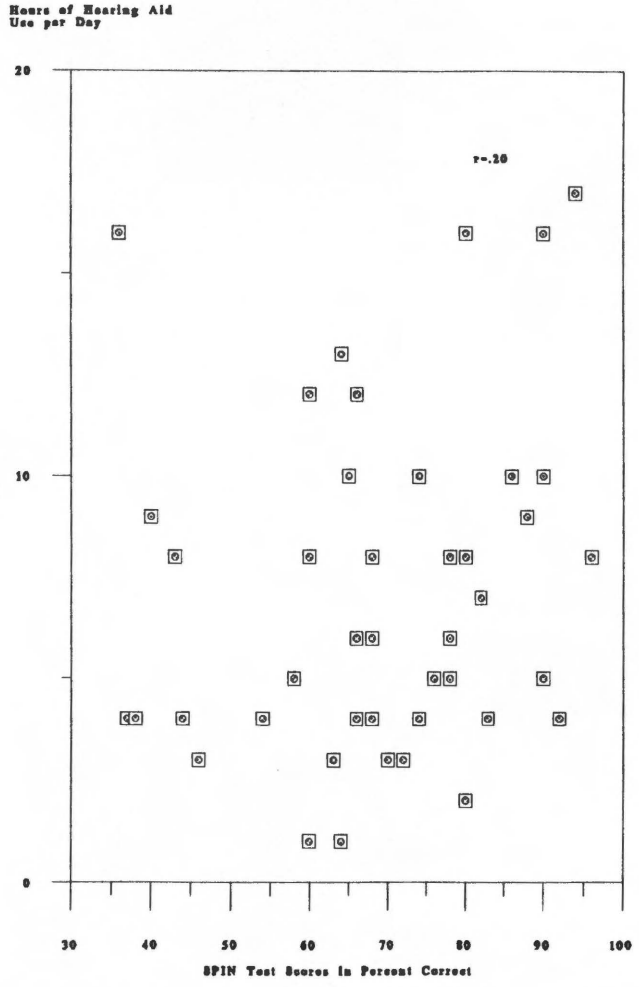


Figure 178. The relationship between SPIN test scores and hours of hearing aid use per day.

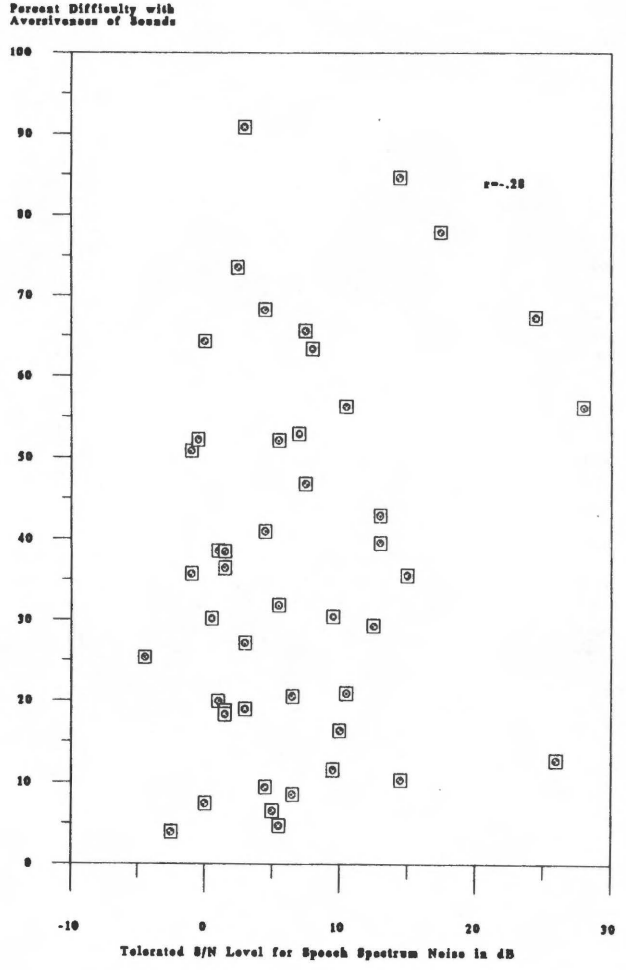


Figure 179. The relationship between tolerated S/N level for speech spectrum noise and Aversiveness of Sounds subscale scores from the PHAP.

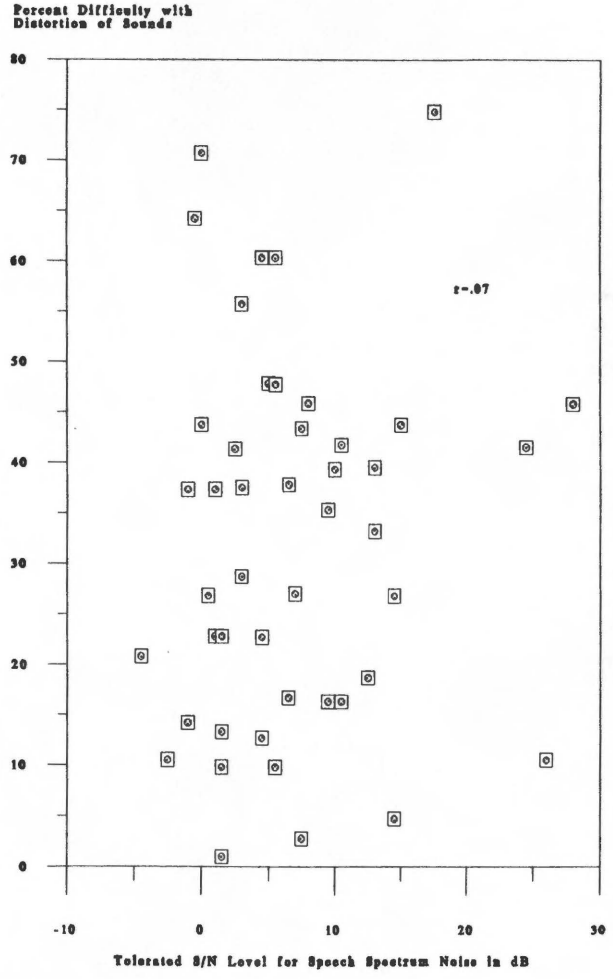


Figure 180. The relationship between tolerated S/N level for speech spectrum noise and Distortion of Sounds subscale scores from the PHAP.

