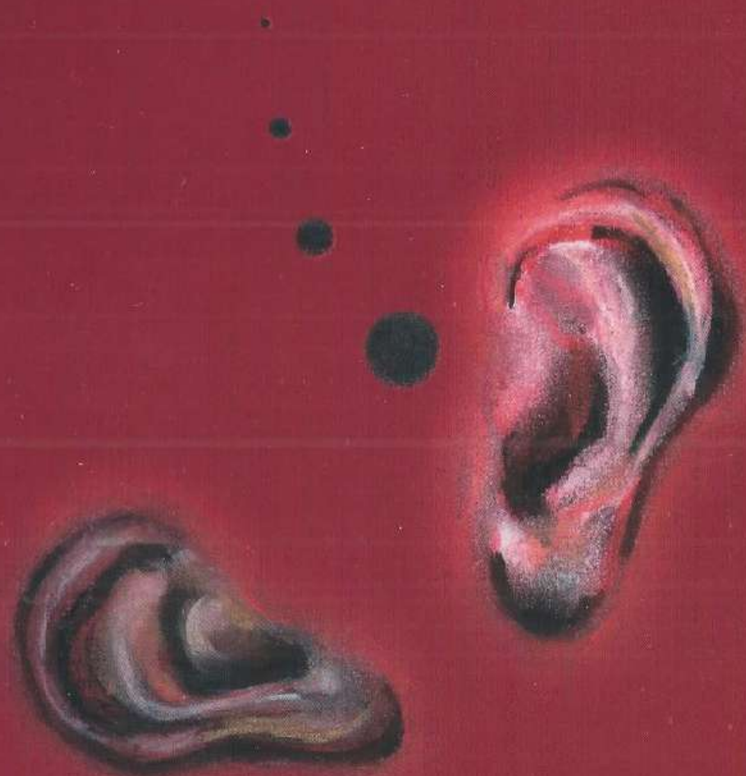
Assessment of hearing disability and handicap

A multidimensional approach



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VRIJE UNIVERSITEIT

ASSESSMENT OF HEARING DISABILITY AND HANDICAP

A multidimensional approach

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Aan mijn ouders
Aan José

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Contents

1

GENERAL INTRODUCTION

About 7 percent of the Dutch population (1.2 million people) reports some difficulty in hearing (Chorus et al., 1995). This percentage corresponds to the incidence of hearing impairment in the United States of America (Dobie, 1993). In Great-Britain about 16 percent of the adult population has a bilateral hearing impairment (Davis, 1989). Though the majority of persons with an auditory problem are more than 65 years old, hearing difficulty can be met at any age and can even be present at birth.

The treatment of auditory impairment depends on the type of hearing loss. Different types are usually distinguished as conductive or sensorineural or a mix of both. A disturbed conduction of the sound identifies conductive loss in the middle ear. Medical or surgical treatment of the mechanical system in this part of the ear usually results in a reduction of the loss. The prognosis of sensorineural loss on the other hand is less optimistic. This type originates in the inner ear or the auditory nerve and is not treatable.

Hearing impairment can be considered as one of the most frequently occurring chronic diseases. People suffering from a hearing impairment may experience serious problems in daily-life. Difficulties in general conversation are most commonly rated as the greatest problem, but hearing loss may also result in the inability to hear different kinds of (warning) signals, such as the doorbell, telephone, and cars on the street. Other complaints concern difficulties in hearing from which direction sounds are coming, both inside and outside the house, and difficulties in recognizing signals and people's voices. It is not seldom that hearing problems result in feelings of anxiety, embarrassment, isolation or unsafeness (Hétu, 1987). Also, the need of extra effort and concentration during listening may result in fatigue. Each of these aspects specifically may have an influence on a great variety of situations in daily-life as in social relationships. Of great importance are difficulties at work or in the family and employment problems. Investigations focussed on assessing the impact of hearing impairment in daily-life are therefore of great social concern.

Definition of terms

Systematic investigation of hearing loss and its consequences in everyday life requires clear definition of the terms used. In the classification of the World Health Organization (WHO, 1980) distinction is made between the concepts *impairment*, *disability* and *handicap*. These concepts are essential to this thesis and are defined according to the classification of the WHO.

Impairment refers to any loss or abnormality of psychological, physiological or anatomical structure or function. It is the dysfunction of the auditory system resulting from pathological changes. For the evaluation of the type and severity of a hearing *impairment* different functions of the auditory system have to be examined. Sensitivity for sounds (tone audiogram) is considered as the most fundamental characteristic of the auditory system. Other characteristics are the ability to discriminate sounds (speech), stability of the ear, the dynamic range, low internal noise and cooperation of both ears. (Kapteyn, 1997; Dobie, 1993). *Impairment* can be characterized by loss or abnormalities of one or more of the above-mentioned hearing functions and is primarily determined by an otolaryngologist.

Disability covers a wider area than that of *impairment*. It is concerned with consequences of defects in any of the hearing functions. It indicates how much the individual becomes aware of his impairment. *Disability* reflects the consequences of impairments in terms of functional performance and activity by the individual in every-day life. It refers to any restriction for a human being to perform an activity in a normal manner or within the range considered normal.

Handicap is a social phenomenon, representing the social and environmental consequences of hearing *disability*. It is the disadvantage for a given individual that limits or prevents the fulfilment of a role that is normal (depending on age, sex, social and cultural factors) for that individual.

Hearing status

To examine a person's hearing status thoroughly not only the *impairment*, but also the consequences of impairment in daily-life (*disability* and *handicap*) need to be evaluated separately. This seems self-evident. However, in the international world of audiology only measurements of impairment have been used to assess the hearing status of an impaired person to this day. One reason for this may be that until now the assessment is a medical decision-making process. Physicians carry out an authoritative medical evaluation. The current schemes, applied for compensation purposes and for assessing suitability for work, are based only on measurements of sensitivity for sounds.

The scheme used in the Netherlands is the one developed by the American Medical Association (AMA), which is the most commonly used scheme. In only a few European countries speech-discrimination tests are being used to assess hearing disability and handicap (Feldmann, 1988; Parving, 1986; Brusis, 1995; Glazenburg, 1997). The current scheme in Great Britain is recommended by the British Association of Otolaryngologists (BAOL). The AMA as well as the BAOL use pure-tone thresholds that are converted into formulae to predict the percentage of disability. Great dissatisfaction with such calculations arose when various investigators demonstrated that the formulae are poor predictors of self-reported difficulty experienced in daily-life listening (Noble and Atherly, 1970; Ewertsen and Birk-Nielsen, 1973; Jerger and Jerger, 1979; Salomon and Parving, 1985; Parving et al. 1986; Lutman, 1987; Matthews et al., 1990; King et al. 1992). As a reaction, self-report became an important alternative approach to assess hearing status. During the last several decades many self-assessment instruments have been introduced (Noble and Atherly, 1970; Ewertsen and Birk-Nielsen, 1973; Kapteyn, 1977; Habib and Hinchcliffe, 1978; Giolas et al., 1979; Jerger and Jerger, 1979; Stephens 1980; Show and Nerbonne, 1982; Ventry and Weinstein, 1982; Salomon and Parving, 1985; Demorest and Erdman, 1986; Lutman et al., 1987; Hétu et al., 1994; van den Brink, 1995). However, despite the fact that self-report proved to be very useful in clinical practice, it is not a satisfactory method for (financial) compensation purposes since people can easily falsify their results. Objective measures are therefore indispensable. As long as no alternative method to assess the hearing status becomes available the current schemes will be used. However, no doubt exists about the need for a more accurate method to quantify disability and handicap.

This thesis presents an approach for the assessment and quantification of a person's overall hearing status. Each chapter describes a step in that approach, concerned with the assessment of auditory disability and handicap.

Assessment of Disability

The first aim of the research project was to explore the domain of hearing disability. A great variety of difficulties experienced by hearing-impaired people can be used to describe hearing disability. However, systematic investigation of what is meant by the term 'disability' would be greatly simplified if it were possible to identify a relatively small number of underlying dimensions that represent relationships among sets of many interrelated hearing difficulties. This was attempted in our first study as described in chapter 2. To uncover a reduced set of factors or dimensions of disability affecting the individual in daily-life hearing, the Amsterdam Inventory for Auditory Disability and Disability was developed. Chapter 2 describes the development of the inventory as well as the factor analysis that was performed. The results show that five factors should be considered as fundamental in auditory disability: *distinction of sounds*, *auditory localization*, *intelligibility in noise*, *intelligibility in quiet* and *detection of sounds*. This outcome emphasizes the multidimensional character of hearing disability. These factors or dimensions run through this thesis like a continuous thread.

Even though other investigators like Noble (1978), Lutman (1987) and Stephens (1980) recognize the importance of detection of non-speech sounds and localization in daily-life hearing, the current formulae and schemes (as mentioned earlier) are not yet adapted. The main reason for this is that no adequate objective measurements of disability are available at the present time. This finding motivated us to initiate the second part of the research project.

It was our goal to develop a set of performance tests to quantify each of the five above-mentioned dimensions of disability. The project was an attempt to develop a more complete and adequate method to assess hearing disability. Both newly developed and conventional tests like the pure-tone ideogram have been used. Stepwise multiple regression analysis have been performed to study relationships between the five disability factors and the various performance tests. Particularly the limited role of the pure-tone audiogram in describing everyday difficulties is discussed. Procedures and results of the study are described in chapter 3 and chapter 4.

Assessment of Handicap

Assessing handicap is more complicated than estimating disability since handicap refers to personal consequences of disabilities that vary from person to person. It involves the great diversity of psychosocial disadvantages experienced by the hearing-impaired individual. While it is assumed that the degree of hearing handicap generally increases with increased hearing disability, handicap may vary, depending on the attitudes and perceptions of the affected individual as well as on the demands placed on one's ability to hear. The concept handicap has been extensively investigated by Hétu et al. (1988). Their work presents an overview of expressions of handicap, and their findings induced them to make a useful distinction between *primary* and *secondary* handicap.

Primary handicap results directly from disability and it is usually expressed as the limitation of certain activities. It is defined as the extent to which people are annoyed by experiencing feelings of anxiety, unsafeness, isolation.

Secondary handicap results from trying to compensate for the disabilities experienced in everyday activities that are otherwise pursued normally. It refers to the cost of adjustment to prevent or minimize the disabilities and is characterized by increased mental effort.

Stephens and Hétu (1991) even proposed an extension of the WHO classification to include these two dimensions of handicap. In line with these findings and in order to contribute to a better understanding of the handicap concept and its relationship to disability, we also made a distinction between *primary* and *secondary* disability. The two concepts have been studied successively. Chapter 5 addresses the study in which *primary* disability has been investigated by means of the Amsterdam Inventory. The weight (severity and limiting effect) of each of the five disabilities felt and rated by hearing-impaired participants has been examined and reported. Also, the frequency of occurrence of each disability in the population has been described. The chapter deals with the question if it is justified to assume that all five disabilities are equally important in daily-life.

The last part of this thesis addresses the notorious aspect of *secondary handicap*: the demand of extra effort and concentration during listening. Auditory fatigue as a result

of extra concentration is a serious and often-reported complaint of hearing-impaired individuals. It is particularly this aspect that affects the social relationships and activities of the hearing-impaired person and it should therefore be considered seriously in any assessment process. However, the problem here is that self-report seems to be the only possible approach to assess *secondary* handicap while objective measurements are required. We therefore decided to direct the last stage of the project to this issue and started to investigate the possibility to quantify mental effort required during listening. A number of international studies have shown that dilatation of the pupil is a sensitive measure of the degree of mental effort demanded by a task (Janisse, 1977). According to this finding we used pupil dilatation as an index of mental effort in our study and investigated the variation of the pupil diameter of both normal-hearing and hearing-impaired listeners during a speech reception task. The study was an attempt to explore new ways in the assessment of hearing handicap. Encouraging findings are presented in chapter 6.

2

FACTORS IN SUBJECTIVE HEARING DISABILITY

This report describes an approach to identify different factors in hearing disability. On the basis of interviews and case studies The Amsterdam Inventory for Auditory Disability and Handicap was developed. It consists of thirty questions, dealing with a variety of everyday listening situations. Reports of 274 hearing-impaired subjects are presented. Item and factor-analysis on the questions resulted in five factors, interpreted as five basic auditory disabilities: 'distinction of sounds', 'intelligibility in noise', 'auditory localization', 'intelligibility in quiet' and 'detection of sounds'. Investigation of one excluded item showed that 'intolerance of noise' may be a sixth aspect.

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INTRODUCTION

Auditory disability represents the difficulties experienced in everyday hearing. In this study and according to the International Classification of the WHO (1980), disability refers to the auditory consequences of hearing impairment. It is concerned with what happens in daily-life as a result of a hearing impairment and takes form as a failure in accomplishments. Several attempts have been made to explore the auditory disability domain and its relationship with auditory impairment.

Hitherto, information mainly derived from pure-tone audiometry (PTA) and sometimes speech audiometry has been used in order to assess the difficulties that hearing-impaired people experience in daily-life. Using formulae, hearing disability has been calculated on the basis of pure-tone thresholds (AAOO, 1979; BAOL, 1983) or on the basis of data derived from speech audiometry (Feldmann, 1988).

Dissatisfaction with these calculations arose when various investigators demonstrated that PTA is a poor predictor of subjective difficulty experienced in daily-life listening (High et al., 1964; Ewertsen and Birk-Nielsen, 1973; Kapteyn, 1977; Rosen, 1979; Lutman and Robinson, 1992).

Self-report became an important tool for the assessment of auditory disability and during the last decades many questionnaires have been developed, as reviewed by Schow and Gatehouse (1990). However, most of the questions contained in these questionnaires cover communication (High et al., 1964; Ewertsen and Birk-Nielsen, 1973; Giolas et al., 1979; Demorest and Erdman, 1986). The same is the case in other experimental tools that have been developed to quantify auditory disability/handicap, such as the QUAH (Jerger and Jerger, 1979) and the disability/handicap-scaling procedure of Salomon and Parving (1985). In 1979, Noble distinguished disability related to non-speech sounds and spatial localization. Besides speech intelligibility, other basic aspects of hearing, like localization and recognition and identification of sounds, evidently are important in daily-life listening (Noble, 1979,1995; Barcham and Stephens, 1980; Lutman et al. 1987; Stephens, 1987; Davis, 1987; Hétu et al. 1988; Stephens and Hétu, 1991;). A disability in any of those aspects implies restrictions in daily-life. However, standardized instruments for assessing all these disabilities separately are not available yet. The goal of the present study was to make an inventory of the relevant factors of disability in individual hearing functioning in daily living.

The study was undertaken to provide information about what constitutes hearing disability. Correlations between difficulties in speech discrimination and localization disability have been recently discussed by Noble and colleagues (1995). So our goal includes an inquiry of the correlations between different factors of hearing disability.

The present report describes the development of The Amsterdam Inventory for Auditory Disability and Handicap, based on a number of interviews and case studies. It was our aim to determine statistically which different auditory disabilities can be distinguished in everyday hearing. Only when these basic disabilities have been discovered can a score be attributed to each of them. In that way a profile of the individual's disabilities can be obtained. Results of this study can be used to investigate the disabled effect of disabilities. The present study forms part of a larger investigation. In the next stage the subjective disabilities have to be evaluated by means of a battery of appropriate psychoacoustical tests. Comparison of these test results and the subjective information derived from the inventory may lead to a better understanding of the relationship between auditory impairment and disability in everyday hearing.

Terminology

The terms impairment, disability and handicap are defined according to the classification of the WHO (1980). Impairment: any loss or abnormality of psychological, physiological or anatomical structure or function.

Disability: any restriction or lack (resulting from an impairment) of the ability to perform an activity in the manner or within the range considered normal for a human being. Handicap: a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal (depending on age, sex and social and cultural factors) for that individual.

PROCEDURE

To investigate what hearing-impaired people themselves consider to be the most difficult situations in daily-life, as a consequence of their hearing impairment, we conducted unstructured interviews with patients who came to visit the audiology center. The patients were asked to report their main difficulties and to explain how they experience their hearing loss in different situations in daily-life. Evaluation of these reports, combined with information derived from international studies (High et al., 1964; Giolas et al., 1979; Noble, 1979,1995; Barcham and Stephens, 1980; Demorest and Erdman, 1986; Lutman, 1987,1992) and knowledge of staff-members from different disciplines of the audiology center, made it clear that functional restrictions mainly express themselves in certain activities of daily-life.

Based on these findings different aspects of hearing disability were suggested. For each of those aspects we developed five questions:

Speech intelligibility in noise (items 1,7,13,19,25), speech intelligibility in quiet (items 2,8,14,20,26), auditory localization (items 3,9,15,21,27), recognition and identification of sounds (items 4,10,16,22, 28), detection of sounds in general (items 5,11,17,23,29) and perception of music (items 6,12,18,24,30). Table 2.2 shows the item numbers and questions.

The response scales ranged from 'almost never', 'occasionally', 'frequently' to 'almost always'. The responses were coded as 3, 2, 1, 0 respectively. For two questions these categories were ranged in a reversed order. This was done to try to counteract response biases. In order to keep the respondents unaware of the fact that five questions were developed for one aspect, items on the same topic were scattered over the questionnaire.

The first set of thirty questions was presented to normally hearing people (N=11) in order to eliminate inadvertent biases such as ambiguities and leading questions. Items that appeared to be too complex or vague were rephrased, replaced or simplified.

After the first revision, the questionnaire was used in a face-to-face interview with hearing-impaired people (N=11) to make sure that every respondent interpreted the questions as intended. These interviews showed that again some items had to be rephrased or replaced and, moreover, that not every respondent had the same listening situation in mind when reading a question. So, we decided to illustrate every question with a small picture. When the first experimental form was administered to a few hearing-impaired persons it turned out that the layout caused some difficulties and had to be reconsidered.

The present version of the inventory consists of thirty questions (see Appendix A). Each question is divided into three parts. In part one, the hearing-impaired person judges how often he or she experiences auditory difficulties in the mentioned situation.

The second part of every question deals with former hearing performance. This part was included in order to be able to investigate the frame of reference of the respondent in the next stage of the inquiry. It is important to know whether the person has ever been able to hear normally in that situation or if the hearing impairment was present at birth.

In the third part the respondent is asked to judge how handicapped he or she feels by having difficulties in hearing in the mentioned situation. This part has to be completed only if the respondent rated 'almost never' or 'occasionally' to be able to hear in part one of the question. The four answer categories are as follows: no, slightly, moderately, considerably.

A study on the third part of every question (assessing the handicapping effect of disability) is presented in chapter 5 of this thesis.

Subjects are asked to respond on the basis of their experiences *without* a hearing aid. This remark is repeated in every question. Hearing-aid users who have never performed without an aid and, as a consequence, do not know how they would function without, are asked to respond on the basis of their experience with an aid. When this occurred, an extra circle had to be marked (see Figure 2.1).

In order to obtain some general information about the respondents, an appendix consisting of questions about age, sex, occupation and intolerance of noise was added to the inventory.

KUNT U IEMAND DIE U AANSPREEKT IN EEN DRUKKE STRAAT VERSTAAN?

25a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

O Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

25b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

O Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 25c hoeft u alleen te beantwoorden als u bij vraag 25a bijna nooit of soms invulde!

25c. Vindt u het hinderlijk dat u iemand, die u aanspreekt in een drukke straat, slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

Figure 2.1. *An example of one item of the inventory*

SUBJECTS

In total, 541 adults, who participated in a previous study about hearing impairment and their occupations (Kapteyn et al. 1997), were sent an inventory. These subjects, from all over the country, had been referred to audiologists and otolaryngologists for very different reasons. The audiologists and otolaryngologists had informed their patients about the previous study and had asked them to participate in that inquiry. The only requirements for participation were a hearing impairment (mean hearing threshold level of at least 25 dB for the frequencies 0.5, 1, 2 and 4 kHz averaged across the two

ears) and an age not exceeding 70 years. The age limit was introduced since the aims of the previous study required an occupational population. Occupational specialities were varied as were the types of hearing loss. This is noted to emphasize that our sample was a mixed group of patients, not restricted to subjects with noise-induced hearing loss. The participants in the previous study had to be informed about the results of that study and the inventory was included in the mailing, together with a reply-paid envelope and a letter of introduction. The subjects did not have any financial interest in this study. People who did not respond within three months received a reminder. 310 subjects (57 percent) returned the questionnaire of which 36 were excluded because of incomplete answers. The age of the subjects (199 male and 75 female) ranged from 16 to 66 (M=48.3).

METHODS

In order to obtain information about the variability among the responses to each question, frequency distributions for the first parts of all items of the questionnaire were examined.

As it was our purpose to identify a set of aspects of disability that can be distinguished, a factor-analysis with principal components was performed on the first parts of the thirty items of the inventory, concerning the subjective disability. The analysis proceeded in a few steps. First, the correlation matrix for all variables was computed. In a second step, factor extraction was determined. We also ascertained how well the chosen model fitted the data by performing Bartlett's test of sphericity and by measuring the sampling adequacy. Lutman et al. (1987) and Noble et al.(1995) showed an interdependence between the various aspects of hearing disability as distinguished in their studies and therefore first orthogonal (varimax) and then oblique rotation methods were employed. Different scales, resulting from factor-analysis, were analyzed with regard to coherence. Particularly the alpha-coefficient, being a measure of internal consistency (Cronbach, 1990), is of great interest. All analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 4.0).

RESULTS

Figure 2.2 shows the frequency distributions for all 30 questions. The shapes of the distributions show a great variability among the responses. This indicates that the items provide information about individual differences.

None of the distributions has an obvious central value, although the items 2 and 8 have the maximum response as 'almost always'. Almost all items showed substantial positive correlations (Pearson's $r > 0.30$) with at least 20 of the other variables. The highest correlation was found between the items on understanding the presenter of the news on the television and understanding the presenter of the news on the radio ($r = 0.81$). The item on 'intolerance of loud music' (item 18) showed negative correlations with the vast majority of the other questions. This item seemed to measure something on its own and, hence, was eliminated before proceeding with the factor-analysis and considered separately. The exclusion of this particular item resulted in a Kaiser-Meyer-Olkin (KMO) measure of 0.94 and a highly significant test of sphericity ($p < 0.001$).

Bartlett's test of sphericity can be used to test the hypothesis that the correlation matrix is an identity matrix. If the population correlation matrix is an identity matrix, the use of the factor model should be reconsidered. The test of sphericity was highly significant, so it appears unlikely that the model should be reconsidered.

The Kaiser-Meyer-Olkin measure of sampling adequacy is an index for comparing the magnitudes of the observed correlation coefficients with the magnitudes of the partial correlation coefficients (Cureton and d'Agostino, 1983). If the sum of the squared partial correlation coefficients among all pairs of variables is small (when compared to the sum of the squared correlation coefficients), the KMO measure is close to one. Small values for KMO measure indicate that a factor analysis of the variables may not be a good idea. Since the KMO measure was 0.94, we decided to proceed with the factor analysis without the item mentioned before.

Six factors with eigenvalues greater than 1 were extracted, explaining 60.8 percent of the variance. The least important factor, the sixth, was characterized by only one single item dealing with the phenomenon of missing parts of music while listening to music or songs (item 30). A factor existing of only one single item is not well determined and

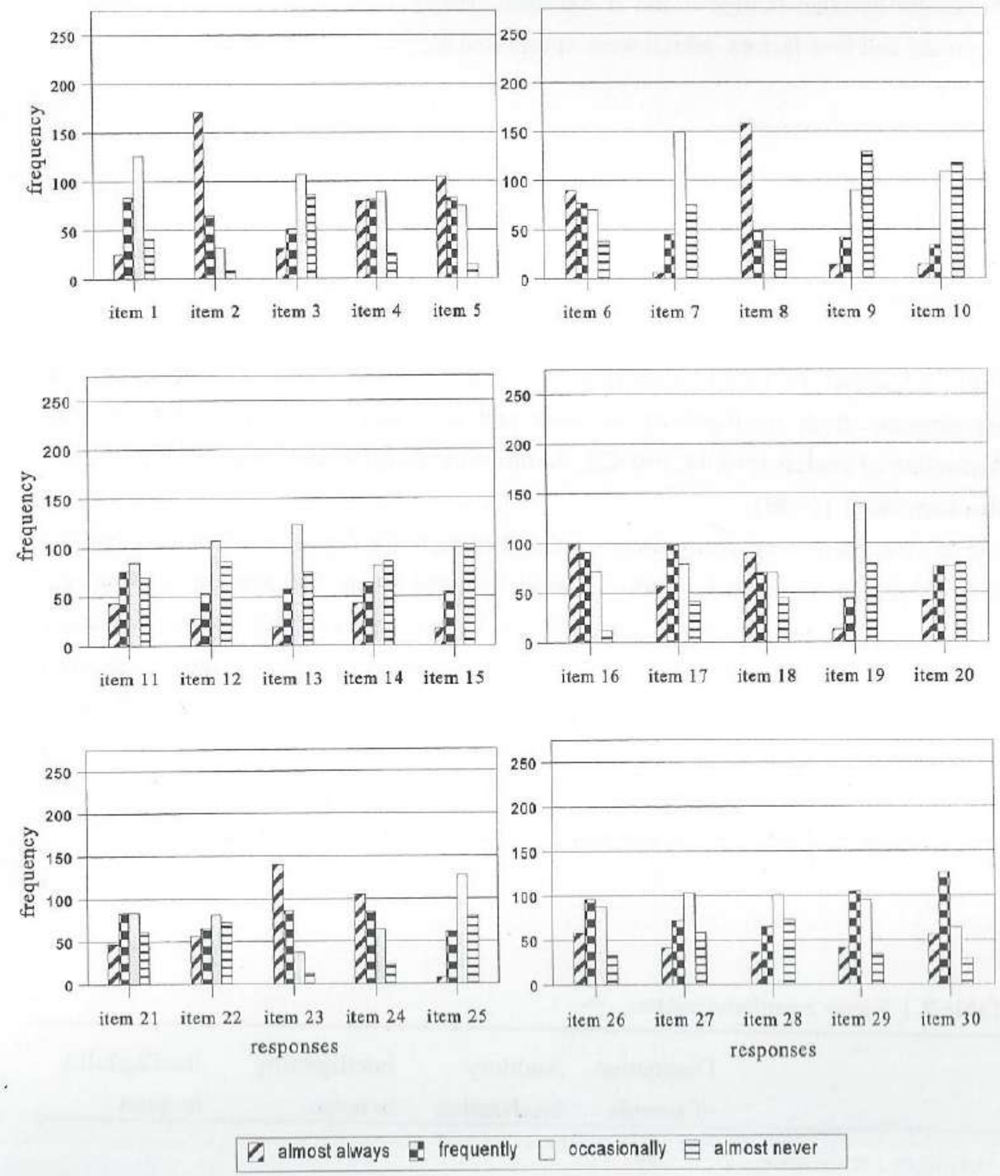

Figure 2.2. *Frequency distributions for all 30 items of the inventory.*

should be avoided (Cureton and d'Agostino, 1983). Hence, we proceeded with 28 questions and five factors, which were interpreted as:

A. distinction of sounds
B. auditory localization
C. intelligibility in noise
D. intelligibility in quiet
E. detection of sounds

Table 2.1 shows the factor correlation matrix. Some of the factors showed substantial correlations. Both *intelligibility in quiet* and *detection of sounds* correlated with *distinction of sounds* (r=0.44, r=0.42). *Auditory localization* and *intelligibility in noise* also correlated (r=.43).

The 28 remaining items were categorized according to the factor on which they had the highest loading. Three items loaded on more than one factor. The item on 'hearing cars passing by' correlated with the factor *distinction of sounds* (r=0.40) and with *auditory localization* (r=0.38). The item on 'a telephone conversation' correlated with both *intelligibility in quiet* (r=0.44) and *distinction of sounds* (r=0.42). The item on 'hearing somebody approaching from behind' correlated with *detection of sounds* (r=0.50) and *intelligibility in noise* (r=0.45). The resulting five scales showed rather high alpha coefficients (see Table 2.2), suggesting that coherent entities were being measured.

Table 2.1 *Factor correlation matrix.*

	Distinction of sounds	Auditory localization	Intelligibility in noise	Intelligibility in quiet
Auditory localization	.39			
Intelligibility in noise	.37	.43		
Intelligibility in quiet	.44	.26	.34	
Detection of sounds	.42	.26	.27	.29

Table 2.2 *Factor structure of items of the inventory with factor loadings and alpha coefficients of the different scales.*

Item	Factor	Alpha Coeff	Factor loading
	Distinction of sounds	**.89**	
24	Can you hear rhythm in music or songs?		.81
23	Can you distinguish between male and female voices?		.71
5	Do you recognize members of your family by their voices?		.68
29	Can you recognize and distinguish between different musical instruments?		.66
6	Can you recognize melodies in music or songs?		.64
26	Can you distinguish intonations and voice inflections in people's voices?		.59
17	Can you discriminate the sound of a car and a bus?		.57
4	Can you hear cars passing by?		.40
	Auditory localization	**.88**	
15	Do you immediately look in the right direction when somebody calls you in the street?		.87
3	Do you immediately hear from what direction a car is approaching when you are outside?		.81
27	Do you hear from what direction a car horn is coming?		.80
21	Can you hear from what corner of a room someone is talking to you being in a quiet house?		.66
9	Can you hear from what corner of a lecture room someone is asking a question during a meeting?		.65
	Intelligibility in noise	**.81**	
7	Can you carry on a conversation with someone during a crowded meeting?		.75
25	Can you carry on a conversation with someone in a busy street?		.70
19	Can you follow a conversation between a few people during dinner?		.67
1	Can you understand a shop-assistant in a crowded shop?		.63
13	Can you easily carry on a conversation with somebody in a bus or car?		.60
	Intelligibility in quiet	**.85**	
14	Can you understand the presenter of the news on TV?		.80
20	Can you understand the presenter of the news on the radio?		.80
11	Do you recognize a presenter on TV by his/her voice?		.52
12	Can you understand text that's being sung?		.46
8	Can you carry on a telephone conversation in a quiet room?		.44
	Detection of sounds	.77	
28	Do you hear birds singing outside?		.65
16	Can you hear noises in the house holding like running water, vacuuming, a washing machine?		.55
22	Can you hear the door-bell at home?		.55
2	Can you carry on a conversation with someone in a quiet room?		.50
10	Can you hear somebody approaching from behind?		.50
	Excluded items:		
18	Do you experience that music is too loud for you, while others around don't complain about the loudness?		
30	Do you miss parts of music while listening to music or songs?		

The excluded item on 'intolerance of loud music' was compared to the question about 'intolerance of loud noise' in the appendix of the inventory. The chi-square test for linear association showed an extremely high observed level of significance ($p < 0.001$) (Spearman rank correlation is 0.54).

Subjects who reported to have 'almost always' or 'frequently' difficulties with loud noises were telephoned (N=42) and asked for explanation in order to make sure that they had understood the question. Most of these subjects confirmed that they did recognize and experience the problem of intolerance of loud noise. The majority of complaints seemed to relate to recruitment phenomena and/or middle-ear surgery.

DISCUSSION

The inventory that we developed in our center deals with many daily-life listening situations. The present results support the statement that different aspects of hearing should be distinguished and taken into account separately in audiological research with regard to disability. This study not only recognizes the significance of factors other than hearing for speech, but it also shows how these factors' intercorrelate. Five separate factors, which we interpret as five basic aspects of auditory functioning, were identified by factor-analysis. Determination of the factor's *C* (*intelligibility in noise*) and *D* (*intelligibility in quiet*) was expected as it is evident that speech intelligibility is very important in daily-life listening. Also Lutman's data (1987) distinguished between speech in everyday situations (comparable with our factor C) and in quiet. The same applies to the factor *auditory localization.*

Examination of *intelligibility in quiet* shows that almost all items seem to refer to non-live voice. It is worth mentioning here that Stephens and Hétu (1991) in their proposed classification of disabilities in listening to speech, make a distinction between live-voice and non-live voice. Our results seem to support their classification. In common with Noble et al. (1995) we found a correlation between *auditory localization* and *intelligibility in noise*. Differentiation of *distinction of sounds* and *detection of sounds* is quite interesting. As shown in Table 2.1 the items of *detection of sounds* appear to reflect situations in which information about the acoustical environment is essential.

The items of *distinction of sounds* refer to the timbre of the perceived sounds. Thus the distinction of those two factors *A* and *E* makes clear that it is very important whether the perceived non-speech sounds contain essential information about the environment or whether the perception is concerned about the color or timbre of the sound only. The latter aspect may seem to be a luxury problem only, but for recognition and interpretation of sounds and particularly for certain occupational groups (like musicians) it is an indispensable ability. Although we expected a separate aspect 'music', this aspect did not appear as a factor in the analysis. The questions about this topic were scattered through the other factors. This means probably that listening to music is a complex auditory ability in which various basic aspects of hearing are involved.

The item on 'intolerance of loud music' appeared to be deviant during the performance of the factor analysis. It might be reasonable to think that the meaning of the question was not clear or that the reversed order of answering categories caused a bias. However, the information obtained by telephone and the result of the chi-square test for linear association of this item and the question about 'intolerance of noise' in the appendix, indicates that the deviant character of this item is not due to these biases. Rather it might be possible that the difficulty related to 'intolerance of noise' is another aspect of hearing disability. This finding supports the classification of disabilities proposed by Stephens and Hétu (1991). Disability relating to tolerance of noise is also listed in the WHO document. Further investigation of this topic is required.

A few items loaded on more than one factor. It is reasonable to suggest that these items are not clearly formulated.

It must be noted that all the data described in this report were gathered mainly from a working population. An advantage of the sample used is that subjects are aware of their hearing disability and are motivated to report the difficulties that they experience in daily-life. The participants did not have any financial interest in the study. Financial interests could have biased the responses.

Compared to the self-assessment tools developed in the past, this inventory is quite different in the way it approaches the handicap that a hearing-impaired person might experience: items describing concrete emotional and behavioural consequences of the disability are not included. These consequences are supposed to differ widely in and between persons. Of greater importance is the impact of limitations in hearing on individuals, assessed in the third part of every question of this inventory. In this report, factor-analysis was performed on the first parts of the questions only. Therefore, a separate factor 'handicap' did not emerge. It should be noted here that a comparable tool, the Initial Disability Interview, has recently been developed by Gatehouse (1994).

The results of the present study form the basis for the next step in the research project. Reported restrictions on each of the separated factors will be scored. After plotting these scores, a hearing disability profile for every individual becomes available. The next chapter will be focussed on a comparison between the self-reported disabilities (as distinguished in this study) and psychoacoustical measurements.

3

THE RELATIONSHIPS BETWEEN SELF-REPORTED HEARING DISABILITY AND MEASURES OF AUDITORY DISABILITY

Although required for many practical purposes, adequate measures of hearing disability are not available yet. In an attempt to identify a set of performance tests for predicting hearing disability in daily-life the relationship between self-reported disability scores and measures of auditory disability was examined. The Amsterdam Inventory was completed by 51 respondents aged 30 to 70 years who also performed on various tests. Earlier factor analysis of the inventory scores resulted in the distinction of five aspects of auditory disability. Stepwise multiple regression analysis in the present study shows that the tests describe and differentiate quite well between these five aspects. Multiple correlation coefficients range from R=0.60 to R=0.74.

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INTRODUCTION

Hearing disability is a frequently used term in audiology. According to the classification of the WHO (1980) this term refers to any restriction or lack of ability to perform an activity in a normal way. In other words, it concerns the difficulties that hearing-impaired persons experience in everyday listening. Estimation of degree of hearing disability has frequently been the object of study in audiological research. Both self-rating procedures (Schow et al., 1990) and performance tasks have been used to assess hearing disability (Gatehouse, 1989; Haggard et al., 1986). Various schemes (AAOO, 1979; BAOL, 1983; King et al., 1992) have been developed in which the percentage disability is calculated on the basis of pure-tone thresholds or on the basis of data derived from speech reception tasks. Hearing disability is then identified by speech/word identification and predicted by audiometric parameters. Recognition of the limitations of these calculations as being representative for daily-life hearing (Saunders et al., 1992; Middelweerd et al., 1990; Ferman et al., 1993) resulted in growing acceptance of the estimation of hearing disability by means of self-report. In some situations, however, for instance in compensation cases or for assessing suitability for work, self-assessment might be inadequate, since individuals can easily exaggerate or deny their actual disability. Therefore, in these cases, objective measurements of hearing disability are preferred. In order to know which performance tests should be considered as representative for disability in daily-life hearing, comparison of self-reported data with audiological results may provide useful information. During the last 20 years a few studies have been focussed on those comparisons. Despite the attempts to quantify auditory disability by means of psychoacoustic tests, no successful results could be reported till now. (Noble et al., 1970; Weinstein and Ventry, 1983).

It is remarkable that in most of the studies concerning the assessment of hearing disability, the importance of sounds in everyday hearing other than speech is ignored. Lutman (1987, 1992) recognized this problem and stated: " a uni-dimensional scale of hearing disability does not take account of the many facets of disability affecting the individual and cannot be construed to give a complete description of disability." Also Noble (1970,1995) acknowledged the significance of different facets. He recognized and examined not only the disabilities associated with hearing for speech but also those associated with impaired auditory localization. The relevance of factors other than hearing for speech in daily-life listening is shown in the previous chapter. Investigation of self-assessed restrictions in everyday hearing in the previous chapter resulted in the identification of five distinguished disabilities.

The aim of the present study is to examine the relationship between these self-assessed disabilities, derived from the Amsterdam Inventory and appropriate performance tests. The study is undertaken to compare types of tests with the different scales of the inventory. This chapter focusses on the quantification of self-reported disabilities by means of various measures of auditory disability. The study is part of a larger research project concerned with the estimation of hearing disability and handicap.

METHODS

Participants

Participants in this study comprised a subset of the population of 274 people that completed the inventory and whose responses were subjected to factor-analysis as described in the previous chapter. Persons from this population were selected so that a wide range of self-reported disability scores would be encountered in the sample of the present study. Selected respondents were informed of the sampling in a telephone call and asked for their participation. The sample (N=51) consisted of both male (N=34) and female (N=17) participants and the ages ranged from 30 years to 70 years with a mean of 52 years. Seventy-five percent of the participants had a sensorineural hearing loss, 8 percent a conductive loss and 17 percent a mixed hearing loss. Four persons had one totally deaf ear.

Self-reports

Self-reported disability was assessed using The Amsterdam Inventory for Auditory Disability and Handicap. This inventory consists of 30 questions, dealing with a variety of everyday listening situations. For example "Can you carry on a conversation with someone in a busy street?" Responses to each question of the inventory were given on a scale, ranging from 'almost never', 'occasionally', 'frequently' to 'almost always'. The responses were coded as 3, 2, 1, 0 respectively. In this inventory, five factors, interpreted as five basic auditory disabilities are distinguished: *intelligibility in quiet, intelligibility in noise, distinction of sounds, detection of sounds* and *auditory localization.* Four factors consist of five questions and one factor (*distinction of sounds*) consists of eight questions. Disability scores were calculated by summing the responses to the corresponding questions included in each factor.

In the inventory, participants were asked to respond on the basis of their experiences without a hearing aid. Twelve hearing aid users had never performed without an aid and, hence, did not know how they would function without one. They responded on the basis of their experiences with an aid. These severely hearing-impaired people were not excluded from the sample in view of our aim to encounter a wide range of scores in the sample.