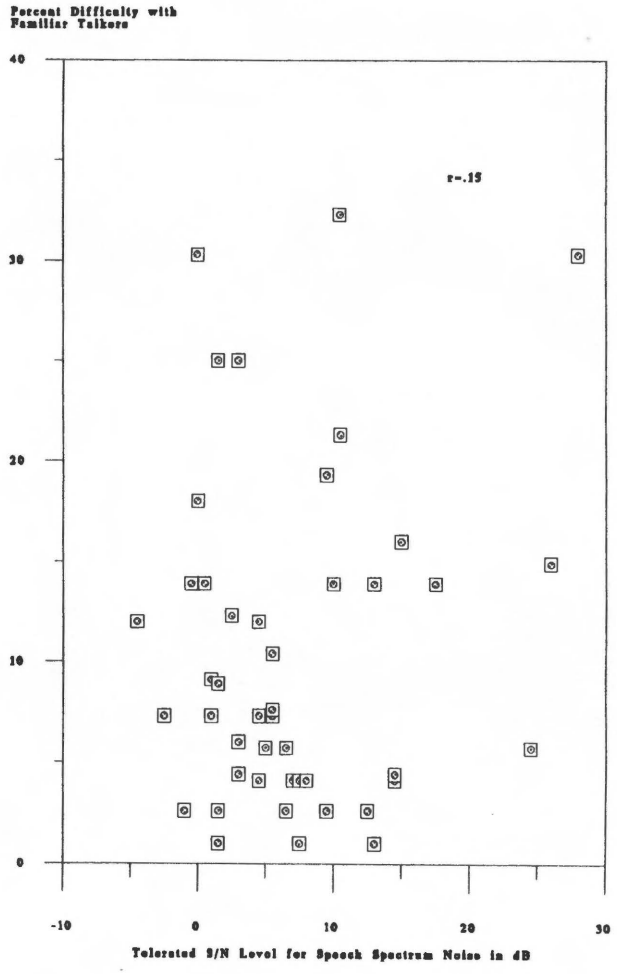


Figure 181. The relationship between tolerated S/N level for speech spectrum noise and Familiar Talkers subscale scores from the PHAP.

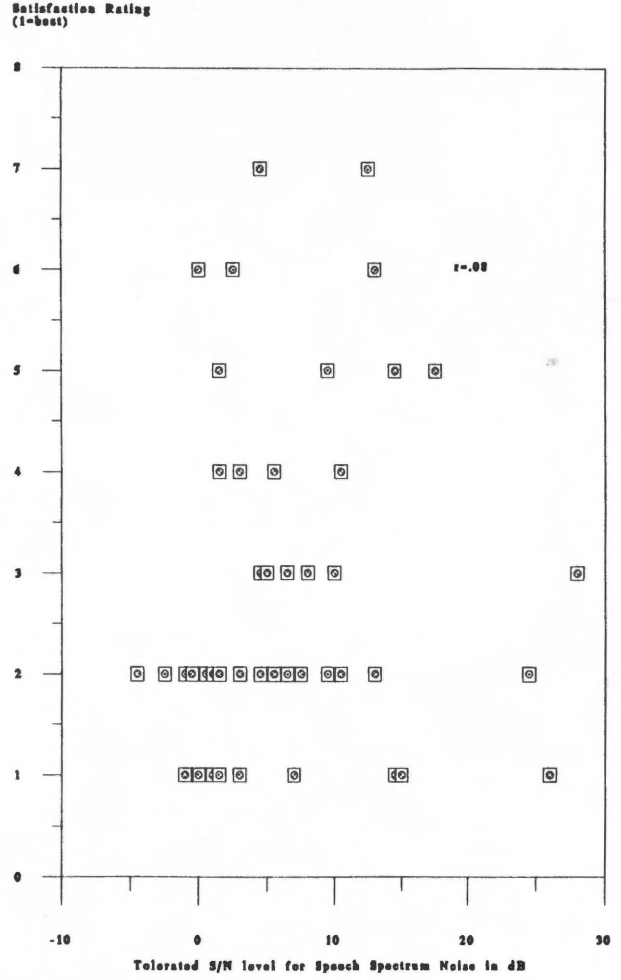


Figure 182. The relationship between tolerated S/N level for speech spectrum noise and hearing aid satisfaction ratings.

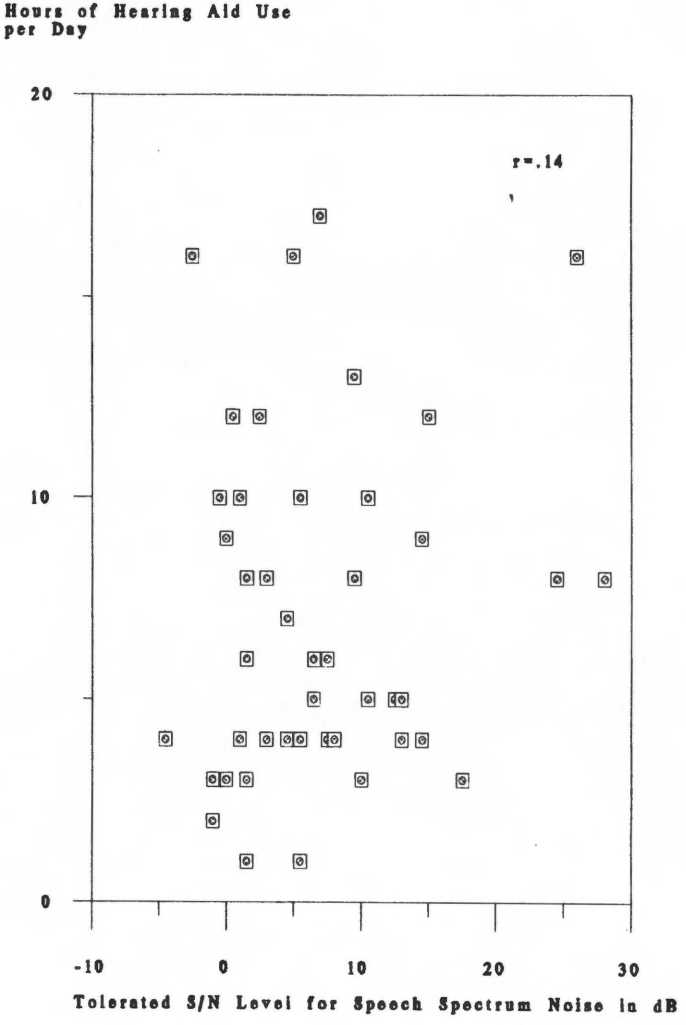


Figure 183. The relationship between tolerated S/N level for speech spectrum noise and hearing aid usage.