Test battery

A battery consisting of six performance tests was constructed in which the following tests were included:

1. *Pure-Tone audiometry*

Pure-tone audiograms were obtained with a conventional audiometer (Madsen OB 822). For each ear the hearing loss, averaged over 500, 1000, 2000 and 4000 Hz was calculated. The average of both ears was referred to as Hearing Threshold Level (HTL). In case of one totally deaf ear the average loss of the deaf ear was taken as 100 dB. The absolute difference between the right and left hearing threshold level was referred to as DIF. The influence of inequality of the two ears in the regression model is examined subsequently.

2.*Speech-discrimination*

Speech discrimination was measured in conformity with the standard procedure in the Dutch audiology centers, using lists of 10 Dutch CVC words presented through earphones at various sound-pressure levels. Both ears were tested separately. The maximum percentage correctly identified phonemes for the better ear was used as an index of speech discrimination (SD).

3.*Speech-reception threshold in quiet*

The speech-reception threshold (SRT) for sentences in quiet was measured in free-field. Subjects were seated in a silent room facing a loudspeaker at a distance of 1 meter. The SRT was determined according to an up-down adaptive procedure (Plomp and Mimpen, 1979): a list of 13 sentences, read by a female speaker was presented in a fixed order. The first sentence was presented at a level below the reception threshold. This sentence was repeated with increasing sound level until the listener could reproduce it correctly. The level was then decreased by 2 dB for the presentation of the second sentence. For the remaining sentences, which were presented only once, the speech level was decreased by 2 dB after a sentence was repeated correctly and increased by 2 dB after it was reproduced incorrectly. The average adjusted level for the last 10 sentences was adopted as the SRT in quiet (SRTq) which is defined here as 50 percent intelligibility.

4.*Speech-reception threshold in noise*

SRT in noise was measured in free-field using steady-state noise (SRTns) (Plomp and Mimpen, 1979). Independent noise signals were produced over two identical loudspeakers, which were located diagonally opposite the subject (45 deg) (Figure 3.1).

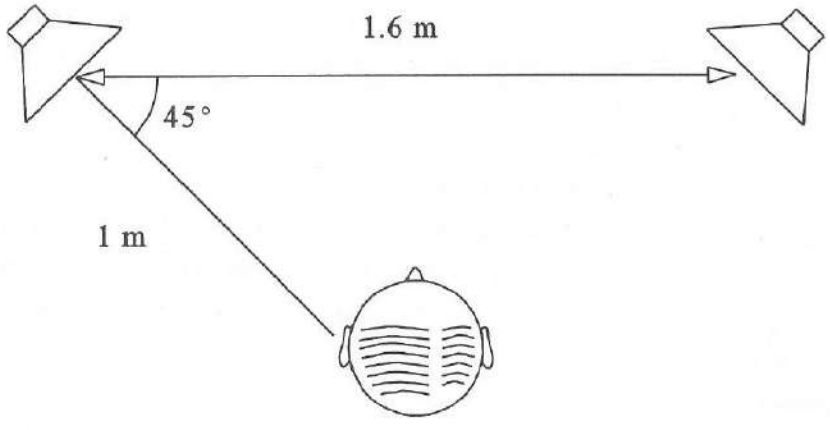


Figure 3.1. *Position of the subject and the loudspeakers during the speech-reception threshold measurements in noise.*

The speech signals from both loudspeakers were identical, creating a phantom speech source. Participants were not allowed to move their head and had to look straight ahead. For every subject, the level of noise was chosen at a 20dB higher level than the SRT in quiet, with a minimum of 60 dBA. For 24 participants the SRT in fluctuating interfering (SRTnf) noise was measured as well. Fluctuating noise signals were created according to the procedure described by Festen et al. (1990). Both the steady and the fluctuating noise had a spectrum equal to the long-term average spectrum of the female voice. The further procedure was the same as described for SRT in quiet. The speech to noise ratio was adopted as the SRT in noise (SRTns or SRTnf) which is defined as 50 percent intelligibility in noise.

5. *Localization of sounds*

For this test, developed by Smoorenburg (1990), the subject was surrounded by eight loudspeakers in a large room (200 m3) with a reverberation time of about 0.5 s (Figure 3.2). Tone bursts of 300 ms in duration were presented through one of the eight loudspeakers and had to be localized by the subject. For this purpose listeners used a response box with eight buttons corresponding with the eight loudspeakers. Masking pink noise of 70 dBA was presented through a loudspeaker, 1.5 m over the subject's head. Participants were not allowed to move their head and had to look straight ahead. The bursts were complex tones consisting of ten harmonics added in sine phase with amplitudes decreasing with 6dB/octave. The total intensity of the signal was 85 dBA.

In order to exclude the possibility that participants could recognize the loudspeakers by their timbre, eight fundamental frequencies (230 Hz to 370 Hz, 20 Hz apart) were used. Tone bursts were presented in a random sequence over eight loudspeakers and eight frequencies (64 presentations). To average out a possible inhomogeneity in the room this test was repeated once with a new sequence, with the listener facing the opposite way to that in the first test. The percentage correctly localized signals was referred to as LOC.

6. *Recognition of voices*

The ability to recognize voices was measured using pairs of pre-recorded three-digit numbers read by female speech therapists. The numbers were presented successively in pairs through a loudspeaker in front of the subject. For every pair the subject had to judge whether the two numbers were spoken by the same woman or by two different women. The test was performed in free-field in quiet in a silent room. Participants

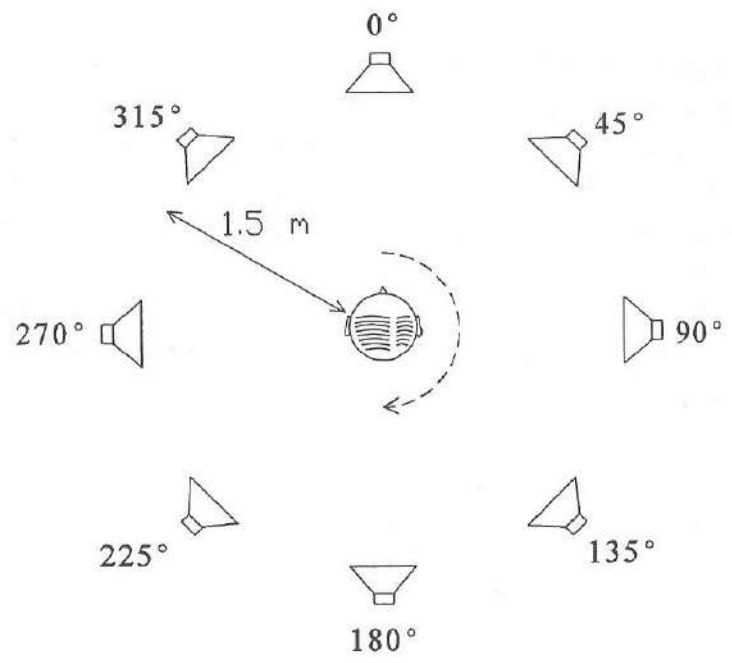


Figure 3.2 *Position of the subject and loudspeakers during the test localization of sounds (LOC).*

were allowed to choose their most comfortable loudness level. In total 45 pairs of voices were presented. The first five trials were used as an exercise. The percentage correctly judged pairs was referred to as recognition of voices (RV).

For all participants the pure-tone audiogram and speech-discrimination were measured without the use of hearing aid. As noted earlier, 12 respondents estimated their hearing disability on the basis of the use of a hearing aid. Hence, these people used their hearing aid during the remaining tests: SRT in quiet, SRT in noise, recognition of voices and localization of sounds.

The complete test session lasted about two hours.

Statistical Analysis

As it was our goal to find which tests relate most closely to the different factors of the inventory, Stepwise Multiple Regression analyses were performed with the disability scores as the dependent variables and the performance test results as the explanatory variables. For each factor separately a regression equation was generated that relates the scores on the inventory to the test results. The residuals, which are assumed to be normally distributed in a regression analysis, were examined. Since the hearing aid can be a possible confounding variable, it was included in all the regression equations. The criterions for inclusion and exclusion in the regression model were p values of 0.15 and 0.20 respectively.

For ease of the survey all variables are given as follows:

The independent variables:

HTL (hearing threshold level)
SD (speech-discrimination)
SRTq (speech-reception threshold in quiet)
SRTn(s/f) (speech-reception threshold in steady (s) or fluctuating (f) noise)
LOC (localization of sounds)
RV (recognition of voices)
Hearing aid (AID)
Difference in HTL between both ears (DIF)

The dependent variables:

Self-reported summed scores on each of the five sections of the inventory:
Intelligibility in quiet
Intelligibility in noise
Distinction of sounds
Detection of sounds
Auditory localization
All the analyses were performed using the Statistical Package for the Social Sciences (SPSS).

RESULTS

The means, standard deviations, minima and maxima are given in Table 3.1 in order to provide insight into the data.

Table 3.1 *Means, SD's, minima and maxima of all variables as well as the number of participants (N).*

Variable	Mean	Std dev	Minimum	Maximum	N
Intelligibility in quiet	7.4	3.8	1	15	51
Intelligibility in noise	9.6	2.7	3	15	51
Distinction of sounds	8.0	4.6	1	19	51
Detection of sounds	6.9	3.2	0	13	51
Auditory localization	9.5	3.7	1	15	51
SRTq (dB)	37.2	13.7	10.6	71.0	51
SRTns (S/N ratio)	-1.5	3.6	-7.0	7.0	51
SRTnf (S/N ratio)	-2.8	4.0	-9.8	3.8	24
HTL (dB)	52.4	17.6	24.3	91.2	51
DIF (dB)	18.3	22.2	0.0	78.8	51
SD (%)	92.6	12.1	57.0	100.0	51
RV (%)	76.2	9.2	55.0	95.0	51
LOC (%)	41.3	15.5	12.0	75.0	51

Pearson's correlation coefficients between the test results and self-reported disability scores are shown in Table 3.2. As noted earlier a higher score on the inventory indicates poorer hearing. The correlations among the independent variables are given in Table 3.3. Multiple correlation coefficients and the percentage variance explained by each of the significant independent variables are presented in Table 3.4. As shown, the multiple correlation coefficient between *intelligibility in quiet* and the score on the

Table 3.2. *Pearson's correlation coefficients between the self-reported disability scores and the test results (N=51).*

	SRTq	SRTn	HTL	SD	RV	LOC	DIF
Intelligibility in quiet	.58**	.65**	.51**	-.52**	-.06	-.19	-.28
Intelligibility in noise	.24	.45**	.32	-.21	-.15	-.40*	.21
Distinction of sounds	.52**	.46**	.46**	-.22	-.26	-.25	-.18
Detection of sounds	.57**	.49**	.42**	-.31	-.03	-.04	-.32
Auditory Localization	.21	.20	.43**	-.14	-.12	-.46**	.37*

(* $p < 0.01$ ** $p < 0.001$).

performance tests is 0.73. This means that 53 percent of the observed variability in *intelligibility of speech in quiet* (reported in the inventory) can be explained by measures of *'SRT in steady noise' (SRTns)*, *'SRT in quiet' (SRTq)* and *'speech discrimination' (SD)*. In order to investigate the role of the *'HTL'* in the prediction of *intelligibility of speech in quiet* the *'HTL'* was forced into the regression procedure prior to other variables. No more than 25 percent of the variance could be explained. Only when the inequality of the two ears was taken into account did the *'HTL'* start to play an important role in the prediction of *intelligibility of speech in quiet*. This result is described in the following paragraph.

Table 3.3. *Pearson's correlation coefficients among the independent variables (N=51).*

	SRTns	HTL	SD	RV	LOC	DIF
SRTq	.50**	.61**	-.22	.02	-.14	-.35*
SRTns		.53**	-.70**	-.33*	-.18	-.29
HTL			-.39*	-.05	-.65**	.04
SD				.41*	-.09	.30
RV					.03	.12
LOC						-.53**

(* $p < 0.01$ ** $p < 0.001$)

For the prediction of *distinction of sounds*, *'SRT in quiet'*, *'recognition of voices' (RV)* and *'localization of sounds' ('LOC')* together can reach R=0.62. More than 30 percent of the variance explained in the equation to describe *detection of sounds* is contributed by *'SRT in quiet'*. The remaining amount of the variance explained (5 percent) is contributed by *'SRT in steady noise'*. The difference in *'HTL'* between the two ears (*'DIF'*) and the *'SRT in steady noise' (SRTns)* is significant in the equation to describe *intelligibility in noise*.

Initially, the *'SRT in fluctuating noise' (SRTnf)* was not added to the set of independent variables in the analysis, since data on this test were available for only 24 participants. In order to investigate the influence of fluctuating noise, the analysis was repeated with those 24 participants including *'SRT in fluctuating noise'* instead of *'SRT in steady noise'* in the set of explanatory variables. This resulted in a significant contribution of *'SRT in fluctuating noise'* and *'Speech-discrimination' (SD)* in the equation to describe *intelligibility in noise*. The multiple correlation coefficient reaches 0.69.

The assumption of normally distributed residuals in all the above-mentioned regression equations was met.

As shown in Table 3.4, the hearing aid is a confounding variable in the equation to describe *auditory localization*. In order to be able to investigate the relation between *auditory localization* and the independent variables without the effect of a hearing aid, the analysis was re-run with the remaining 39 unaided subjects. As shown in Table 3.4 the pure-tone audiogram then appears to be significant. The hearing threshold level (*'HTL'*) together with the difference in *'HTL'* between both ears (*'DIF'*) explain 36 percent of the total variance (R=0.60). Pearson's correlation coefficient between self-assessed *auditory localization* and localization performance on the *'LOC'* test is R=0.46. In order to gather baseline data, the localization performance of 16 normal-hearing people was also measured. The mean percentage correctly localized signals of this group was 60 percent. It must be noted here that some hearing-impaired persons report in the inventory severe difficulties in localizing sounds while they perform quite well on the *'LOC'* test. The opposite does rarely occur: a high estimation of the ability to localize sounds and a poor performance on the psychoacoustic test.

Table 3.4. *Outcomes of the stepwise multiple regression analysis relating each dependent variable (left column) to measures of auditory disability. The multiple coefficients are given in the right column (N=51).*

Self-reported disabilities	SRTq	SRTns	SRTnf	HTL(1:1) 0.5,1,2, 4 kHz	HTL(5:1) 1,2,4 kHz	SD	RV	LOC	DIF	AID	Multiple correlation coefficient
Intelligibility in quiet	9%***	42%*				2%					0.73
Intelligibility in noise		20%***							13%***		0.56
"			33%***			15%**					0.69#
Distinction of sounds	28%***						7%**	4%			0.62
Detection of sounds	33%***	5%**									0.62
"					47%***	7%**					0.74##
Auditory localization				8%				22%**		5%***	0.60
"				23%***					13%**		0.60##

\# N=24
\## N=39 unaided participants
* p < 0.1 ** p < 0.05 *** p < 0.01

In the analyses performed as described above, the average of both ears is referred to as the *'Hearing threshold level' (HTL)*. In order to study the effect of different frequency regions and inequality of the two ears, the regression models were recalculated with the *'HTL'* defined according to the formula: (5 x better ear + 1 x poorer ear)/6. The ratio 5:1 was chosen since it is applied by the British Association of Otolaryngologists (BAOL , 1983) as well as by the American Academy of Otolaryngology (AAOO, 1979).

The following combinations were applied:

(a).HTL=(5 x better ear + 1 x poorer ear)/6, each ear averaged at 0.5,1,2,4 kHz.
(b).HTL=average of both ears at 0.5, 1,2 kHz.
(c).HTL=(5 x better ear + 1 x poorer ear)/6, each ear averaged at 0.5 1,2 kHz.
(d).HTL=average of both ears at 1,2 and 4 kHz.
(e).HTL=(5 x better ear + 1 x poorer ear)/6, each ear averaged at 1,2 4 kHz.

The first formulation resulted in a significant change in the equation to describe *intelligibility in quiet* only when the hearing aid was left out of consideration and when the regression analysis was repeated with 39 unaided participants. The contribution of '*HTL*' then became highly significant ($p < 0.01$). The multiple correlation coefficient reached a value of 0.71. The formulations (b), (c) and (d) did not result in a significant change in any of the regression equations. Only small alterations in the levels of significance could be reported. A 5:1 weighting, averaged at 1,2 4 kHz as shown in (e) resulted in a change in the equation to describe *detection of sounds*. The hearing aid appeared as a confounding variable in the regression equation and, hence, the analysis was re-run with the remaining 39 unaided subjects. The results are shown in Table 3.4. The '*HTL*' (5:1)(1,2,4 kHz) together with '*speech-discrimination*' *(SD)* appear to be significant in the equation. The multiple correlation coefficient reaches 0.74, which means a more successful contribution of the '*HTL*' when the high frequencies and the ratio 5:1 are taken into account.

DISCUSSION

Although it is generally assumed that laboratory performance tests do not encompass all the aspects of everyday hearing (Dixon, 1983), the tests used in this study appear to describe and differentiate quite well between disabilities experienced in daily-life listening. Only certain aspects of psychoacoustical function located in the impairment domain (e.g. hearing threshold levels) appear to predict auditory disability. Most of the performance tests in this battery are themselves located in the disability domain. The results therefore show a limited relationship between measures of hearing impairment and self-reported disability and they demonstrate high correlations between performance measures of auditory disability and self-assessment data obtained with the Amsterdam Inventory.

A remarkable result is the importance of speech-reception threshold measurements in predicting disability scores. The regression analysis chooses *'SRT'* measures above pure-tone averages in the equations to describe *intelligibility of speech*. Hearing threshold levels only become significant for the prediction of *intelligibility in quiet* when ear-asymmetry is taken into account even though the amount of the variance explained by these threshold levels is not more than the variance explained by the speech-reception thresholds. This suggests that pure-tone measurement, although widely used in the assessment of hearing disability, is not the most sensitive test to estimate the many facets of disability affecting the individual in daily hearing. We do not attempt to argue that pure-tone audiometry does not provide useful information. For the diagnostic differentiation between various types of hearing loss the pure-tone audiogram is indispensable. The correlation coefficients in Table 3.2 and Table 3.3 show the contribution of the hearing threshold levels. Table 3.4 shows a material contribution of the *'HTL'* (5:1)(1,2,4 kHz) in the equation to predict *detection of sounds*. This will be discussed subsequently.

Our findings agree with the results of Smoorenburg (1992) who reported high correlations between pure-tone averages (< 4 kHz) and the SRT in quiet in a group of subjects with noise-induced hearing loss. It seems to be that a 5:1 weighting of the hearing threshold levels, averaged at 0.5,1,2 4 kHz is a good predictor of *intelligibility in quiet*. Pure-tone audiometry may therefore be used for the description of this aspect of

disability. However, the speech-reception threshold test (*'SRT')* provides a little bit more information, even though *'HTL'* and *'SRT'* seem to be similar to each other in the equation to describe *intelligibility in quiet*. Although all the included questions in the section *intelligibility in quiet* concern speech understanding in quiet situations, the *'SRT in steady-state noise'* contributes significant information (Table 3.4). An explanation for this phenomenon may be the fact that real silence does not exist in daily-life situations.

Another interesting result of this investigation is the relevance of fluctuating noise in describing *intelligibility in noise*. The addition of speech reception threshold measurements in fluctuating noise (*'SRTnf'*) (instead of *'SRT in steady-state noise'*) to the list of explanatory variables resulted in an increased multiple correlation coefficient. In *intelligibility in noise* a number of factors play a role: hearing the speech sound (particularly high frequencies), the location of the speaker, the distinction of the speech sound and the discrimination and recognition of the speech sound in a noisy environment in order to understand. The ability to distinguish the speech sound is reflected in the *'SRT in fluctuating noise'* (temporal resolution) and the ability to discriminate and recognize a sound is reflected in speech discrimination (frequency resolution). These variables explain a greater part of the variance compared to *'SRT in steady-state noise'* and *'DIF'*. A tentative conclusion may be that fluctuating interferences of speech are more common in daily situations than steady-state noises. It must be noted here that the last mentioned results are based on 24 persons only. However, in an extensive study Festen and Plomp (1990) also found that SRT in fluctuating noise offers a better measure for the ability of hearing-impaired listeners in speech communication than SRT in steady-state noise.

In the preceding chapter the differentiation between the factors *distinction of sounds* and *detection of sounds* was a quite interesting result. It is encouraging to see that the performance tests do differentiate between those two sections of the inventory. The high frequencies seem to be important in *detection of sounds*. The prediction could be enhanced by the hearing threshold level (5:1) when the high frequencies (1,2 and 4 kHz) were taken into account. The *'LOC'* test was entered in the equation to describe *distinction of sounds* even though the contribution of additional information was not highly significant as shown in Table 3.4. The fact that the regression analysis does enter this variable may indicate that the localization ability may be potentially relevant. It is probably an important aspect when sounds have to be distinguished.

The description of *auditory localization* seems to be complicated. The *'LOC'* test yields a moderate explanation of the self-assessed localization ability, but the results on this test are confounded by the hearing aid. Exclusion of the hearing aid resulted in a substantial contribution of the *'HTL'* and *'DIF'*. It makes little difference whether the high or low frequencies or whether the 5:1 ratio or 1:1 ratio is taken from the audiogram. Comparable results are reported by Noble et al. (1994) who extensively investigated the effects of high- and low-frequency loss as well as the type of loss on sound localization. When evaluating the relation between the self-reported scores and the performance measurements of localization it is remarkable that there is a tendency of a few participants to report to have severe difficulties with localizing sounds in daily-life while their performance during the test is quite good (compared to normals). An explanation for this phenomenon might be the fact that localizing sounds is a difficult ability, even for normal-hearing people. This was suggested by Noble et al. (1995). In their study normal-hearing people assessed themselves as having some difficulty in localizing sounds in daily-life. Hearing-impaired people may emphasize their localization disability and may attribute their failure strongly to the fact that they are hearing-impaired and therefore judge their inability as poor compared to an assumed norm.

Comparisons of the above-mentioned test results and the subjective information derived from the inventory indicate that an appropriate test battery can be constructed. Regarding the total amount of the variance explained, it must be noted that some of the variance can be attributed to measurement error and non-audiological factors such as age, IQ and personality (Gatehouse, 1991). The effects of the last mentioned variables on the relation between the self-reported disabilities and performance tests used in this study should be examined when a greater number of cases are available. Test-retest reliability of both the dependent and all the independent variables should be determined before the battery can be considered for use in a clinical setting. Nevertheless, this study emphasizes the importance of the distinction of the many facets of

hearing disability in everyday hearing. This is not only shown by self-assessment study as described in chapter 2. The present chapter also shows substantial correlations between self-reported disabilities and performance measures of auditory disability. The findings should be considered when hearing disabilities have to be evaluated.

4

COMPARISON OF TWO TYPES OF LOCALIZATION TESTS AND PURE-TONE LOSS WITH SELF-REPORTED LOCALIZATION ABILITY

ADDENDUM TO CHAPTER 3

Part of an article in preparation

INTRODUCTION

Chapter 3 presents a battery of performance tests, which clearly describes and differentiates the five self-reported auditory disability factors. For each factor a substantial amount of the variance can be explained by the performance tests. Evaluation of the results shows that the poorest correlation between self-reported and measured disability was found for *auditory localization*. The multiple correlation coefficient did not reach a higher level than R=0.60. One of the reasons for this may be that people do not know how to estimate their localization ability in a proper way. However, it may just as well be possible that the laboratory test used in the study is not representative for localization performance in daily-life. One of the reasons for the test being nonrepresentative may be the use of tone bursts as signals instead of everyday sounds and the use of steady-state noise as a masking background. Another reason may be the fixed time-interval between successive signals. Particularly unexpected sounds make localization performance very difficult. Subjects who participated in the study reported that the test does not reflect any element of surprise which they do experience as a difficult aspect in localizing sounds in daily-life.

In view of the above-mentioned findings the present experiment was added to the study, attempting to investigate if there is room for improvement in the domain of localization performance tests. The original test was modified to reflect a more realistic degree of the ability to localize sounds in daily-life. According to the observations in the preceding study and the comments of the participants, changes were made in the domain of the signals, the masking noise and the signal-to-noise ratio. A varying time-interval between signals was also introduced.

Self-reported scores of a new group of 24 hearing-impaired participants, who performed on both the original localization test and the modified test, are given on the following pages. A stepwise multiple regression analysis was used to compare self-reports with test results and pure-tone loss. The present experiment is undertaken in an attempt to enhance the correlation coefficient between self-reported and measured auditory localization. As mentioned before, it is a further exploration of the study described in the preceding chapter.

METHODS

Participants

The sample consisted of 24 hearing-impaired participants. Their ages ranged from 17 to 67 years with a mean of 49 years. Two persons had one totally deaf ear. One person had a conductive loss in one ear. All the others had a sensorineural loss.

Self-report

Self-reported disability was assessed using the Amsterdam Inventory for Auditory Disability and Handicap. Response categories and codes are given in the preceding chapter on page 26. For this study only scores on the factor *auditory localization* were used. This factor consists of five questions that are given in table 2.2. The *auditory localization* disability score was obtained by summing the responses to the five questions.

Tests

For each participant the pure-tone hearing threshold levels were measured. The hearing loss, averaged over 500, 1000, 2000 and 4000 Hz was calculated for each ear. The average of both ears was referred to as hearing threshold level ('*HTL*'). In the case of one totally deaf ear the loss of the deaf ear was taken as 100 dB. The absolute difference between the right and left hearing threshold level was referred to as '*DIF*'.

Two types of localization tests were used in this study:
The first test has been used in the previous study and is extensively described in the preceding chapter on page 28. It will be further mentioned as '*LOC1*'.

The second test was a modification of '*LOC1*'. The position of the subject and the loudspeakers was the same as for '*LOC1*'. During the test eight everyday sounds were used both as masking sounds and as signals: a barking dog, big-ben, birds, a telephone, sirens, a laughing child, a guitar, pouring water. The masking noise was created by just mixing seven of the eight above-mentioned sounds (the sound of the telephone was not included). Generation of the sounds, comprising the masking noise, occurred in randomly chosen succession. Each sound was generated about 0.5 s after the onset of the preceding one. This means that always four sounds were generated together. As in the preceding test, the masking noise was presented through the loudspeaker above the subject's head. Signals were presented one at a time through the eight loudspeakers around the subject with a mean time interval of 3.5 s.

In total 64 times one of the eight sounds was presented. Participants were instructed to listen to each sound but to respond and localize (press a button) only when the target sound (the telephone) was heard. Of the 64 signals presented 32 were telephone sounds. These were presented in a random sequence over the eight loudspeakers (four times the telephone sound per loudspeaker). As it was our purpose to leave the subject in uncertainty about the occurrence of the target signal (telephone), the sequence of the 32 telephones within the 64 presentations was randomized, causing a variable time-interval between the successive telephone sounds.

The remaining 32 presentations were the above-mentioned seven other sounds which were also presented in a random sequence. The signals were presented at approximately 70 dBA as was the level of the masking 'daily-sounds-noise' (signal-to-noise ratio = 0 dB). The percentage correctly localized telephone sounds was referred to as *'LOC2'*.

Statistical Analysis

A stepwise multiple regression analysis was performed with the summed self-reported disability score as the dependent variable and the test results as the explanatory variables. The criteria for inclusion and exclusion in the regression model were p values of 0.10 and 0.15 respectively. The analysis was performed using the statistical package for the social sciences (SPSS 7.0).

Table 4.1. *Descriptive statistics of all variables.*

	Minimum	Maximum	Mean	Std.Deviation
Self-reported localization	0	15	8.5	4.1
LOC1	14.1	59.4	45.9	11.5
LOC2	9.4	81.3	52.5	19.9
HTL	13.1	66.9	40.9	13.4
DIF	0	95	17.2	27.6

For ease of the survey all variables are given as follows:

Independent variables:
HTL (hearing threshold level)
DIF (difference in HTL between both ears)
LOC1 (localization test type 1)
LOC2 (localization test type 2)

Dependent variable:
Self-reported summed scores on the factor *auditory localization.*

RESULTS and DISCUSSION

Descriptive statistics of all variables are given in Table 4.1. Table 4.2 presents Pearson's correlation coefficients between test results and self-reported disability. The result of the stepwise multiple regression analysis, as shown in Table 4.3, is an interesting finding, since it shows the importance of the *'LOC2'*. The regression analysis chooses *'LOC2'* above *'LOC1'* in the equation to describe self-reported *localization.* Together with measures of the pure-tone thresholds *'LOC2'* yields a multiple correlation coefficient of R=0.76. This indicates a notable improvement compared to the outcomes of the preceding study. The multiple correlation coefficient in that chapter did not reach a higher level than R=0.60.

Table 4.2. *Pearson's correlation coefficients between self-reported localization ability and performance test scores (N=24).*

	LOC1	LOC2	HTL	DIF
Self-reported localization	-.38	-.61**	.62**	.28
LOC1		.68**	-.56**	-.63**
LOC2			-.53**	-.75**
HTL				.38

** p < 0.01

A remarkable result is the role of the pure-tone audiogram in the regression equation. In both the previous and the present study a substantial amount of the variance is explained by the hearing threshold levels and the difference between both ears. It must be noted, however, that pure-tone measures alone do not explain more than about 39 percent of the variance. This is in agreement with the findings of several other investigators who found poor correlations between localization performance and usual audiometric results (Durlach et al, 1981). An additional localization test appears to be of great importance.

Table 4.3 *Result of the stepwise multiple regression analysis. The percentage of the variance explained by each of the variables in the equation is given in this table.*

	HTL	LOC2	DIF	Multiple Correlation Coefficient
Self-reported localization	39%**	12%**	8%*	0.76

* p < 0.1, ** p < 0.05

The present findings support our assumption that the original localization test (*'LOC1'*) is less representative for disability in localizing sounds as experienced in everyday life. The alternative test (*'LOC2'*) appears to be a better indicator of that capability.

Further study should be performed to find out which changes in the original test (everyday sounds, signal-to-noise ratio, masking noise, time-interval) are responsible for the enhanced correlation, even though we assume that all the changes made for the development of the alternative test (*'LOC2'*) better represent real-life conditions.

5

THE SELF-REPORTED HANDICAPPING EFFECT OF HEARING DISABILITIES

This study investigates to what extent individuals see themselves as being handicapped by a hearing disability. Self-reports were obtained with the Amsterdam Inventory for Auditory Disability and Handicap which distinguishes five basic disabilities: distinction of sounds, auditory localization, intelligibility in noise, intelligibility in quiet and detection of sounds. Responses of 239 hearing-impaired persons with varying types of hearing loss have been examined. The occurrence of the five disabilities in the population as well as the self-reported limiting and annoying effect per disability has been investigated. This study shows that the handicapping effects of the disabilities do not have equal weights. Handicap resulting from the disability understanding speech in noise is most strongly felt. This chapter argues that the type of disability is jointly determining the severity of a person's handicap.

Accepted for publication in AUDIOLOGY

INTRODUCTION

In studies concerning auditory handicap performed during the last several decades, the estimation of the degree of hearing handicap appeared to be very complicated (Giolas, 1990). The complexity is caused by the subjectivity of the handicap concept and the involvement of a wide range of non-auditory effects of hearing impairment and disability. This is clearly expressed in the definition of hearing handicap given by the World Health Organization (WHO, 1980) and used in this thesis: handicap is a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex, social and cultural factors) for that individual. In an attempt to construct a taxonomy of handicap the WHO identifies six dimensions: orientation, physical independence, mobility, occupation, social integration and economic self-sufficiency. Stephens and Hétu (1991) propose an extension of the classification of the WHO. They distinguish between the handicaps resulting directly from the experience of impairment and disability and those that result from the use of various means to compensate for the disabilities. The latter are identified as *secondary* handicaps as opposed to the *primary* handicaps resulting directly from the experience of disability. A great variety of psycho-social disadvantages that can be experienced is collected and categorized by Hétu et al. (1987, 1988).

The above-mentioned investigations deal with the existence of all kind of consequences resulting from impairment and disability and the observation of specified aspects of hearing handicap. The results show that disadvantages may express themselves in attitudes, behaviour (fatigue, stress) and emotions (anxiety). These aspects are considered as very subjective and personal and are related to character, physical condition and circumstances. Hence, they differ widely among and within persons. Even though Stephens and Hétu in 1991 already stated that the handicap resulting from auditory impairment and disability merits systematic investigation within different sub-populations of hearing-impaired people, a search of literature did not reveal information about the relative importance of the consequences resulting from hearing difficulties in daily-life. Therefore, the present study was undertaken. It is our aim to investigate the weight attached by hearing-impaired persons to the experience of hearing disabilities.

Starting from the assumption that all kind of consequences can be experienced by hearing-impaired persons, the present study can be seen as an extension of the foregoing studies.

In agreement with the WHO the line is taken that handicap is linked to disability. On the basis of this principle the Amsterdam Inventory for Auditory Disability and Handicap was developed as described in chapter 2. Each question of the inventory deals with a situation in daily-life. In the first part of each question the subject is asked to report how often he or she is able to hear effectively in that situation. Experimental data in chapter 3 demonstrate that these parts of the question assess the degree of disability. The questions appeared to correlate significantly with various performance tests. In an accompanying part of each question the respondent is asked to judge how handicapped he or she feels by having difficulties in that situation.

According to the classification of the WHO, the term *handicap* in the inventory is defined as the extent to which respondents are annoyed by the experience of difficulty in hearing in the mentioned situation and the extent to which they feel limited in doing activities as a result of their hearing problem.

Investigation of part one of the questions (chapter 2) resulted in the distinction of five factors, interpreted as five basic abilities in hearing: *distinction of sounds, auditory localization, intelligibility in noise, intelligibility in quiet* and *detection of sounds*.

The first part of the present study is an investigation of the occurrence of each of these disabilities in a population of hearing-impaired persons. In a following step the distribution of difficult situations within each factor separately will be examined.

The second part of this study focusses on the handicapping effect of each of the disabilities as described above. Also the handicapping effect of *intolerance of noise* will be evaluated. The aim is to assess to what extent individuals see themselves as being handicapped by a hearing problem. The study is undertaken to investigate the relevance of different hearing disabilities in daily-life and is meant to contribute to a better understanding of the handicap concept.

PARTICIPANTS

Participants in this study were 239 hearing-impaired persons (69 female and 170 male) who completed the Amsterdam Inventory. The sample of subjects was a mixed group of patients, not restricted to persons with noise-induced hearing loss. Table 5.1 shows the distribution of hearing threshold levels per frequency separately per ear. Threshold levels at frequencies to the nearest 5 dB step were obtained with a conventional audiometer (Madsen OB 822). The maximum hearing loss was set at 100 dB. The absolute difference between the right and left hearing threshold level is referred to as DIF. Values of the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentile are given. In total 59 respondents completed all questions of the inventory on the basis of their experience with a hearing-aid. Occupational specialities varied widely as well as the type of hearing loss. The participants (ages ranging form 23 years to 73 years with a mean of 48.6 years) did not have any financial interest in this study.

Table 5.1. *Percentile values of hearing threshold levels per frequency separately per ear. The absolute difference between the left and right threshold level is referred to as DIF.*

Ear	Frequency (kHz)	Percentiles				
		10%	25%	50%	75%	90%
Left	0.5	10	20	40	60	90
	1	10	23.8	50	75	100
	2	15	30	50	80	100
	4	25	45	70	90	100
Right	0.5	10	30	47.8	70	95
	1	15	35	55	80	100
	2	16.5	30	60	80	100
	4	26.5	45	70	95	100
DIF	0.5	0	0	10	20	53.5
	1	0	5	10	25	50
	2	0	0	10	21.3	48.5
	4	0	0	10	20	48.5

METHODS

Self-reported disability and handicap scores were obtained with The Amsterdam Inventory for Auditory Disability and Handicap. The inventory consists of 30 items and includes five basic disability factors (chapter 2) dealing with a variety of everyday listening situations:

1. *Distinction of sounds* (items 24,23,5,29,6,26,17,4) (see Table 5.1),
2. *Auditory localization* (items 15,3,27,21,9),
3. *Intelligibility in noise* (items 7,25,19,1,13),
4. *Intelligibility in quiet* (items 14,20,11,12,8) and
5. *Detection of sounds* (items 28,16,22,2,10)

In the first part of each question of the inventory the respondent is asked how often he or she is able to hear effectively in the mentioned situation. An example: "Can you carry on a conversation with someone in a busy street?". Whenever the subject reports 'almost never' or 'occasionally' to be able to hear, the respondent is asked to judge how handicapped he or she feels by having difficulties in that situation. For example: "Do you feel handicapped by having difficulty in carrying on a conversation with someone in a busy street?". Again it is noted that in the introduction of the inventory the term 'handicap' is defined as the extent to which respondents are annoyed by the experience of difficulty in hearing in the mentioned situation and the extent to which they are limited in doing activities.
The four answer categories are as follows: no, slightly handicapped, moderately handicapped, considerably handicapped. Responses were coded as 1, 2, 3, 4 respectively.
In case a subject reports not to have any difficulty in hearing in the mentioned situation (as assessed in the first part of the question), the following handicap-part of the question is irrelevant. In that case respondents were instructed to skip the handicap-part. This so called 'no-disability' was coded as 0. The request to complete the handicap-part of a question only when the respondent reports in the first part of the question to experience a hearing difficulty, expresses the assumption that a handicap can only be felt when a disability is experienced. A consequence of this construction is that the

number of completed handicap parts depends on the number of difficulties rated in the first parts of the questions.

Therefore, the first step in the data analysis was to examine the number of items on which the respondent rated a difficulty in hearing (with a minimum of 0 and a maximum of 28 items). If a restricted number of the 28 situations are rated as difficult, in what area of auditory functioning are the problems then located? In order to answer this question the distribution of difficulties over the five basic disability factors was investigated.

The second step in the data analysis was focussed on the distribution of difficulties within each disability factor separately. Every factor consists of at least five items each referring to a situation in daily-life hearing. How many times a situation is rated as difficult by how many persons? This second step was undertaken to investigate if all situations within one factor are equivalent to each other.

The third step was the examination of the weight given to a hearing problem in each of the situations mentioned in the inventory. The weighting (handicapping effect) is expressed in the values reported in the handicap-part of each question. To assess the handicapping effect of each of the five above-mentioned basic disabilities separately, the values of the handicap-parts within each factor were examined. Items belonging to one factor were grouped together and the means of the handicap-parts of the questions per factor were calculated accordingly. Even though it cannot be considered as a separate factor in this study, since only one item (18) of the inventory refers to this aspect, the handicapping effect of *intolerance of noise* was also examined.

RESULTS

The first step in the data analysis was the examination of the number of items on which respondents rated a difficulty in hearing. This step was followed by an investigation of the area of auditory functioning in which the problem is located in case a difficulty is reported. The distribution of difficulties over the five basic disability factors was examined. For example: in the population 7 subjects are rating each 12 (different) items as difficult. The value on the x-axis is then 12. When the 12 items are grouped, the percentage disability per factor (5 data-points) is plotted along the y-axis.

The values are calculated as follows: In this group of 7 subjects the number of items with reported disability on *auditory localization* is 22.

The maximum value is (7*5)=35. (The factor *localization* consists of 5 items). So, the percentage is (22/35)=63 percent. This is shown in Figure 5.1. It presents the distribution of difficulties per factor as a function of the number of difficulties rated in the inventory. Different curves represent different factors. Only for *intelligibility in noise* and *distinction of sounds* individual data points are given. The curved lines are polynomial fits to the data.