APPENDIX I

Graphs of relationships between response variables

(Figures 184- 200)

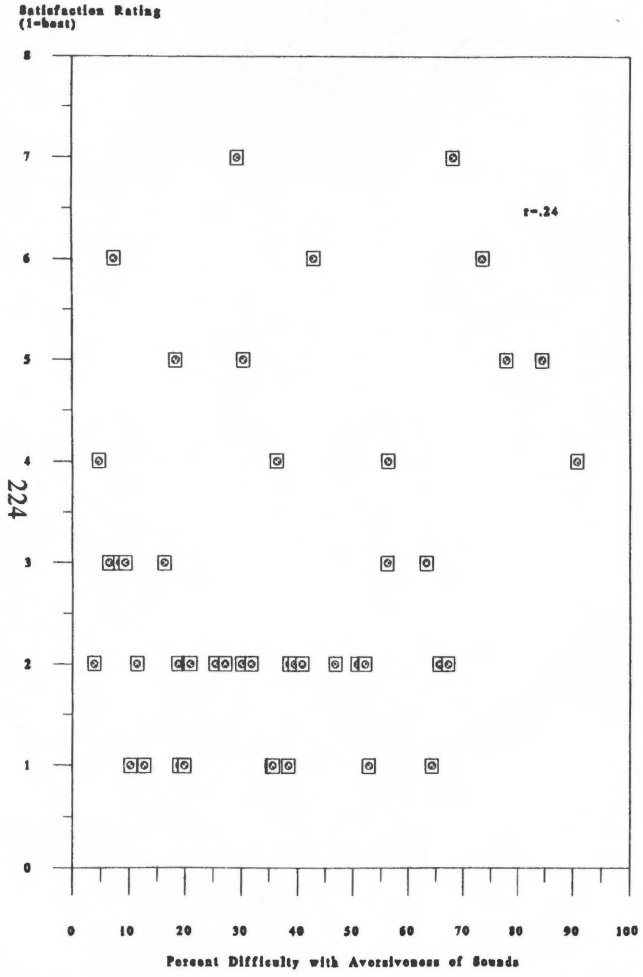


Figure 184. The relationship between Aversiveness of Sounds subscale scores from the PHAP and hearing aid satisfaction ratings.

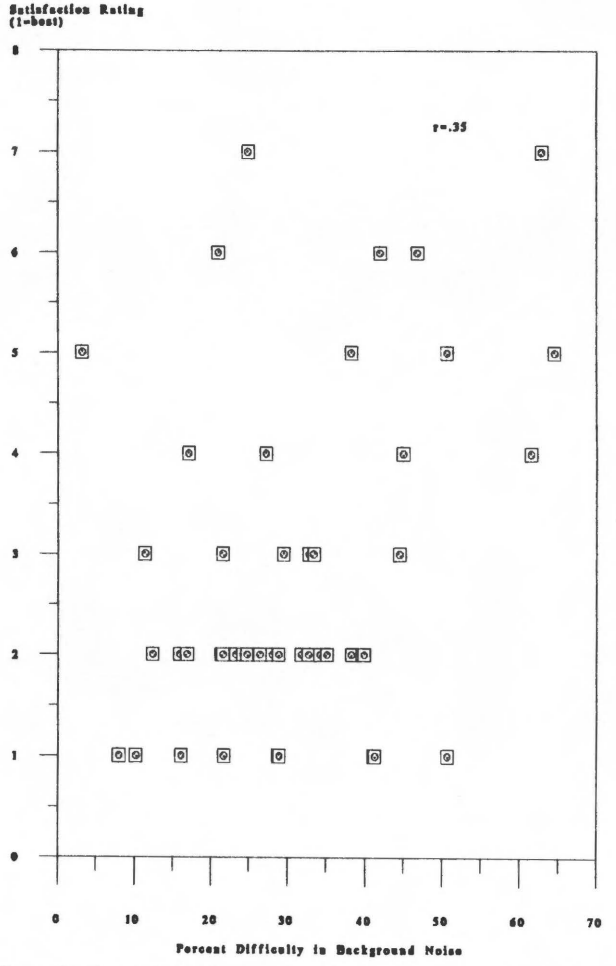


Figure 185. The relationship between Background Noise subscale scores from the PHAP and hearing aid satisfaction ratings.

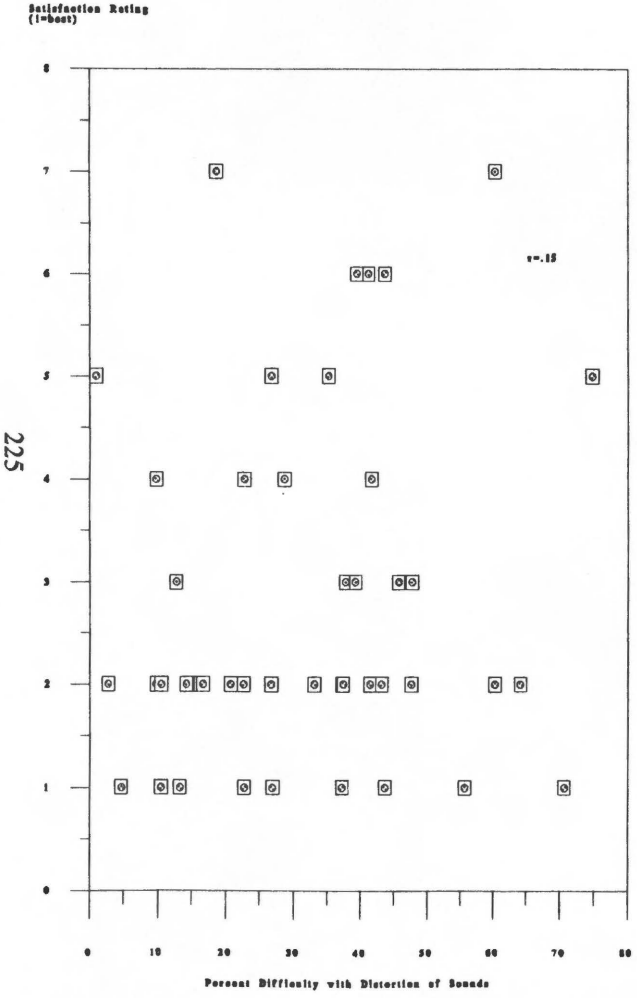


Figure 186. The relationship between Distortion of Sounds subscale scores from the PHAP and hearing aid satisfaction ratings.