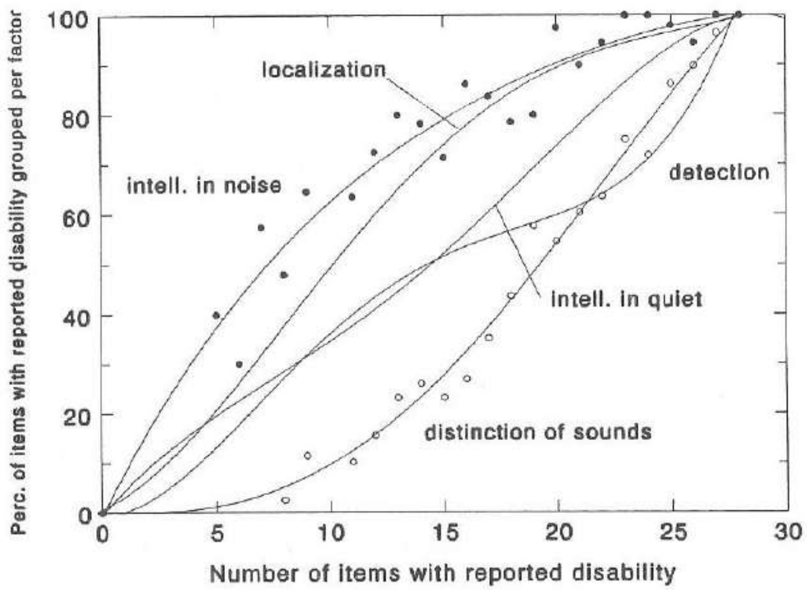


Figure 5.1. *Percentage per factor of items on which the respondents reported experiencing disability, displayed as a function of the number of items of the inventory with reported disability. Different curves are for different factors. Only for 'intelligibility in noise' and 'distinction of sounds' individual data points are given. The curved lines are polynomial fits to the data. Data below a total of five items are too noisy and are therefore not included.*

Not being able to understand speech in noise is the most-frequent disability and *distinction of sounds* is the least-frequent disability. A notable result is that even in the group of participants (number of items < 10) difficulties can occur in all five areas of auditory functioning.

Each of the above-mentioned factors consists of at least five items each item describing a situation in daily-life hearing. Therefore, the second step in the data analysis was the examination of the distribution of difficulties within each disability factor separately. Some participants reported experiencing difficulty in only one of the five (or eight) situations per factor. It is then important to know if this is the same situation for all these participants. Per disability factor five groups of respondents are distinguished (for *distinction of sounds* eight groups are distinguished):

1. difficulty rated in 1 of the 5 (or 8) situations
2. in 2 of the 5 (or 8) situations
3. in 3 of the 5 (or 8) situations
4. in 4 of the 5 (or 8) situations
5. in all five situations (in 5 of the 8 situations)

(6. in 6 of the 8 situations)

(7. in 7 of the 8 situations)

(8. in all 8 situations)

Frequencies are presented in Figure 5.2. To understand the onset of auditory difficulties, examination of the situations that are difficult for persons belonging to group 1 is important. These persons report to have difficulty in only one of the five situations per factor. Figure 5.2 shows that if only one situation is rated as difficult this situation is not the same for every participant. This indicates that all individual questions of the inventory have their relevance.

However, some situations are exceptional. As shown, many persons in group 1 experience difficulty in situations described in item 9 (hearing from which corner of a lecture room someone is asking a question), item 12 (understanding text that's being sung) and item 10 (hearing somebody approaching you from behind). It may be that normal-hearing people will have difficulties in these situations as well. In order to investigate this assumption the Amsterdam Inventory was presented to a group of 58 normal-hearing persons.

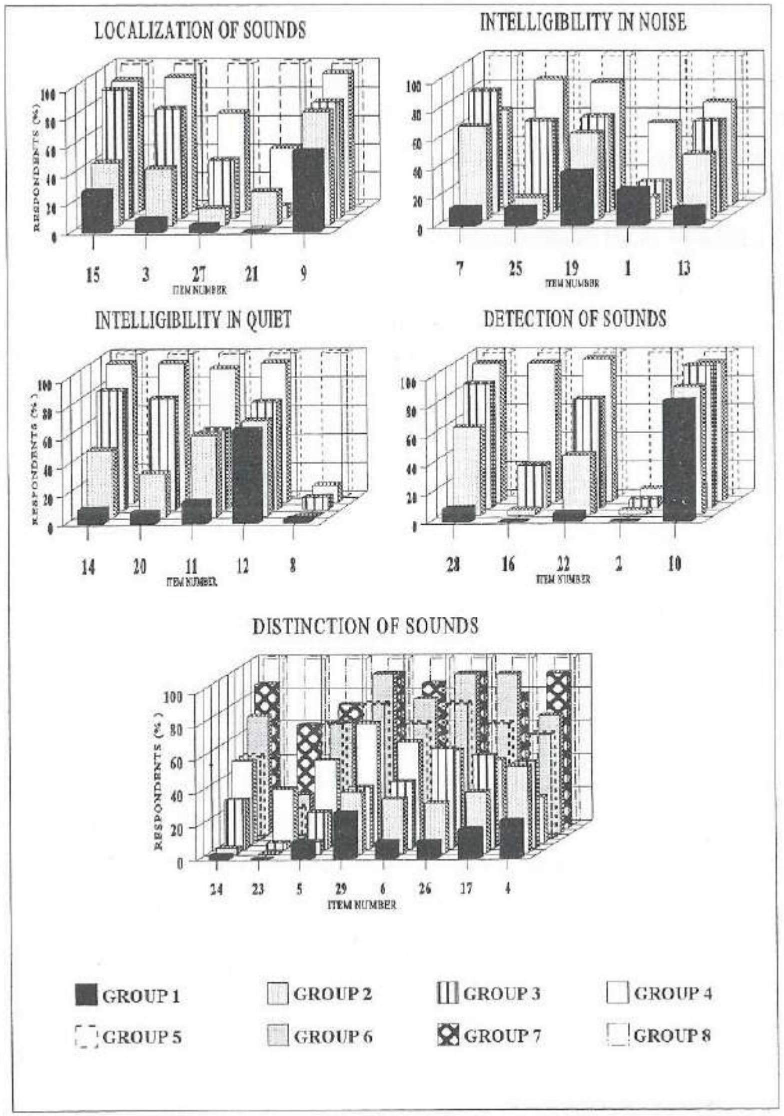


Figure 5.2. *Percentage per group of respondents who rated a difficulty in one or more of the items of a disability factor. Respondents are divided into groups as mentioned under 'results'. Groups are represented by bars in this Figure. In the lowest part there are eight groups because the factor 'distinction of sounds' consists of eight questions.*

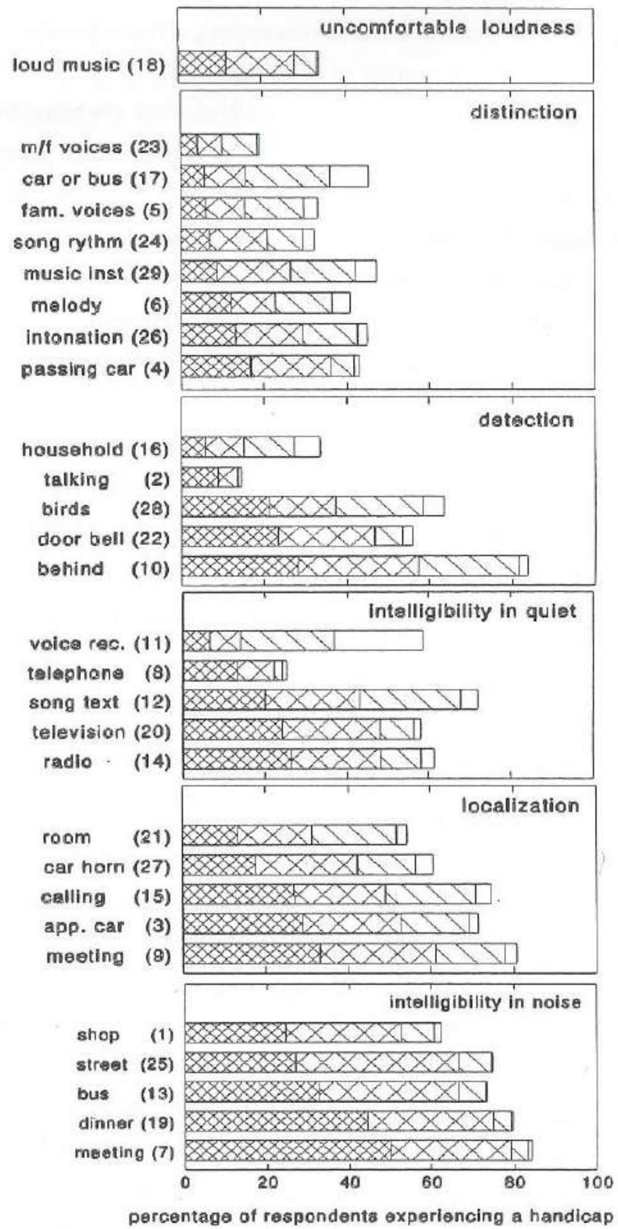
The results show that sometimes these situations also cause difficulty for normal-hearing persons: the percentage of normal-hearing participants who experience a difficulty in situations described in item 9, item 12 and item 10 is 21 percent, 50 percent and 24 percent respectively. Figure 5.2 shows a gradual increase for all items per factor. Exceptions are item 8 (telephone conversation) and item 2 (conversation with someone in a quiet room). These situations cause difficulty for persons who experience difficulty in all other situations as well.

The results presented up to here only deal with the incidence of difficulties in a population of hearing-impaired persons. In the following part of this chapter the handicapping effect of disabilities will be examined. It is the third step in the data analysis.

The self-reported handicapping effect is expressed in the values reported in the handicap-part of every question in the inventory. Figure 5.3 shows the variability among these values. Frequencies of handicap scores and 'no-disability' for all questions are given.

To further elaborate the information given in Figure 5.3, the handicapping effect of each separate disability was examined. To be able to calculate these values, the handicapping effect of each situation as mentioned in the items of the inventory was determined first. The mean values of the responses of the handicap-parts (mean handicap score) were calculated. It should be noted here again that the handicap-part of a question is only completed by persons who experience a disability in that situation (as assessed in the first part of the question). The number of completed handicap-parts therefore differs between items.

Figure 5.3. *Frequency distributions of the handicap-parts of all items of the disability factors. The percentage of respondents reporting to feel handicapped varies between the items since the handicap-part of a question is only completed by persons who reported to experience a disability (fine hatched=considerably handicapped, double hatched=moderately handicapped, single hatched=slightly handicapped, open=not handicapped).*



The results are shown in Table 5.2 which shows the number of disabled respondents (N) in the given situation and the mean handicapping effect reported by these people. The items are listed in decreasing order of handicap.

It can be seen in Table 5.2 that disabled respondents feel considerably handicapped when not being able to have a conversation in noisy situations. Handicap resulting from the disability in listening to speech in noise is most strongly felt. This is more clearly shown in Table 5.3 in which items are grouped together on the basis of the five factors of auditory functioning. The mean handicap scores per disability express the self-assessed handicapping effect of each disability separately. An important result, shown in this Table, is that the handicapping effects of the five disabilities do not have equal weights.

The mean handicap scores per disability of the subjects who reported always using their aid were compared to the scores of the participants who rated each situation of the inventory without an aid. No significant difference was found. Moreover, the values reported in both groups did not differ significantly from the scores as shown in Table 5.3.

Distinction of sounds seems to be the least frequent and least handicapping disability. This is shown in both Table 5.2 and Table 5.3. Investigation of the group of respondents that reported to feel handicapped by experiencing disability in *distinction of sounds* showed that a small part of this group is musically trained. The responses on the handicap-parts and on a question in the appendix of the inventory concerning playing a musical instrument appeared to be related. The chi-square test for linear association showed a high observed level of significance ($p < 0.01$).

Musically trained hearing-impaired participants experiencing a disability in *distinction of sounds* feel more handicapped than impaired participants who report not to play an instrument. Another question in the appendix of the inventory is as follows: 'did you stop doing certain activities because of your hearing impairment?' The responses on this question appeared to be related to the responses on the handicap-parts of the questions. The chi-square test for linear association showed a high observed level of significance ($p < 0.001$). This result indicates that the respondents did not have different ideas about what was being asked for in the questions of the inventory in which we used the term 'handicap'.

Table 5.2. *Number of disabled respondents in the given situation (N) and the mean handicapping effect reported by these participants per item.*

Item	Do you feel handicapped by having difficulty in:	Mean Handicap Score	N
7	carrying on a conversation with someone during a crowded meeting?	3.53	201
19	following a conversation between a few people during dinner?	3.49	190
2	carrying on a conversation with someone in a quiet room?	3.46	35
8	carrying on a telephone conversation in a quiet room?	3.38	60
13	carrying on a conversation with somebody in a bus or car?	3.34	176
25	carrying on a conversation with someone in a busy street?	3.24	179
20	understanding the presenter of the news on tv?	3.22	139
22	hearing the door-bell at home?	3.21	134
1	understanding a shop-assistant in a crowded shop?	3.21	149
4	hearing cars passing by?	3.19	103
18	do you feel handicapped by experiencing that music is too loud for you?	3.16	81
14	understanding the presenter of the news on the radio?	3.16	147
9	hearing from what corner of a lecture room someone is asking a question during a meeting?	3.13	193
3	hearing from what direction a car is approaching when you are outside?	3.11	171
10	hearing somebody approaching you from behind?	2.99	200
15	in hearing from what direction somebody calls you in the street?	2.97	178
27	hearing from what direction a car horn is coming?	2.92	145
26	distinguishing intonations and voice inflections in people's voices?	2.88	108
28	hearing birds singing outside?	2.84	152
12	understanding text that's being sung?	2.82	172
24	hearing rhythm in music or songs?	2.78	77
21	hearing from what corner of a room someone is talking to you being in a quiet house?	2.77	130
6	recognizing melodies in music or songs?	2.74	98
23	distinguishing between male and female voices?	2.70	46
29	recognizing and distinguishing different musical instruments?	2.64	113
5	recognizing members of your family by their voices?	2.56	79
16	hearing noises in the house holding?	2.44	80
17	discriminating the sounds of a car and a bus?	2.27	109
11	recognizing a presenter on TV by his/her voice?	1.99	140

Table 5.3. *Self-reported handicap scores per disability. Items are grouped together on the basis of the five factors of auditory disability. Per factor the mean of the items (see Table 5.2) is calculated. The handicapping effect of 'Intolerance of Noise' (represented by only one item) is also shown in this Table.*

Disability	Mean handicap score per disability
Distinction of sounds (items 24,23,5,29,6,26,17,4)	2.72
Auditory localization (item 15,3,27,21,9)	2.98
Intelligibility in noise (items 7,25,19,1,13)	3.36
Intelligibility in quiet (items 14,20,11,12,8)	2.91
Detection of sounds (items 28,16,22,2,10)	2.99
Intolerance of noise (item 18)	3.16

DISCUSSION

Before starting a discussion on the handicapping impact of different hearing disabilities it is important to consider the occurrence of disabilities in a population of hearing-impaired persons. It is in this context important to note that the results of this study were not influenced by any financial or other interests of the participants. The results of the first part of this study show that difficulties in *intelligibility in noise* and *auditory localization* are the most-frequent disabilities followed by *intelligibility in quiet* and *detection of sounds* (Figure 5.1). All curves are gradually increasing except for the one of *detection of sounds*. The S-shape of this curve seems to be related to the use of a hearing-aid. A group of 59 respondents have never performed without an aid and hence responded on the basis of their experience with a hearing-aid. The majority of hearing-aid users (70 percent) experience a difficulty in more than 15 situations (number of items > 15). The S-shape of the latter curve might show that the increase of

difficulties in *detection of sounds* in this group can be reduced up to a certain extent by the use of a hearing aid.

This influence of the hearing-aid is not shown in the curves of the other disabilities, which is in agreement with the clinical practice, except for *intelligibility in quiet*. An explanation for this result may be that the items of the factor *intelligibility in quiet* deal with situations which are not really silent. It must be noted that real silence in daily-life situations is exceptional, as is discussed in chapter 3.

Distinction of sounds seems to be the least-frequent disability. However, a remarkable result of the present investigation is that even in moderately disabled participants (number of items < 10) (Figure 5.1) all five disabilities are present. This means that there is no convincing evidence available to suggest that some of the disabilities start to play a role only in severely disabled groups. This outcome corresponds to the results of Lutman et al. (1987) who did not find evidence for a 'low fence' in a function describing the relationship between self-reported disability/handicap and hearing loss. Therefore, regardless of the type and the severity of hearing loss, all five disabilities should be evaluated separately in order to describe the hearing status and to estimate the hearing handicap.

Figure 5.2 shows the variability among situations that cause difficulty in daily-life hearing. Some situations are difficult for only a few people. Examples are 'understanding somebody in a quiet room' (item 2) and 'carrying on a telephone conversation in quiet' (item 8). However, the respondents who report experiencing difficulty in these situations report experiencing hearing problems in all other situations as well. This means that the hearing status of a person who reports to have difficulty in these situations must be rather poor. Other situations cause difficulty to persons who report having no problem in any other situation. Examples are item 9 (from what corner of a lecture room someone is asking a question during a meeting), item 10 (can you hear somebody approaching from behind) and item 12 (Can you understand text that's being sung). From our results it seems likely that these situations may yield difficulty even by normal-hearing people. A substantial percentage of the 58 normal-hearing persons in this study indeed reports to experience a difficulty in some of these situations.

The results in Figure 5.3 show that not every listening situation leads to a feeling of being handicapped, despite the presence of a hearing difficulty (as assessed in the preceding part of the question). This means that someone can be disabled in certain situations in daily-life without having a feeling of being handicapped. The Figure also shows that the number of disabled respondents is not the same in every situation. Not many respondents report to be disabled in carrying on a conversation with someone in a quiet room (item 2). However, whenever this occurs, the handicapping effect is large (Table 5.2). The hearing handicap of a person depends on the disabilities he or she really experiences.

Even though Dobie (1993) states that "there is a general consensus that hearing handicap should be assessed in terms of the effects a hearing loss has on speech communication in the activities in daily living, rather than on the hearing of non-speech sounds", the results of this study clearly show that handicap can also be caused by not being able to perceive sounds other than speech. Although handicap resulting from disability in listening to speech in noise is most strongly felt by hearing-impaired people (Figure 5.3 and Table 5.3) the additional handicap from other disabilities, if present in a person, should not be ignored. Also other investigators, such as Noble (1978), Barcham and Stephens (1980) and Lutman (1987) showed the importance of non-speech disability and localization. A remarkable finding in this study is the substantial handicapping effect resulting from *intolerance of noise*, as is shown in Table 5.3. *Intolerance of noise* is a serious complaint of many hearing-impaired people. It should therefore not be ignored in the assessment of handicap.

All factors should be taken into account in assessing a person's hearing handicap, particularly when handicap is seen as a result of disability and calculated accordingly. It seems to be important first to estimate the magnitude of a person's hearing disabilities.

Not any of the values in Table 5.3 are smaller than 2 (slightly handicapped) which means that not any of the disabilities is negligible. In fact all values of the mean handicap score per disability are around 3 on a scale ranging from 1 to 4. In general this means that any of these disabilities are moderately handicapping. The weights may appropriately be used as a first indication of a person's primary handicap (Stephens and Hétu, 1991). For the estimation of a person's total handicap attention should be paid to the individual situation. Ineffective coupling conditions between the individual

and his environment (Hallberg, 1991; Noble, 1994) increase a person's handicap. Inappropriate demands of the (working) environment constitute secondary handicaps like stress, fatigue etc. (Gatehouse, 1990). These so-called secondary handicaps were not included in this study. The fact that the individual situation is important for the determination of a person's total handicap is clearly emphasized by the musicians in this study. The ability to distinct sounds appeared to be an important factor particularly for musicians. It is reasonable to suggest that for this sub-population the restriction of the ability to 'distinct sounds' should weight more heavily. The values of the weights should be further evaluated in other sub-populations of hearing-impaired people living in different sociocultural environments.

6

ASSESSING ASPECTS OF HEARING HANDICAP BY MEANS OF PUPIL DILATATION

The demand on extra effort and concentration during listening is are notorious handicapping effects of hearing impairment as is shown by self-assessment studies. In an attempt to explore new ways of assessing hearing handicap, the present study focusses on an objective measure of mental effort during listening. Pupil dilatation is used as the index of mental effort. Results of 14 hearing-impaired and 14 normal-hearing listeners show a relation between pupil dilatation and difficulty in speech reception in noise, as manipulated by the speech-to-noise ratio. In addition the study shows that, with regard to effort and concentration, hearing-impaired subjects benefit less than normals from easier listening situations (e.g. at 5dB above the individual speech-reception threshold). The results show a significant correlation between self-rated handicap and pupil dilatation.

AUDIOLOGY, 36:155-164, 1997

INTRODUCTION

Hearing handicap is characterized by the experience of disadvantages in daily-life as a result of hearing impairment. Among the various disadvantages the demand of extra effort and auditory fatigue are notorious. Extra effort is needed to listen more carefully and to concentrate more. These handicaps are often reported by hearing-impaired persons, like the participants in a study by Hétu et al. (1988) who conducted interviews on consequences of hearing impairments. In their model of the structure of auditory handicap, effort and fatigue are distinguished as secondary handicaps. These handicaps result from the cost of adapting to a disability which is also acknowledged by Demorest and Erdman (1986): 'The individual's attempts to compensate and to communicate optimally require vigilance: a constant effort to hear, to pay attention and to respond appropriately.' Stephens and Hétu (1991) report that social interactions of the hearing-impaired person are altered due to increased effort, stress and fatigue in trying to cope with the disabilities. These alterations have their impact on the quality of everyday life of a hearing-impaired person. Stephens, therefore, even proposes an extension of the WHO classification (1980) of handicap to include these levels of disadvantage.

Different attempts have been made to estimate the handicapping effect of hearing difficulty. The assessment, however, is very complicated since handicap refers to a great diversity of individual experiences. The involvement of subjective quantities makes it difficult to measure the disadvantages. Although desirable for many purposes, adequate objective measures of the degree of handicap are not available. Measurements based on the perception of pure-tones have proved not to be completely satisfactory. Questionnaires and interview techniques seem to be the only appropriate tools to explore the domain of effects of hearing impairment/disability. The present study proposes the application of pupil response during listening as a method to quantify aspects of hearing handicap.

Extensive research has shown that the variation of the pupil diameter is a sensitive measure of the degree of mental effort demanded by a task (Janisse, 1977; Heemstra, 1988). At the end of the nineteenth century, Heinrich and Roubinovitsch had already observed the phenomenon of pupil dilatation during mental problem solving by just looking into a person's eye while asking him to mentally solve a problem such as

multiplying 8 by 13 (Hess and Polt, 1964). In the early 1960s, Hess and Polt started to investigate the pupil diameter in relation to mental activity during the solving of simple mathematical problems. They found that the diameter of the pupil increases with the difficulty of the problem. Important observations have been described by Kahneman and Beatty (1966). In a short-term memory task the pupil dilated while the subject was listening to information whereas it constricted giving a response. Kahneman and Beatty also demonstrated that major pupillary dilatations are closely related to rehearsal and other active modes of information processing. In an experiment complex sentences were auditorily presented to normal-hearing subjects and pupil dilatation was observed at the termination of each sentence. The investigators reported that this is the time at which the sentences are actively rehearsed by the subjects in an effort to make sense of it. Wright et al. (1971) observed similar pupil reactions during the presentation of sentences. All these investigations demonstrate pupil diameter to be a function of task difficulty, suggesting that pupil dilatation provides an effective index of processing load. It is because of the work of Kahneman and Beatty (1966) that concepts like effort, processing and loading are not only related to pupillary activity, but are, in many cases, even defined by the pupillary response. Hoeks (1995) recently demonstrated the relationship between pupillary dilatation and production of speech.

The present study was undertaken in an attempt to explore new ways of assessing and quantifying auditory handicap. The experiments were designed to test the hypothesis that there is a relationship between the pupillary response and different levels of difficulty in the reception of speech in noise, as manipulated by the speech-to-noise ratio (SNR). A second motive is verification of the hypothesis that there is a difference in pupil response between hearing-impaired and normal-hearing listeners during listening to speech. As far as pupil dilatation can be used as an index of mental effort we expect that near the threshold for speech reception, hearing-impaired listeners and normal-hearing people will use the same amount of mental effort, while the demand of effort in relatively easier listening situations will be greater for hearing-impaired listeners. This chapter argues that the pupil can serve as an objective measure of a non-audiological aspect that is jointly responsible for the experience of a hearing-impaired person feeling handicapped.

METHODS

Apparatus

Participants were tested individually in a sound-insulated room. They were seated in an adjustable chair, one meter in front of a loudspeaker, with their heads fixed in a Whittaker head rest. During the experimental runs the subject viewed a fixation point on the loudspeaker at eye level.
The pupil diameter was measured by an infra-red video pupillometric system (Whittaker 1994-S Eye View Monitor). Reflections from the pupil were recorded from a source light that was directed continuously at the eye, while a TV-camera monitored the subject's eye. Pupillary data were sampled at a rate of 50 Hz and sent to a DEC PDP-11/44 outside the room for further analyses. The ambient light level was held constant during the experimental session but varied between subjects depending on the initial pupil diameter. The illumination was adjusted such that the initial pupil diameter was within the range of 4 to 6 mm.

Task

Before starting the experiment, the subject's speech-reception threshold in quiet and in fluctuating noise was determined, according to an up-down adaptive procedure as described by Plomp and Mimpen(1979). Fluctuating noise signals were created according to the procedure described by Festen and Plomp (1990). The speech-reception threshold (SRT) is defined here as the level for 50 percent intelligibility. The 'SRT in noise' is expressed as signal-to-noise ratio (SNR). The subject's speech-reception threshold in noise (SRTn) was used as his reference point.

During the experiment four conditions were distinguished:
A. Sentences at the subject's speech-reception threshold in noise (SRTn)
B. Sentences at a 5 dB higher level than the threshold (SRTn+5)
C. Sentences at a 10 dB higher level than the threshold (SRTn+10)
D. Thirteen times presentation of noise only (noise)

For each condition a list of 13 everyday Dutch sentences, read by a female speaker, was presented in fluctuating noise through the loudspeaker. Subjects were instructed to repeat every sentence as accurately as possible. No feedback about the correctness was given. Each sentence was presented only once.

The experimental conditions differed in signal-to-noise ratio which implies different levels of difficulty in reception of speech in noise. The level of the noise was 20 dBA higher than the person's speech-reception threshold in quiet but at least 60 dBA with a maximum of 80 dBA.

The sequence of conditions varied between subjects to avoid effects of measurement order. The entire session lasted about 45 min per participant.

Participants

Two groups of subjects participated in this study. The first group existed of 14 normal-hearing people aged 23 to 37 years with a mean of 29 years. Their speech-reception thresholds in fluctuating noise (SRTn) ranged from -9 dB to -15.8 dB with a mean of -12 dB. Their speech-reception thresholds in quiet ranged from 28 dB to 39 dB with a mean of 32.9 dB.
The second group existed of 14 hearing-impaired persons aged 24 to 62 years with a mean of 44 years. Their speech-reception thresholds in fluctuating noise ranged from -8.5 dB to 3 dB with a mean of -2.6 dB. The pure-tone thresholds of the hearing-impaired subjects ranged from 28 dB to 78 dB (average of both ears at 0.5,1,2,4 kHz) with a mean of 55 dB. Their speech-reception thresholds in quiet ranged from 41 dB to 60.4 dB with a mean of 52.1 dB.

Self-reports

Self-reported handicap scores were assessed using the Amsterdam Inventory for Auditory Disability and Handicap. In this inventory five factors, interpreted as five basic auditory disabilities are distinguished. Five items included in the factor *intelligibility in noise* were used for this study. All five items deal with situations in noise. Hearing handicap was assessed by asking the respondent to judge how handicapped he or she feels by having difficulties in hearing in a noisy situation. For example: "Do you feel handicapped by having difficulty in carrying on a conversation with someone in a busy street?". The four answer categories are as follows: no, slightly handicapped, moderately handicapped, considerably handicapped. Responses were coded as 1, 2, 3, 4 respectively. Handicap scores were calculated by summing the responses. These scores were available for the hearing-impaired participants.

Pupil responses

During the presentation of every sentence the pupil diameter was measured. Sampling started 2.5 sec before the start of the sentence and ended 4 sec after the sentence was finished. The total time of pupil measurement per sentence summed to 10 seconds: 2.4 sec silence, 0.6 sec noise only, 2.4 sec sentence in noise, 0.6 sec noise only, 4 sec silence. Participants were asked to reproduce each individual sentence after the 4 sec silence. The pupil diameter recorded over the 10-sec period is called a trace (Figure 6.1).

Since artifacts in the signal, like blinkings or eye movements, can seriously distort the calculations all traces were processed to eliminate these artifacts.
In order to remove blink artifacts, characterized by a rapid drop in the apparent pupil diameter, traces were 'de-blinked' by linear extrapolation across the region of the blink (0.1s). The result of 'de-blinking' is shown in Figure 6.1B. After 'de-blinking' the signal was filtered by a low-pass filter (Figure 6.1C). For all traces a sliding median was then determined with a window size of 0.2 sec to correct for other disruptions in the pupillary response as shown in Figure 6.1D.

Finally every pupil trace, related to a single sentence, was inspected visually in order to detect errors resulting from eye movements. These traces were removed from the data set. Because of this removal (an average of 2 traces per list) the number of traces was not the same for every subject.

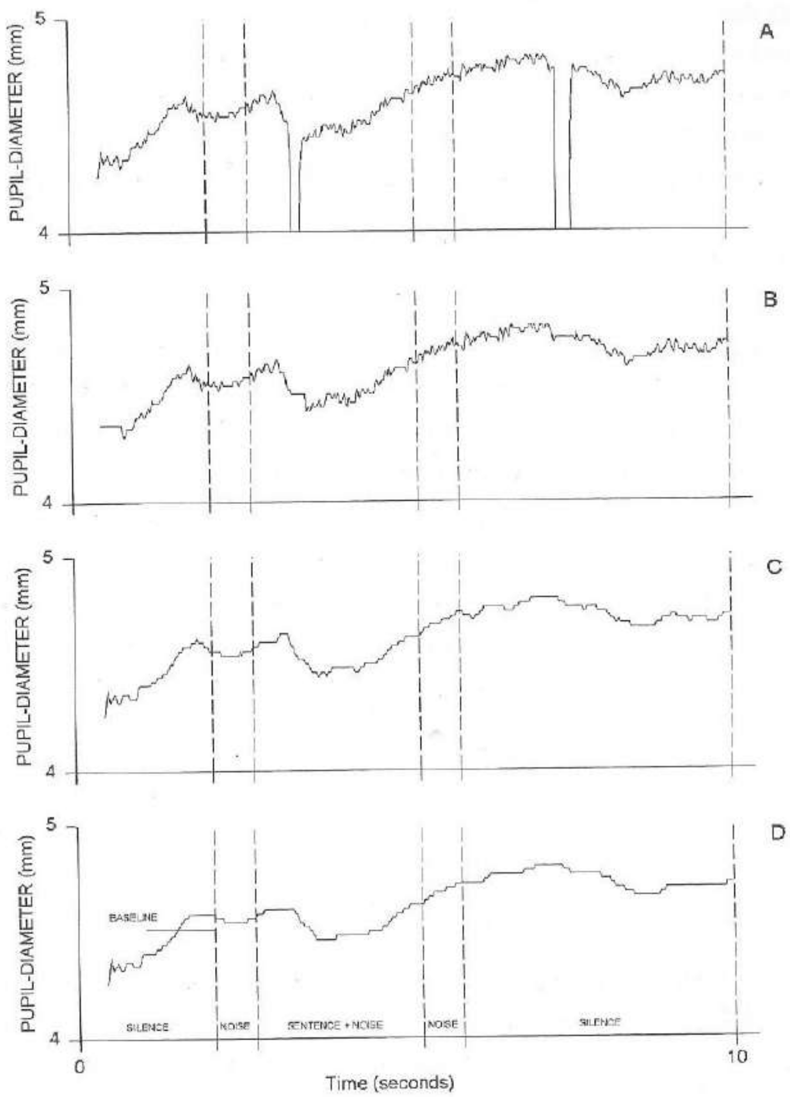


Figure 6.1. *Example of a pupil diameter during sentence reception. The different traces show successive stages of data processing. (A) Raw trace showing the pupil diameter with blink artefacts and measurement noise. (B) The same trace after de-blinking. (C) The same trace filtered by a low-pass filter. (D) The same trace after a sliding median has been taken.*

The pupillary baseline was considered to be the averaged pupil diameter in the 1-s period before the presentation of the noise (Figure 6.1).
The peak level was the maximum pupil diameter measured within the interval after the start of the sentence until the end of the 10-sec period. Maximum dilatation was defined as the difference between peak level and baseline. For every trace the maximum dilatation was calculated. In total 1321 traces were included in the data set.

Statistical analysis

Since traces from one condition (one list of sentences) can be considered as repeated measurements, an analysis of variance (ANOVA) with repeated measurements was performed with the factors *Hearing* (normal, impaired), *Condition* (A,B,C and D) and Tracenumber. Since the Age distribution in the two groups of participants is different, Age must be considered as a confounder for any relation of *Hearing* with an outcome variable (Miettinen, 1985). Therefore, Age was included as a covariate in the analysis. Due to the removal of traces in lists the design became unbalanced and was analyzed accordingly. The mean pupil dilatation in every condition was calculated for all subjects and plotted. Statistical analyses were performed using BMDP (Dixon, 1992).

RESULTS

Pupil responses

The analysis of variance showed a significant Trace-number effect. Every first trace of a list differs from all the others. We therefore decided to eliminate the first trace of every list and proceeded the analysis with the remaining traces.

To investigate the relation between pupil response and difficulty in speech reception the mean pupil dilatation for all participants (N=28) is plotted against the four conditions ('SRTn','SRTn+5','SRTn+10','Noise') (Figure 6.2). The analysis of variance showed a significant *Condition* effect ($p < 0.01$), indicating that pupil dilatation varies

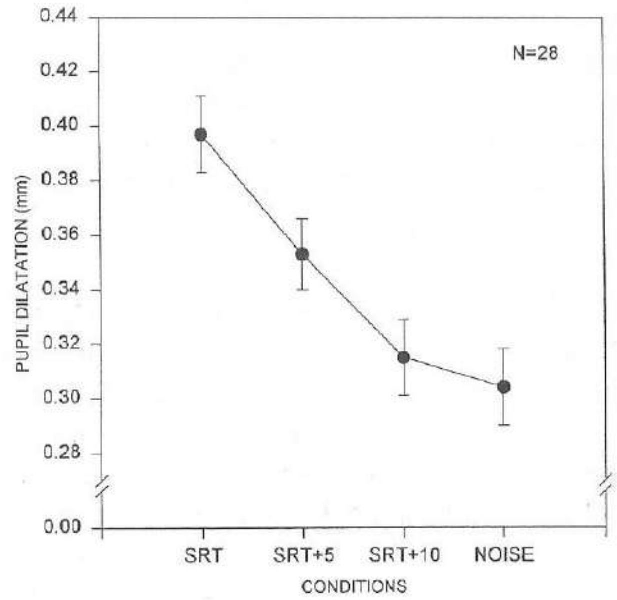


Figure 6.2. *Mean pupil dilatation (averaged from traces per list of sentences) under various conditions of the signal-to-noise ratio. Error bars indicate standard error of the mean.*

across the different levels of difficulty in speech-reception.
Therefore, in a following step, the four conditions were separately tested against each other by means of the following contrasts: (SRTn:SRTn+5), (SRTn+5:SRTn+10), (SRTn+10:Noise). The pupil dilatation in the 'SRTn' condition appeared to be significantly larger ($p < 0.01$) than in the 'SRTn+5' condition.

There was a significant interaction between *Condition* ('SRTn','SRTn+5','SRTn+10','Noise') and *Hearing* (normal, impaired) (p=0.0015). This means that pupil dilatation of the hearing-impaired listeners under the four conditions did not show the same pattern as that of the normal-hearing persons. In order to investigate how hearing-impaired subjects differed from normals, all contrasts were examined separately. The analysis showed a significant interaction between *Hearing* and the contrast among the first two conditions (SRTn:SRTn+5).

In the 'SRTn+5' condition hearing-impaired subjects still showed a large pupil dilatation compared to the 'SRTn' condition, while the normal-hearing people showed a greater decrease in pupil dilatation in the 'SRTn+5' condition. The interactions between *Hearing* and the other contrasts (SRTn+5:SRTn+10) and (SRTn+10:Noise) were not significant.

Figure 6.3 clearly shows the difference between the normal-hearing and hearing-impaired group. It is the reduction of dilatation between 'SRTn' and 'SRTn+5' that appeared to be significant. Therefore, the pupil dilatation at the 'SRTn'-condition (reference point) is set as the norm for each subject separately in this Figure in order to show the reduced dilatation (percent of dilatation in 'SRTn' condition) in the successive conditions (SRTn+5 and SRTn+10). Moreover, the mean reduction in pupil dilatation is plotted as a function of the average signal-to-noise ratio per condition per hearing group. Hence, Figure 6.3 not only shows the above-mentioned significant interaction between *Hearing* and the reduction in pupil dilatation between the 'SRTn' and 'SRTn+5' condition, but it also shows the shifted mean speech-reception threshold in noise of the hearing-impaired participants. As mentioned before Age was included as a covariate in the analysis. There was a significant effect of Age on the above-mentioned relation between *Hearing* and the contrast (SRTn:SRTn+5) ($p < 0.001$). The analysis did not show a significant effect of Age on pupil dilatation. Only a small effect of Age on *Hearing* was shown ($p < 0.05$).

In order to investigate if there is any relation between a person's speech-reception threshold (SRTn, the starting point of the curve) and his/her reduction in pupil dilatation in the successive conditions (expressed as the slope of the curve), correlation coefficients were calculated. A highly significant correlation was found (Pearson's $R = -0.57$ ($p < 0.001$) ($N=28$)) between the subject's signal-to-noise ratio at the threshold (SRTn) and the slope between 'SRTn' and 'SRTn+5'. The relation between the reduction in pupil dilatation and the pure-tone audiogram on the other hand was not significant. The correlation coefficient between the pure-tone thresholds (average of both ears at 0.5,1,2,4 kHz.) and the slope between 'SRTn' and 'SRTn+5' did not reach a higher level than $R= -0.07$.