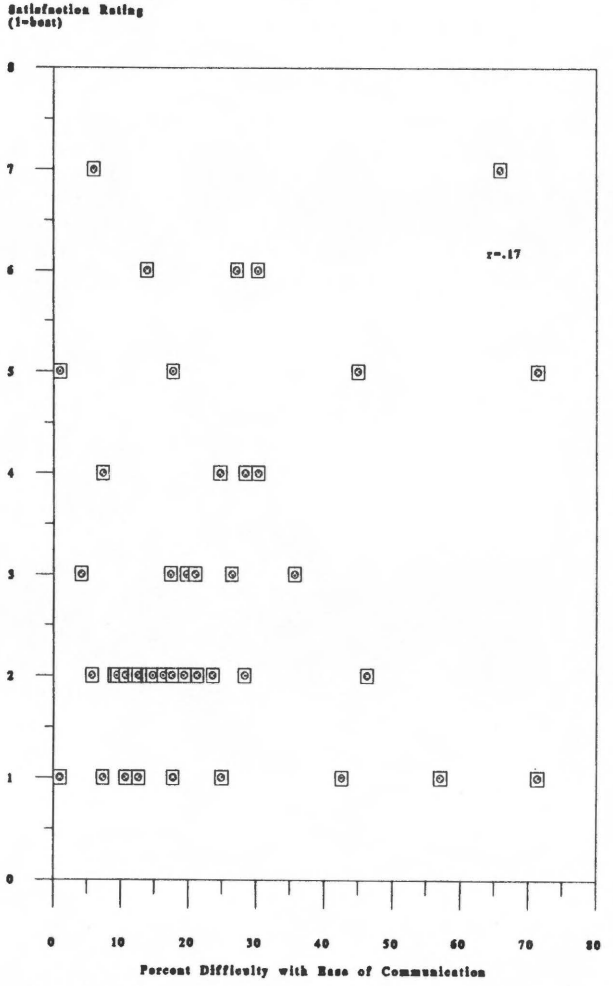


Figure 187. The relationship between Ease of Communication subscale scores from the PHAP and hearing aid satisfaction ratings.

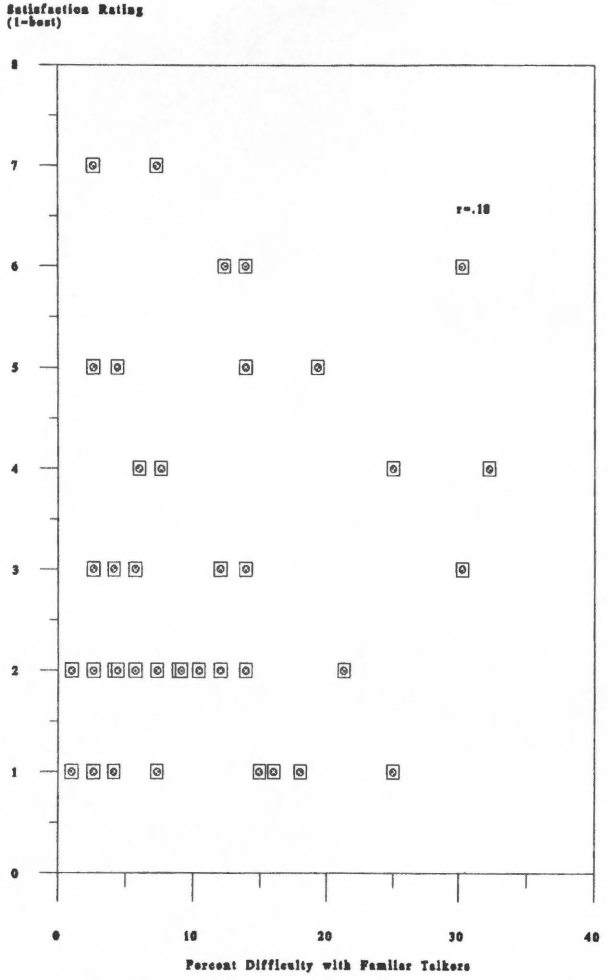


Figure 188. The relationship between Familiar Talkers subscale scores from the PHAP and hearing aid satisfaction ratings.