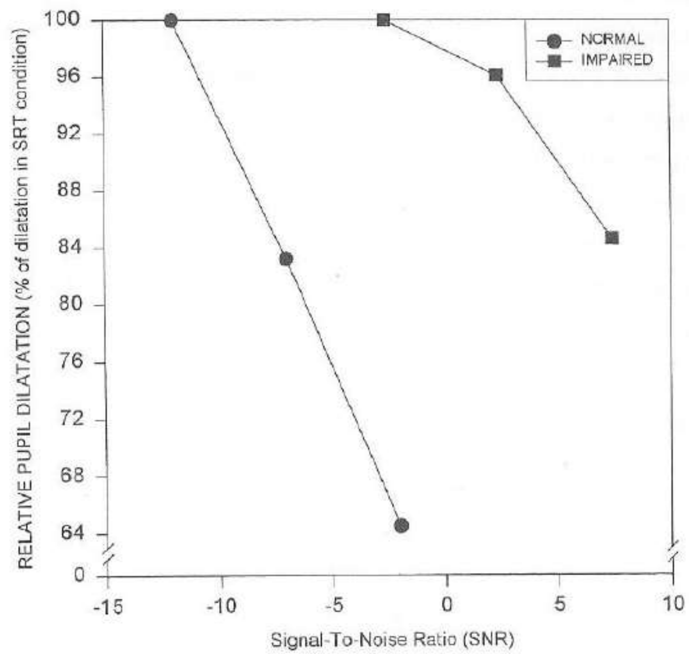


Figure 6.3. *Mean pupil dilatation as a function of the average signal-to-noise ratio per condition per hearing group.*

Speech performance

Some readers may be inclined to simply relate pupil dilatation with the percentage correctly reproduced sentences. Evaluating the slopes in Figure 6.3 the question arises as to whether, performing the same task, the percentage correctly reproduced sentences as a function of signal-to-noise ratio (SNR) shows a similar difference between the two groups of listeners. As we did not score the percentage correctly reproduced sentences for all participants under all conditions in the above-mentioned experiment, our set of performance data was incomplete. We therefore performed a second experiment. The same lists of sentences under the same conditions as described above were presented to 16 normal ears and to 15 hearing-impaired ears. All participants scored 100 percent correctly reproduced sentences at the easier listening level (SRTn+10). The mean percentage correctly reproduced sentences at the 'SRTn', 'SRTn+5' and 'SRTn+10' was 50 percent, 80 percent and 100 percent respectively. There was no difference between the two groups of participants. This finding corresponds to the data of the original sample as far as these data were available. Also in a study by Festen and Plomp (1990) normal-hearing and hearing-impaired participants performed similarly under the same conditions.

Self-reports

Research has shown that effort demanded by a task relates to pupillary activity. Does pupil dilatation relate to self-rated hearing handicap during listening in noise as assessed in this study? To investigate this question pupil responses of the hearing-impaired participants were related to their self-reported hearing handicap scores. A significant correlation was found (Spearman $R= 0.65$ ($p < 0.01$) ($N=13$)) between the self-rated handicap and the reduction in pupil dilatation between the 'SRTn' and 'SRT n+10' condition.

DISCUSSION

The first aim of the present study was to investigate the relationship between the pupillary response and different levels of difficulty in speech reception in noise. The results show an obvious relationship which is plotted in Figure 6.2. A lower level of difficulty in speech reception results in a decrease in pupil dilatation. Since it has generally been acknowledged that pupil dilatation is a sensitive measure of the degree of mental effort and processing load demanded by a task (Janisse, 1977; Hess and Polt, 1964; Kahneman and Beatty, 1966; Wright and Kahneman, 1971) it can be concluded that a more favourable signal-to-noise ratio requires less effort. Evidence for this statement is also found by the significant correlation between self-rated handicap

scores and the increase of the pupil dilatation in the 'SRTn' condition compared to the easier 'SRTn+10' condition. This is an interesting result which supports the argument that pupil dilatation relates to self-rated hearing handicap during listening in noise. The present study confirms the statement that extra effort is needed to listen more carefully and to concentrate more at less favourable S/N ratios.

The second motive of this study was the verification of the hypothesis that there is a difference in pupil response between normal-hearing and hearing-impaired listeners. The difference between the two groups of participants is clearly shown in Figure 6.3. As well as the normal-hearing people, the hearing-impaired subjects show a decrease in pupil dilatation in easier listening situations, but the path of their reduced dilatation differs significantly from that of the normals. The fact that their curve is less steep indicates that for the hearing-impaired subjects the effort required during speech reception in easier listening situations does not decrease as fast as the effort spent by normal-hearing listeners. The mean demand of effort required by the impaired participants at the 'SRTn+5' is only a little less than during the more difficult 'SRTn'-condition.

An accompanying interesting result is the link between the slope of the curve of a person and his/her speech-reception threshold in noise. The reduction in pupil dilatation between the 'SRTn' and 'SRTn+5' conditions correlates significantly to the individual signal-to-noise ratio at the threshold ($R=-0.57$, $p < 0.001$). So, in common with the frequently reported complaints of hearing-impaired persons, we found that the poorer the subject's speech-reception threshold in noise the less benefit is yielded from a more favourable listening situation. There was no significant correlation found between pure-tone threshold levels and the reduction in pupil dilatation. This absence of a correlation indicates that pure-tone measurement is not the most sensitive test to estimate aspects of hearing handicap.

Figure 6.3 shows that the curve of the hearing-impaired listeners starts at a level of 10 dB (mean SNR) above the threshold for the normal-hearing participants. This means that normals are able to reproduce sentences at levels in noise at which hearing-impaired listeners understand less than 50 percent of the presented sentences. This difference (an average of 10 dB) is earlier found by Festen and Plomp (1990).

The above-mentioned findings demonstrate that hearing-impaired subjects not only have a shifted speech-reception threshold in noise with all the unfortunate consequences in daily-life but, also a reduced reduction of mental effort in easier listening situations.

In the additional experiment described in this chapter, no difference was shown between hearing-impaired and normal-hearing listeners with regard to the percentage correctly reproduced sentences during the various conditions relative to the SRTn. This means that pupil-dilatation measures cannot be replaced by just counting the errors made during the task. To achieve equal performance as the normal-hearing subjects, hearing-impaired participants expend extra cognitive effort and concentration. A comparable result is found by Gatehouse and Gordon (1990) who used the response time as an index of the effort required to decode a message. Subjects showed equal performance (percent correct identification of speech stimuli) in both the aided and unaided condition but a reduction in response time was found in the aided condition. Effort seems to be an extra dimension which may account for the disadvantages experienced by the hearing-impaired people in daily-life. Our findings agree with the results of Rakerd et al. (1996) who found evidence that speech listening is abnormally effortful for hearing-impaired listeners. In common with Stephens and Hétu (1991) we argue that effort and concentration during listening to speech should be taken into account in audiological evaluation.

The present investigations show that measurement of the pupil response during listening provides useful information about non-audiological factors that contribute to hearing handicap. These factors are not assessable with traditional audiometric or psychoacoustic tests. The findings encourage further study to explore the domain of (objectively measured) hearing handicap.

Finally, it can be stated that the so often reported complaints of hearing-impaired listeners about extra effort, concentration and fatigue during listening are supported by the results of this study.

CONCLUSIONS

During a speech-reception task, an increase of the Signal-To-Noise ratio (SNR) results in a reduction of pupil dilatation.

The rate of reduction of pupil dilatation with increasing SNR is less for the hearing-impaired listeners.

The rate of reduction of pupil dilatation with increasing SNR correlates significantly with the individual 'SRTn' and not with the PTA-values.

Self-rated handicap correlates well with the increase of pupil dilatation in the 'SRTn' condition compared to the easier 'SRTn+10' condition.

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The rate of reduction of pupil dilatation with increasing SNR correlates significantly with the individual 'SRTn' and not with the PTA-values.

Self-rated handicap correlates well with the increase of pupil dilatation in the 'SRTn' condition compared to the easier 'SRTn+10' condition.

7

GENERAL DISCUSSION

Consequences of hearing impairment are numerous and hearing difficulties experienced in daily-life are divers. This thesis offers a structured set of dimensions or factors that covers the great bulk of disabilities reported by hearing-impaired persons. A graphic representation of the proposed multidimensional approach to assess hearing disability and handicap is shown in Figure 7.1. It illustrates the possibility to insert our findings into the WHO classification of impairments, disabilities and handicaps. Each of the five dimensions of disability should be examined separately for the assessment of a person's hearing status. The test battery (*pure-tone audiogram, speech-discrimination, speech-reception threshold in noise* and *in quiet, localization of sounds* and *recognition of voices*) enables a quantitative assessment to be made of each of the disability factors separately. Weighted measures of disability, as presented in chapter 5, may indicate a person's primary handicap. To assess secondary handicap, the pupil method may provide useful information.

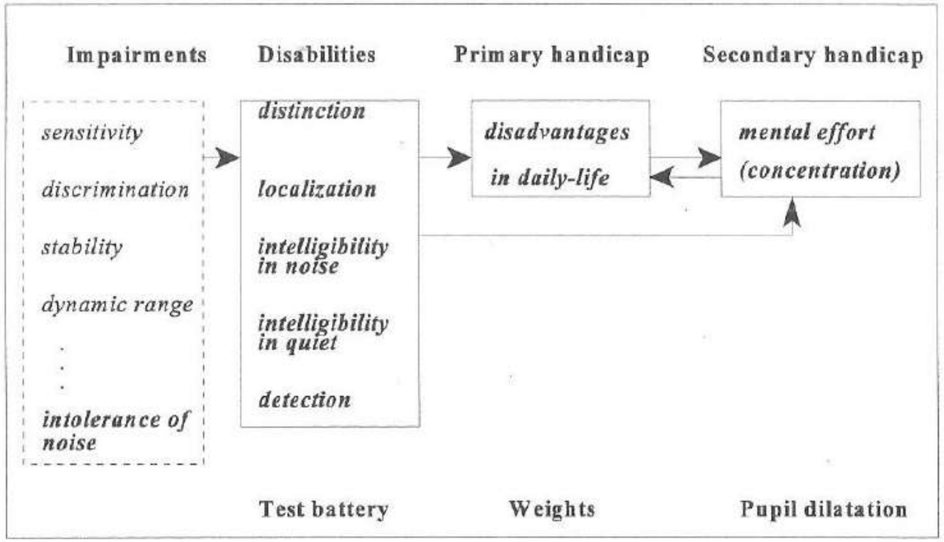

Figure 7.1. *Graphic representation of the proposed multidimensional approach to assess hearing disability and handicap.*

Hearing disability: a multidimensional concept

As shown in Figure 7.1 the diversity of hearing problems can be reduced to five basic disability factors: *intelligibility in noise, intelligibility in quiet, auditory localization, distinction of sounds, detection of sounds.* A sixth aspect *intolerance of noise* should also be taken into account in the assessment of hearing disability and handicap. Even though it did not appear as a separate factor in the analysis (chapter 2) the handicapping effect of *intolerance of noise* may be substantial (chapter 5). The question may arise if no other dimensions of disability are missing in the set, since the 30-questions inventory has been developed by normal-hearing researchers. This, however, seems unlikely. The Amsterdam Inventory deals with all kind of everyday listening situations. About 60 percent of the variance in a population of 274 respondents (chapter 2) could be explained by these dimensions and even though we expected one more factor (music) in the analysis, it did not appear as a separate factor. In the international literature other possible missing factors have not been presented. Determination of disabilities has been the object of earlier investigations. Noble (1978, 1979) and Lutman (1987) already distinguished *intelligibility in noise, intelligibility in quiet* and *localization* and even though Stephens (1980) argued that his approach (an open-ended interview) would yield a more complete picture of real difficulties, he found four of the above-mentioned factors (*intelligibility in noise and in quiet, localization and detection of non-speech sounds*). The existence of other significant factors of disability in daily-life, therefore, seems unlikely.

Inclusion of the five separately considered disability factors in the basic set is imperative for a thorough examination of a person's hearing status. The information in chapter 5 shows that there is no reason to suggest that some of the disabilities start to play a role in severely disabled groups only. Each of the disabilities can occur in every hearing-impaired person. Regarding the findings in chapter 5, dealing with weights attached to the disabilities, there is also no reason to assume that one factor of the set is negligible. Both for diagnostic and for assessment purposes all dimensions of disability need to be examined.

Test battery

This thesis concerns the quantification of hearing disability and handicap, and in doing so the above-mentioned factors run like a continuous thread through the chapters. As mentioned in the general introduction a valid method to assess each of the disability factors would have been the use of a questionnaire. However, self-report does not meet the requirements of objectivity. Performance tests, on the other hand, provide quantitative measurement, but may not reflect auditory functioning of the individual in everyday life. Theoretically, the best method would have been the observation of persons in their own environment and the measurement of disability in real life directly. However, such a method would be too time-consuming and thus too expensive. The most appropriate alternative seems therefore to be the use of representative laboratory performance tests. It is the lack of representative tests which motivated us to initiate the second part of the research project. It was only a few years ago, in 1992, that the British Inter-Society Working group on Hearing Disability proposed a reconsidered method for the quantification of hearing disability for the purposes of description and financial compensation. In their report King et al. stated that "indirect assessment of disability via the audiometric surrogate (pure-tone hearing threshold levels) is necessary in absence of any satisfactory method of direct assessment." Apparently, such a method (AMA, BAOL) does not acknowledge the multidimensional character of hearing disability.

Within this context the third and fourth chapter of this thesis provide new perspectives. The effort to construct a battery of performance tests to quantify each of the self-reported hearing disabilities has been successful. The included tests in the battery appeared to be good predictors of the various self-reported dimensions of disability. Correspondence between several laboratory performance tests and different auditory activities of everyday life has been demonstrated. In agreement with other investigators (Noble and Atherly, 1970; Lutman, 1992; King et al., 1992) the findings in this thesis show that the role reserved for the pure-tone thresholds in the prediction of daily-life hearing is certainly not a major one, despite the fact that for medical diagnostic purposes the pure-tone audiogram is an indispensable tool. One of the concluding remarks of this thesis is that it is that additional performance tests are

undoubtedly necessary to accurately assess the extent to which a person experiences hearing difficulties.

It is noteworthy that it is not just the greater number of tests that matter. The *type* of test administered for assessment purposes is also essential. The experiments in chapter 3 and 4 demonstrate the great importance of real-life simulations in the laboratory. The use of everyday sounds yields enhanced correlation coefficients between performance tests and self-reported scores. For example, the use of fluctuating noise instead of steady-state noise as a masking background resulted in an increased multiple correlation coefficient between self-reported and measured *intelligibility in noise*. Particularly chapter 4 shows that the use of acoustic conditions to be found in ordinary life (background noise, everyday sounds, a signal-to-noise ratio, varying time-interval between stimuli) contributes to a better prediction. These findings should be taken into account in future investigations.

Applicability of results in clinical practice

An important issue which has to be considered at the end of this thesis is the applicability of the test battery in the practice of clinical audiology. A first requirement to use the battery is the availability of normative values of test scores. This will not yield a problem for the pure-tone audiogram (AMA), speech discrimination (NVA, 1985) and the SRT test (Plomp and Mimpen, 1979), but the tests 'recognition of voices' and 'localization of sounds' need more attention with regard to this requirement. Even though baseline data were gathered for the latter test (as described in chapter 3 and 4) a greater number of both normal and impaired participants should perform the test. Future research should therefore be focused on systematically collecting more data which should be brought into schemes.

With regard to the applicability of the findings presented in this thesis it should be noted that the weights expressing the handicapping effect attached to each of the disabilities as presented in chapter 5 are also based on *group* means. We have recommended in this chapter that the weights can be used as a first indication of a person's primary handicap. Each weight, however, is a rough estimation reflecting the handicapping effect reported by the average hearing-impaired. Individuals vary and the experienced handicap is influenced by personal circumstances. The consequence of this is that the mean weights can be applied in general, but exceptional cases (for example hearing-impaired musicians) should be reevaluated.

Pupil dilatation as an indication for secondary handicap

The possibility to apply pupil dilatation as an index of non-audiological effects of hearing disability in clinical practice should be further investigated. In our study (chapter 6) we found significant differences between two *groups* of participants (normals and impaired). A remaining question concerns the extent to which the pupil method is applicable in individual cases. For that purpose a reference task should be developed in order to compare pupil dilatation during both the listening and the reference task. Such a task may be the Speech Reception Threshold test in quiet or a task which does not require any auditory activity. A motivating finding with regard to this issue is the significant correlation between the individual speech-reception threshold in noise and the reduced pupil dilation in a relatively easier listening condition (SRT+ 5 dB). Thus, a telling finding is that, compared to normal-hearing persons, hearing-impaired people not only have a shifted speech-reception threshold in noise, with all the unfortunate consequences in daily-life, but also a reduced reduction of mental effort in relatively easier listening situations. Auditory fatigue as a result of increased effort and concentration is a serious additional dimension in the whole issue of auditory handicap.

Final considerations

The primary goal of this thesis was to develop a method to adequately assess hearing disability and handicap. The necessity of a multidimensional approach to satisfactorily

assess hearing status has been extensively discussed. Reflecting on the findings presented in this thesis one may consider other possible fields of application, such as rehabilitation and advice with regard to education and choice of a profession. The test battery, and particularly pupil dilatation, may prove to be adequate tools in the evaluation of all hearing situations. The proposed methods may contribute to a more detailed estimation of the (mis-)match between the demands of the working environment and the abilities of the hearing-impaired person. A notorious, often reported complaint in the professional environment is the need of extra effort and concentration resulting from hearing disability. It may lead to the necessity to change employment or to reduce working hours. Pupil dilatation may therefore provide a means to further explore this area. Future investigation will have to substantiate this method.

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APPENDIX A

vragen lijst

▷ BIJ ONDERZOEK NAAR BELEVING SLECHTHORENDHEID

▷ *Academisch Ziekenhuis Vrije Universiteit*

▷ *vakgroep keel-, neus-, en oorheelkunde*

VRAGENLIJST BIJ ONDERZOEK NAAR BELEVING SLECHTHORENDHEID

Horen is meer dan waarnemen van geluid. Voor de veiligheid bijvoorbeeld is het belangrijk te weten wat voor soort geluid men hoort en waar dat geluid vandaan komt. Ook de mogelijkheid anderen te kunnen verstaan, is van groot belang. Het luisteren naar muziek is een vorm van horen die eveneens van grote waarde is.
Bij slechthorendheid kunnen de genoemde aspecten van horen in verschillende mate aangetast zijn en ook zijn de diverse vormen van horen niet voor iedereen even belangrijk.

In deze vragenlijst wordt over verschillende aspecten van horen een aantal vragen gesteld. Wij willen graag weten welke van die aspecten bij u moeilijkheden opleveren en met welke regelmaat die moeilijkheden zich voordoen. Daarnaast vragen wij u naar uw gehoor zoals dat vroeger was. Het is mogelijk dat u vroeger goed hoorde en dat uw gehoor in de loop van de tijd slechter is geworden of dat u plotseling slechthorend bent geworden. Daarnaast kan het zijn dat u altijd slecht hebt gehoord. Ook dan is het overigens mogelijk dat uw gehoor is veranderd.

Slechthorenden die goedhorend zijn geweest weten wat het is om als goedhorende in de samenleving te functioneren en welke wezenlijke veranderingen er als gevolg van hun achteruitgang van het gehoor zijn opgetreden. Ook mensen die altijd slecht hebben gehoord kunnen aangeven of zij moeilijkheden in een horende samenleving ervaren. Slechthorendheid kan direkt gevolgen hebben voor het wel-bevinden en voor het functioneren in uiteenlopende situaties.
Wij willen in dit onderzoek daarom eveneens nagaan in welke situaties in het alledaagse leven u door uw slechthorendheid gehinderd wordt.

Niet alle slechthorenden hoeven zich gehinderd te voelen in het functioneren en de beperking hoeft ook niet voor iedereen dezelfde te zijn. Bij de één kan het gevolg van slechthorendheid zich uiten in een onveilig gevoel in het verkeer, omdat er bepaalde geluiden op straat niet meer gehoord of herkend worden en de ander kan zich beperkt voelen omdat bijvoorbeeld het bespelen van een muziekinstrument niet meer mogelijk is. De derde is helemaal niet geïnteresseerd in muziek en zal zich daarom ook niet druk maken om het niet kunnen bespelen van een instrument.

Elke slechthorende zelf kan het beste aangeven waar voor hem of haar de knelpunten liggen. Daarom leggen wij deze vragenlijst aan u voor. Door middel van deze lijst krijgt u de mogelijkheid aan te geven of u door uw slechthorendheid gehinderd wordt en zo ja, wanneer en in welke mate.

Wij vragen u deze lijst zorgvuldig in te vullen.
U zult ongeveer een half uur nodig hebben om alle vragen te beantwoorden.
Neem allereerst grondig de voorbeelden door.
Voor het terugzenden van de vragenlijst kunt u de bijgesloten antwoordenveloppe gebruiken.