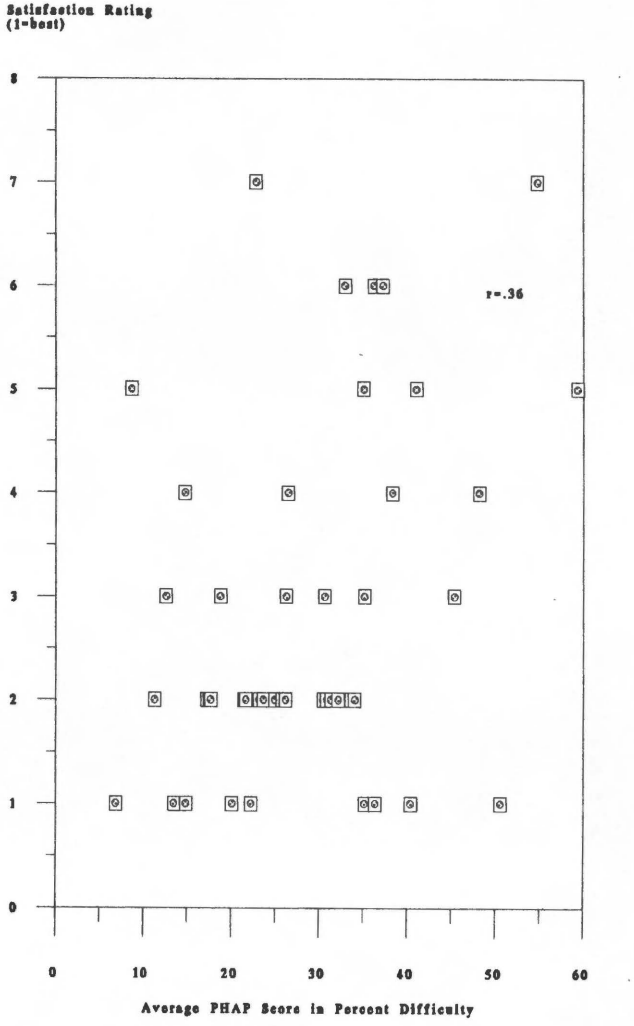


Figure 189. The relationship between average PHAP scores and hearing aid satisfaction ratings.

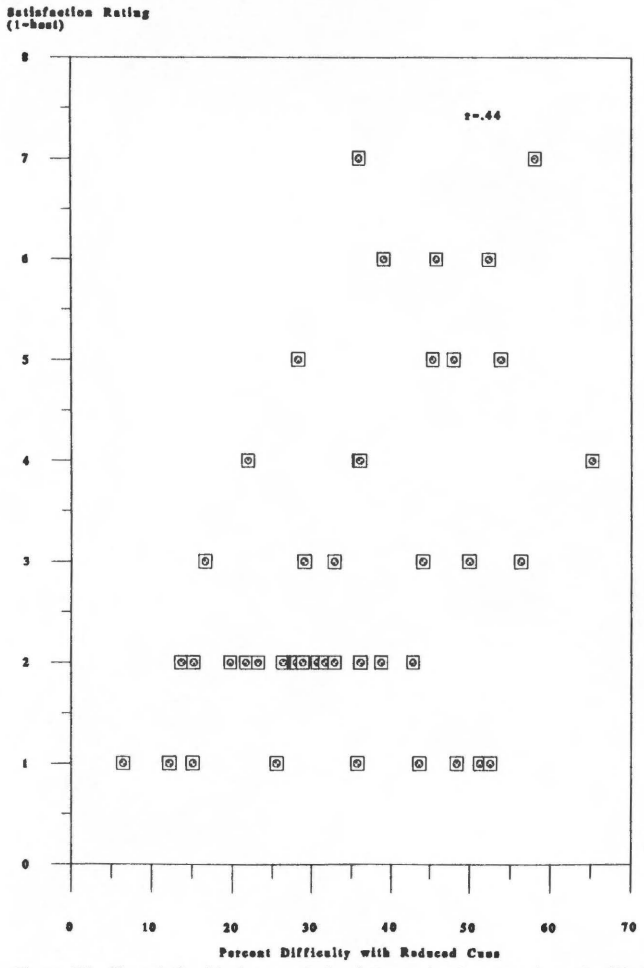


Figure 190. The relationship between Reduced Cues subscale scores from the PHAP and hearing aid satisfaction ratings.

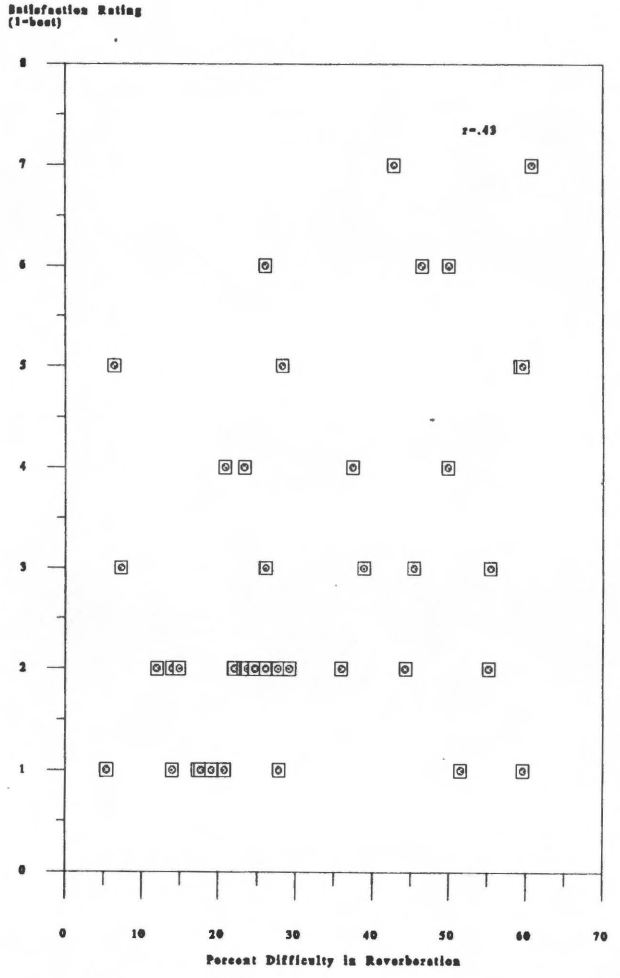


Figure 191. The relationship between Reverberation subscale scores and hearing aid satisfaction ratings.

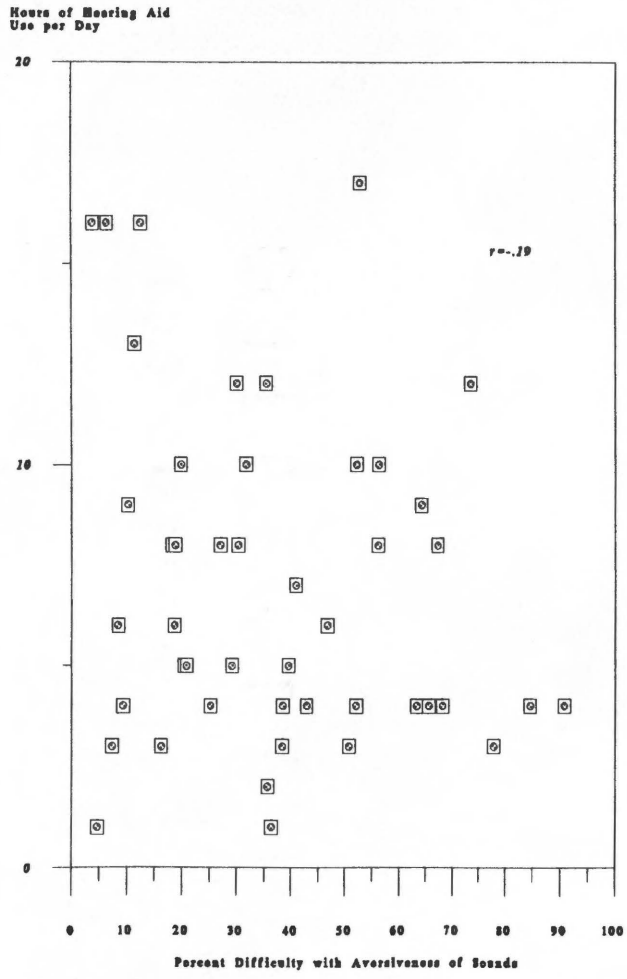


Figure 192. The relationship between Aversiveness of Sounds subscale scores from the PHAP and hours of hearing aid use per day.

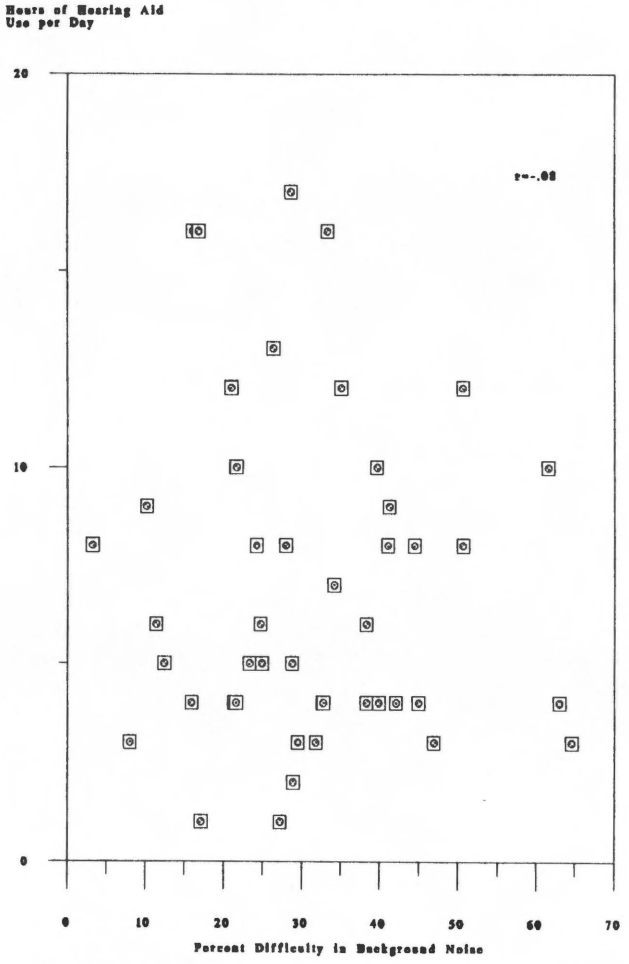


Figure 193. The relationship between Background Noise subscale scores from the PHAP and hours of hearing aid use per day.

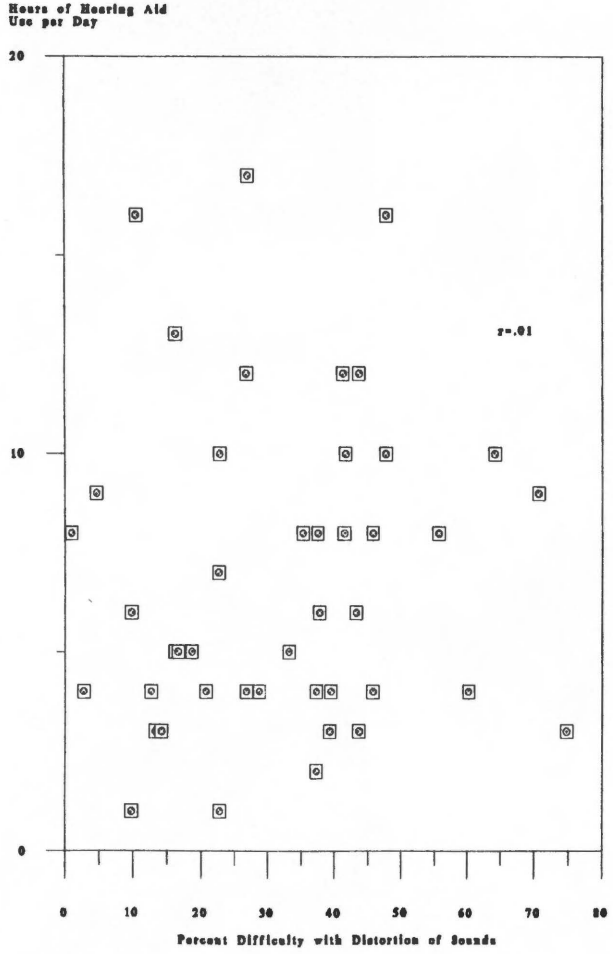


Figure 194. The relationship between Distortion of Sounds subscale scores from the PHAP and hours of hearing aid use per day.

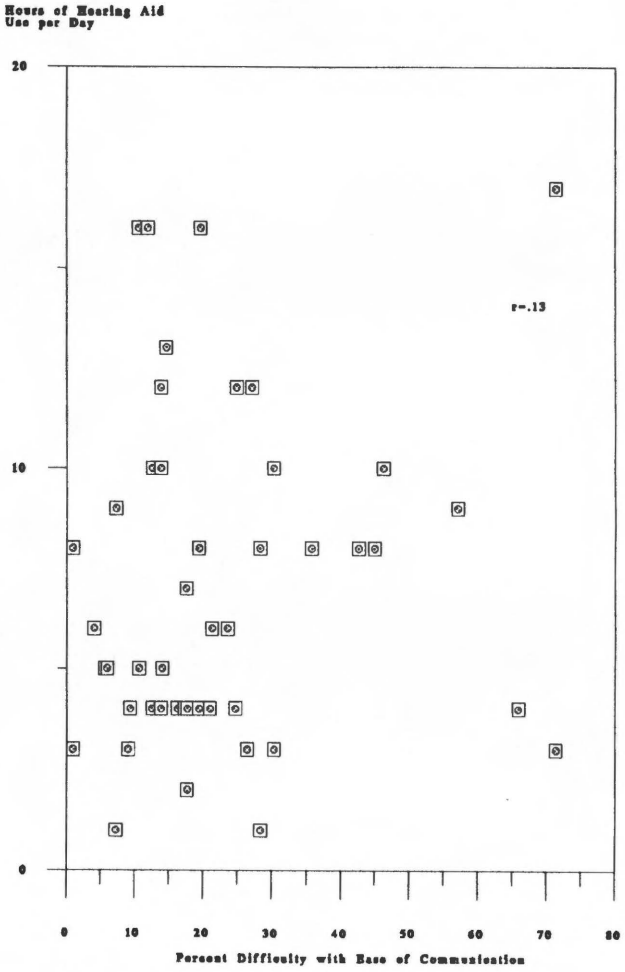


Figure 195. The relationship between Ease of Communication subscale scores from the PHAP and hours of hearing aid use per day.

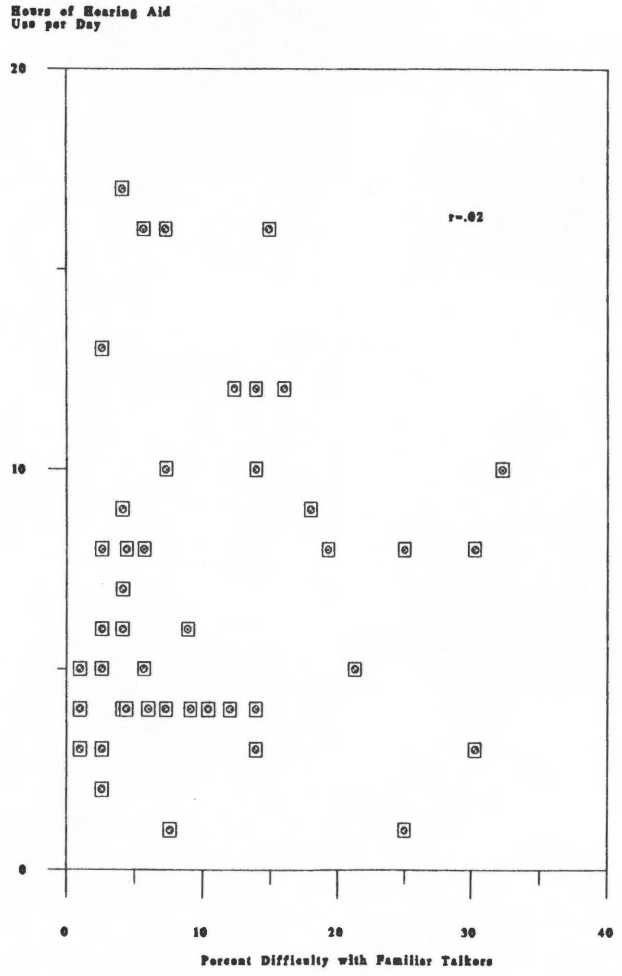


Figure 196. The relationship between Familiar Talkers subscale scores from the PHAP and hours of hearing aid use per day.

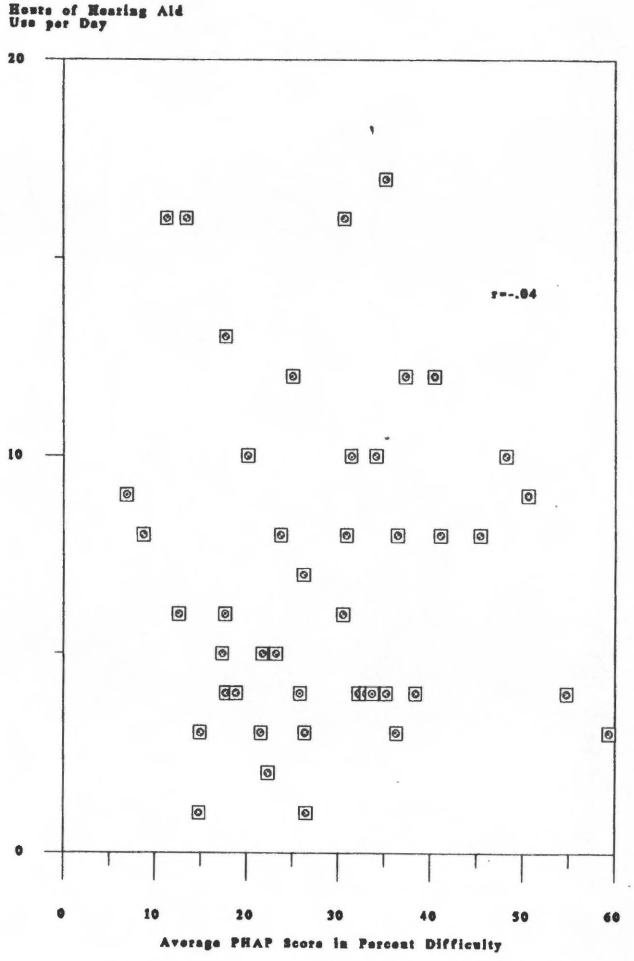


Figure 197. The relationship between average PHAP scores and hearing aid usage.

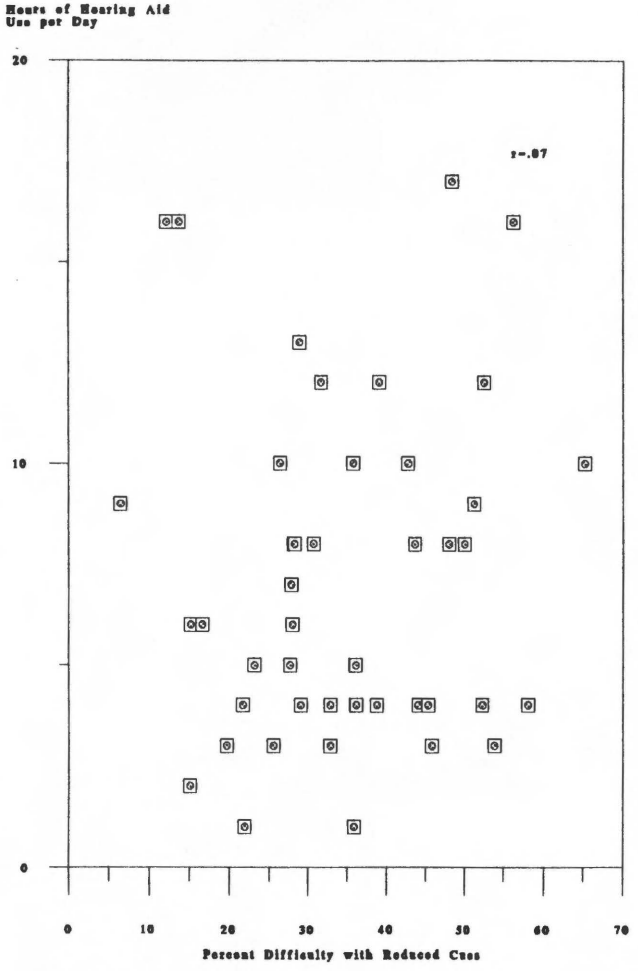


Figure 198. The relationship between Reduced Cues subscale scores from the PHAP and hours of hearing aid use per day.

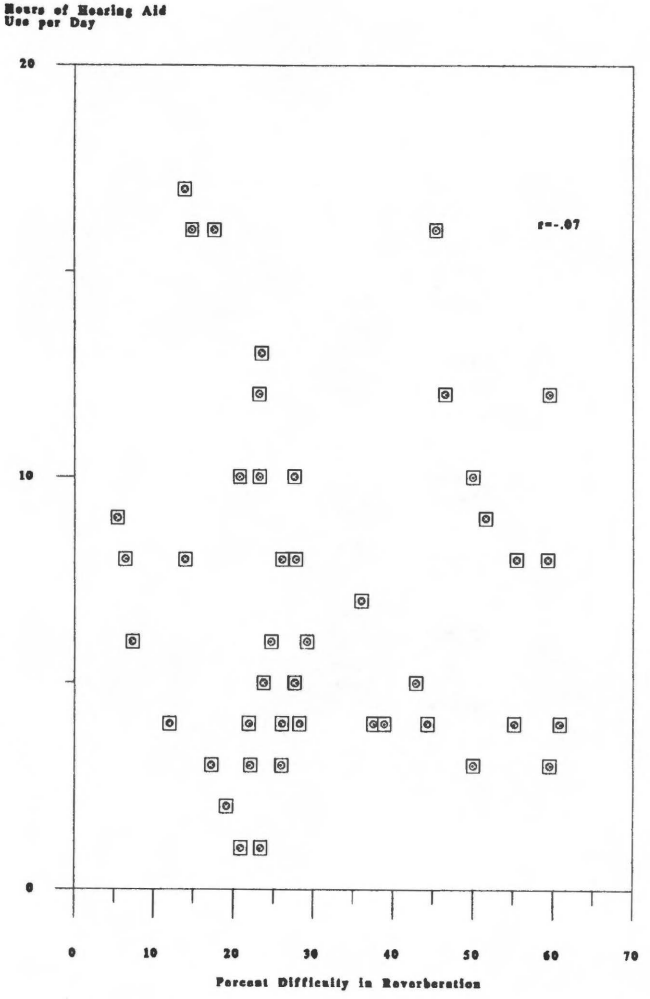


Figure 199. The relationship between Reverberation subscale scores from the PHAP and hours of hearing aid use per day.

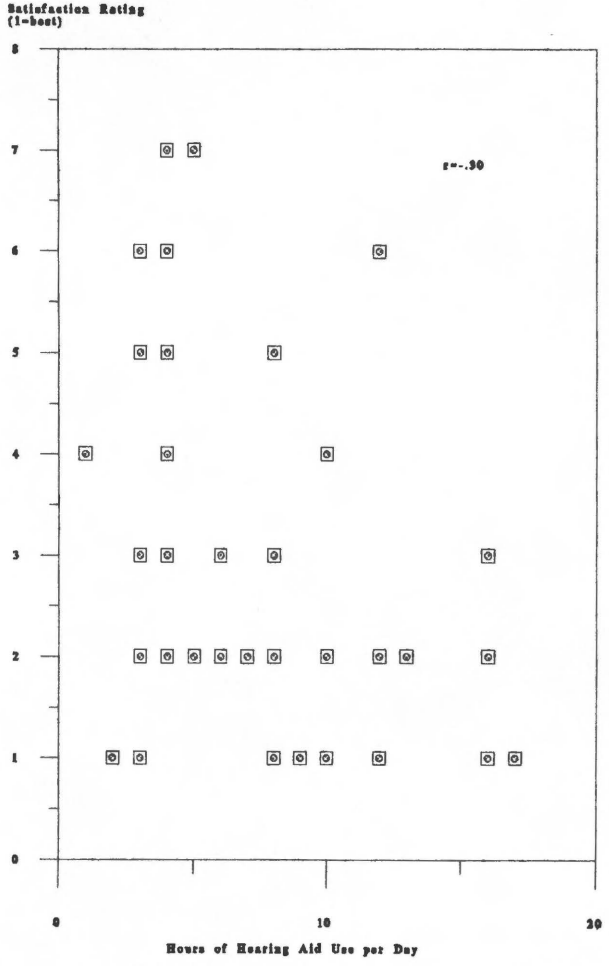


Figure 200. The relationship between hours of hearing aid use per day and hearing aid satisfaction ratings.

VITA

Hilary Jarvis Crowley was born in Washington, D.C. , and attended elementary and secondary schools in Fairfax County, Virginia. She received a Bachelor of Arts degree in Speech Pathology and Audiology from George Washington University in Washington, D.C. in 1980 and a Master of Arts degree in Audiology from Northwestern University in Evanston, Illinois in 1983. She has six years of experience as a clinical audiologist at various clinics, and two years of experience as an Instructor at Radford University in Radford, Virginia. While attending the University of Tennessee she worked as a research assistant for Dr. Anna Nabelek for two years, helping to prepare articles for publication in the area of speech perception.