Wij wijzen u er tenslotte op dat al uw gegevens strikt vertrouwelijk worden behandeld.

VOORBEELDEN

Er volgen nu twee voorbeeldvragen. Neem die en de uitleg daarbij grondig door. Het invullen van de lijst zal dan gemakkelijker verlopen. Het is de bedoeling dat u bij het beantwoorden van de vragen uitgaat van de situatie ZONDER hulpmiddelen, zoals een hoortoestel of een versterker op de telefoon of huisbel.

Het is mogelijk dat er situaties zijn waarin u zich ECHT NOOIT zonder hoortoestel bevindt.
U kunt dan niet aangeven hoe u in die situatie hoort zonder hoortoestel. Ga dan niet gissen, maar ga voor die situatie na hoe u hoort MET hoortoestel. Geef dat aan door het cirkeltje op de aangegeven plaats, direkt onder de vraag, in te kleuren.

Als er situaties zijn waarin u zich soms mét en soms zonder hoortoestel begeeft, ga dan uit van de situatie ZONDER hoortoestel.

Alle vragen van deze lijst zijn opgebouwd uit drie deelvragen. In vraag A wordt gevraagd naar uw gehoor in de aangegeven situatie op dit moment.
In vraag B wordt gevraagd hoe dat vroeger was.
Het laatste deel van elke vraag gaat over de hinder of de beperking die u ervaart als gevolg van het slecht kunnen horen of verstaan in de aangegeven situatie. Deze derde deelvraag is alleen van belang indien bij A is aangegeven dat het horen of verstaan in die situatie moeilijk is. In C wordt gevraagd hoe hinderlijk of lastig het is slechthorend te zijn in deze situatie.
Degenen die bij A aangaven geen moeite te hebben met horen of verstaan in die situatie,

VOORBEELD 1: KUNT U IN EEN RUSTIG HUIS HET GELUID VAN ZOEMENDE MUGGEN HOREN?

1a. Nu en zonder hoortoestel: ◇ bijna nooit ◆ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

1b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◆ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 1c hoeft u alleen te beantwoorden als u bij vraag 1a bijna nooit of soms aankruiste!

1c. Vindt u het hinderlijk dat u in huis het geluid van zoemende muggen slecht kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◆ heel erg hinderlijk

VOORBEELD 2: KUNT U OP STRAAT HONDEN HOREN BLAFFEN?

2a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◆ vaak ◇ bijna altijd

● Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

2b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◆ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 2c hoeft u alleen te beantwoorden als u bij vraag 2a bijna nooit of soms aankruiste!

2c. Vindt u het hinderlijk dat u op straat slecht de honden kunt horen blaffen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

UITLEG BIJ VRAAG 1:

▷ Veronderstel dat u thuis nooit een hoortoestel draagt. U kunt dan nagaan of u zonder toestel muggen hoort zoemen. U heeft wat moeite met het horen van zoemende muggen in huis en daarom kruist u "soms" aan. Het cirkeltje onder deze eerste vraag kleurt u NIET in, want in deze situatie (thuis) bent u altijd ZONDER hoortoestel. (Als u thuis af en toe mét en af en toe zonder hoortoestel bent, ga dan altijd uit van de situatie ZONDER hoortoestel.)

▷ Dan gaat u na hoe het vroeger was. Vroeger hoorde u misschien altijd de muggen zoemen. U kruist dan mogelijkheid "bijna altijd" aan en omdat u vroeger GEEN hoortoestel droeg, kleurt u het cirkeltje onder de vraag NIET in.

▷ Dan volgt vraagt C. Omdat u bij A aangaf dat u soms zoemende muggen hoort, is deze vraag C WEL op u van toepassing.Dat wordt ook boven de vraag in schuine letters aangegeven. Het is dus de bedoeling dat u vraag C beantwoordt. Vindt u het hinderlijk dat u het gezoem van muggen in huis slecht hoort? Het kan zijn dat u het erg vervelend vindt dat u de muggen niet hoort. De kans is immers groter dat u gestoken wordt, omdat u de muggen niet op tijd weg kunt jagen. Telkens op het moment dat u gestoken wordt ontdekt u dat er een mug is en dan is het te laat. U vindt het bijvoorbeeld "heel erg hinderlijk" dat u de muggen niet hoort. Dat geeft u aan door "heel erg hinderlijk" aan te kruisen.

▷ Het is heel goed mogelijk dat een ander het helemaal niet hinderlijk vindt dat hij de muggen niet hoort. Het gezoem van muggen maakt hem nerveus en angstig. Sinds hij de muggen niet (meer) hoort voelt deze persoon zich een stuk prettiger. Deze slechthorende kruist dan ook het hokje "nee" aan. Hij hoort de muggen niet, maar dat is voor hem niet hinderlijk of

UITLEG BIJ VRAAG 2:

▷ Misschien begeeft u zich absoluut nooit zonder hoortoestel op straat. U bent dan altijd MET hoortoestel op straat. In dat geval kunt u niet nagaan of u ZONDER HOORTOESTEL honden op straat hoort blaffen. Het is de bedoeling dat u dan nagaat of u MET hoortoestel op straat honden kunt horen blaffen. Het is mogelijk dat u het vaak hoort als honden blaffen. U kruist "vaak" aan en omdat u deze situatie echt alleeen MET hoortoestel kent, kleurt u extra het cirkeltje onder deze vraag in.

▷ Dan gaat u naar B. U gaat na of u VROEGER honden op straat hoorde blaffen. Als u bijvoorbeeld vroeger geen problemen had met uw gehoor (en dus ook geen hoortoestel droeg) en u hoorde het altijd wanneer een hond blafte, dan kruist u het hokje "bijna altijd" aan. Het cirkeltje direkt onder deze vraag hoeft u dan NIET in te kleuren, omdat u vroeger nooit een hoortoestel droeg.

▷ Tenslotte volgt vraag C. Omdat u bij A invulde dat u VAAK honden hoort blaffen, is vraag C NIET op u van toepassing. U kunt deze vraag C dus overslaan en doorgaan naar de volgende vraag.

KUNT U EEN WINKELBEDIENDE IN EEN DRUKKE WINKEL VERSTAAN?

1a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

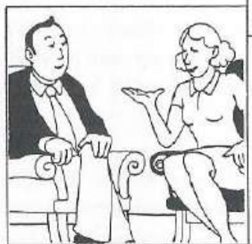
1b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 1c hoeft u alleen te beantwoorden als u bij vraag 1a bijna nooit of soms invulde!

1c. Vindt u het hinderlijk dat u een winkelbediende in een drukke winkel slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U MET ÉÉN PERSOON IN EEN RUSTIGE OMGEVING EEN GESPREK VOEREN?



2a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

2b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 2c hoeft u alleen te beantwoorden als u bij vraag 2a bijna nooit of soms invulde!

2c. Vindt u het hinderlijk dat u moeilijk een gesprek met één persoon in een rustige omgeving kunt voeren? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

HOORT U OP STRAAT ONMIDDELLIJK VANUIT WELKE RICHTING EEN AUTO AAN KOMT RIJDEN?

3a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

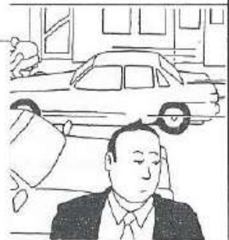
3b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 3c hoeft u alleen te beantwoorden als u bij vraag 3a bijna nooit of soms invulde!

3c. Vindt u het hinderlijk dat u slecht kunt horen vanuit welke richting een auto aan komt rijden? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U AUTO´S HOREN DIE PASSEREN OF AAN KOMEN RIJDEN?



4a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

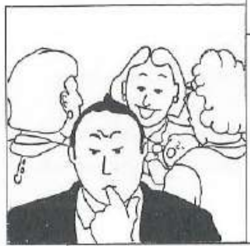
4b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 4c hoeft u alleen te beantwoorden als u bij vraag 4a bijna nooit of soms invulde!

4c. Vindt u het hinderlijk dat u een auto, die passeert of aan komt rijden, slecht kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

HERKENT U VERSCHILLENDE FAMILIELEDEN AAN HUN STEMMEN?



5a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

5b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, du bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 5c hoeft u alleen te beantwoorden als u bij vraag 5a bijna nooit of soms invulde!

5c. Vindt u het hinderlijk dat u familieleden slecht aan hun stemmen kunt herkennen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U EEN BEPAALDE MELODIE IN EEN MUZIEKSTUK OF EEN LIED HERKENNEN?

6a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

6b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, du bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 6c hoeft u alleen te beantwoorden als u bij vraag 6a bijna nooit of soms invulde!

6c. Vindt u het hinderlijk dat u een bepaalde melodie in een muziekstuk of een lied slecht kunt herkennen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijl

KUNT U IEMAND VERSTAAN DIE U AANSPREEKT OP EEN VERJAARDAGSFEEST OF EEN RECEPTIE?

7a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

7b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 7c hoeft u alleen te beantwoorden als u bij vraag 7a bijna nooit of soms invulde!

7c. Vindt u het hinderlijk dat u iemand, die u aanspreekt op een verjaardagsfeest of een receptie, slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U EEN TELEFOONGESPREK VOEREN IN EEN RUSTIGE KAMER?

8a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

8b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 8c hoeft u alleen te beantwoorden als u bij vraag 8a bijna nooit of soms invulde!

8c. Vindt u het hinderlijk dat u een telefoongesprek, in een rustige omgeving, slecht kunt voeren? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U HOREN VANUIT WELKE HOEK VAN DE ZAAL EEN VRAAG GESTELD WORDT TIJDENS EEN BIJEENKOMST?

9a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

9b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 9c hoeft u alleen te beantwoorden als u bij vraag 9a bijna nooit of soms invulde!

9c. Vindt u het hinderlijk dat u moeilijk kunt horen vanuit welke hoek van de zaal een vraag gesteld wordt tijdens een bijeenkomst? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

HOORT U HET WANNEER IEMAND VAN ACHTEREN NAAR U TOE KOMT LOPEN?

10a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

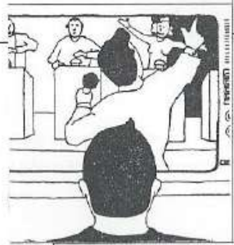
10b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 10c hoeft u alleen te beantwoorden als u bij vraag 10a bijna nooit of soms invulde!

10c. Vindt u het hinderlijk dat u het slecht hoort wanneer er iemand van achteren naar u toe komt lopen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U EEN TV-PRESENTATOR ALLEEN AAN ZIJN STEM HERKENNEN?



11a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

11b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 11c hoeft u alleen te beantwoorden als u bij vraag 11a bijna nooit of soms invulde!

11c. Vindt u het hinderlijk dat u een tv-presentatortator slecht aan zijn stem kunt herkennen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U GEZONGEN TEKST (NEDERLANDS) VERSTAAN?

12a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

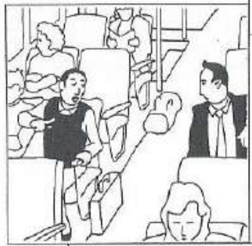
○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

12b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 12c hoeft u alleen te beantwoorden als u bij vraag 12a bijna nooit of soms invulde!

12c. Vindt u het hinderlijk dat u (nederlands) gezongen tekst slecht verstaat? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk



KUNT U ZONDER VEEL INSPANNING IEMAND VERSTAAN DIE NAAST U IN DE BUS OF IN DE AUTO ZIT?

13a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

13b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 13c hoeft u alleen te beantwoorden als u bij vraag 13a bijna nooit of soms invulde!

13c. Vindt u het hinderlijk dat u iemand, die naast u in de bus of in de auto zit, slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

VERSTAAT U DE NIEUWSLEZER OP DE RADIO BIJ EEN NORMAAL VOLUME?

14a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

14b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 14c hoeft u alleen te beantwoorden als u bij vraag 14a bijna nooit of soms invulde!

14c. Vindt u het hinderlijk dat u de nieuwslezer op de radio, bij een normaal volume slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U HET GELUID VAN VERSCHILLENDE MUZIEKINSTRUMENTEN ONDERSCHEIDEN?

29a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

29b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 29c hoeft u alleen te beantwoorden als u bij vraag 29a bijna nooit of soms invulde!

29c. Vindt u het hinderlijk dat u het geluid van verschillende muziekinstrumenten moeilijk kunt onderscheiden? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

ZIJN ER DELEN IN MUZIEKSTUKKEN OF LIEDEREN DIE U MIST, TERWIJL U ANDERE DELEN IN DATZELFDE MUZIEKSTUK WEL KUNT HOREN?

30a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

30b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 30c hoeft u alleen te beantwoorden als u bij vraag 30a vaak of bijna altijd invulde!

30c. Vindt u het hinderlijk dat u vaak of bijna altijd bepaalde delen in een muziekstuk niet hoort, terwijl u andere delen in datzelfde muziekstuk wel kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U OP STRAAT HET GELUID VAN EEN AUTO ONDERSCHEIDEN VAN HET GELUID VAN EEN BUS?

17a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

17b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 17c hoeft u alleen te beantwoorden als u bij vraag 17a bijna nooit of soms invulde!

17c. Vindt u het hinderlijk dat u het geluid van een auto slecht kunt onderscheiden van het geluid van een bus? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

ERVAART U DAT MUZIEK TE HARD IN UW OREN KLINKT, TERWIJL HET VOOR OMSTANDERS AANGENAAM KLINKT?

18a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

18b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 18c hoeft u alleen te beantwoorden als u bij vraag 18a vaak of bijna altijd invulde!

18c. Vindt u het hinderlijk dat muziek vaak of bijna altijd te hard voor u klinkt, terwijl het voor omstanders aangenaam klinkt? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

WANNEER U MET MEERDERE MENSEN AAN TAFEL ZIT TE ETEN, KUNT U HET GESPREK DAN VOLGEN?

19a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

19b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, d bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 19c hoeft u alleen te beantwoorden als u bij vraag 19a bijna nooit of soms invulde!

19c. Vindt u het hinderlijk dat u het gesprek aan tafel, tijdens het eten, slecht kunt volgen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderl

VERSTAAT U DE NIEUWSLEZER OP TV BIJ EEN NORMAAL VOLUME?

20a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

20b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, d bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 20c hoeft u alleen te beantwoorden als u bij vraag 20a bijna nooit of soms invulde!

20c. Vindt u het hinderlijk dat u de nieuwslezer op tv, bij een normaal volume, slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderl

KUNT U IN EEN RUSTIG HUIS HOREN VANUIT WELKE HOEK VAN DE KAMER IEMAND TOT U SPREEKT?

21a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

21b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 21c hoeft u alleen te beantwoorden als u bij vraag 21a bijna nooit of soms invulde!

21c. Vindt u het hinderlijk dat u in een rustig huis slecht kunt horen vanuit welke hoek van de kamer iemand tot u spreekt? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U THUIS DE DEURBEL HOREN?

22a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

22b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 22c hoeft u alleen te beantwoorden als u bij vraag 22a bijna nooit of soms invulde!

22c. Vindt u het hinderlijk dat u thuis de deurbel slecht kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U MANNENSTEMMEN VAN VROUWENSTEMMEN ONDERSCHEIDEN?

23a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

23b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 23c hoeft u alleen te beantwoorden als u bij vraag 23a bijna nooit of soms invulde!

23c. Vindt u het hinderlijk dat u mannenstemmen slecht van vrouwenstemmen kunt onderscheiden? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U RITME IN EEN MUZIEKSTUK OF LIED HOREN?

24a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

24b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 24c hoeft u alleen te beantwoorden als u bij vraag 24a bijna nooit of soms invulde!

24c. Vindt u het hinderlijk dat u ritme in een muziekstuk of een lied slecht kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U IEMAND DIE U AANSPREEKT IN EEN DRUKKE STRAAT VERSTAAN?

25a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

25b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 25c hoeft u alleen te beantwoorden als u bij vraag 25a bijna nooit of soms invulde!

25c. Vindt u het hinderlijk dat u iemand, die u aanspreekt in een drukke straat, slecht kunt verstaan? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

KUNT U HOREN MET WELKE INTONATIE EN STEMBUIGING MENSEN SPREKEN?

26a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

26b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 26c hoeft u alleen te beantwoorden als u bij vraag 26a bijna nooit of soms invulde!

26c. Vindt u het hinderlijk dat u slecht kunt horen met welke intonatie en stembuiging mensen spreken? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

HOORT U OP STRAAT WAAR ZICH EEN TOETERENDE AUTO BEVINDT?

27a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

27b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, du bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 27c hoeft u alleen te beantwoorden als u bij vraag 27a bijna nooit of soms invulde!

27c. Vindt u het hinderlijk dat u op straat slecht kunt horen waar zich een toeterende auto bevindt? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlij

HOORT U BUITEN DE VOGELS ZINGEN?

28a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

28b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, du bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 28c hoeft u alleen te beantwoorden als u bij vraag 28a bijna nooit of soms invulde!

28c. Vindt u het hinderlijk dat u buiten slecht de vogels kunt horen zingen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlij

KUNT U HET GELUID VAN VERSCHILLENDE MUZIEKINSTRUMENTEN ONDERSCHEIDEN?

29a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

29b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 29c hoeft u alleen te beantwoorden als u bij vraag 29a bijna nooit of soms invulde!

29c. Vindt u het hinderlijk dat u het geluid van verschillende muziekinstrumenten moeilijk kunt onderscheiden? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

ZIJN ER DELEN IN MUZIEKSTUKKEN OF LIEDEREN DIE U MIST, TERWIJL U ANDERE DELEN IN DATZELFDE MUZIEKSTUK WEL KUNT HOREN?

30a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

30b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 30c hoeft u alleen te beantwoorden als u bij vraag 30a vaak of bijna altijd invulde!

30c. Vindt u het hinderlijk dat u vaak of bijna altijd bepaalde delen in een muziekstuk niet hoort, terwijl u andere delen in datzelfde muziekstuk wel kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

PERSOONLIJKE GEGEVENS

▷ Naam: .... (○ M / ○ V)

▷ Adres: ....

▷ Postcode + Woonplaats: ....

▷ Telefoon: ....

▷ Woonsituatie: ○ alleenwonend
○ met anderen samen (partner, kinderen)
○ verzorgings-, verpleeg- of bejaardenhuis

▷ Geboortedatum: ........-.........-.........

▷ Nationaliteit ....

▷ Moedertaal ....

▷ Opleiding: ○ lager onderwijs
○ lager beroepsonderwijs (LTS e.d.)
○ middelbaar algemeen onderwijs (ULO, MAVO)
○ middelbaar beroepsonderwijs
○ voortgezet algemeen (HAVO, VWO)
○ hoger beroepsonderwijs (HTS, HEAO)
○ hoger algemeen en wetenschappelijk onderwijs

▷ Wat zijn uw voornaamste dagelijkse bezigheden? ....

....

▷ Heeft u daarbij veel mondeling contact met anderen? ○ ja ○ af en toe ○ nee

▷ Bent u lid van clubs of verenigingen? ○ nee ○ ja

▷ Heeft u hobbies? ○ nee ○ ja, namelijk ....

....

▷ Sinds wanneer bent u slechthorend? ....

▷ Zijn er activiteiten waaraan u NIET MEER deelneemt, sinds u slechthorend bent?

○ nee ○ ja, namelijk ....

▷ Draagt u een hoortoestel? ○ nee ○ ja, sinds ....

▷ Maakt u gebruik van spraakafzien (liplezen)?: ○ nee ○ ja

KUNT U HET GELUID VAN VERSCHILLENDE MUZIEKINSTRUMENTEN ONDERSCHEIDEN?

29a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

29b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 29c hoeft u alleen te beantwoorden als u bij vraag 29a bijna nooit of soms invulde!

29c. Vindt u het hinderlijk dat u het geluid van verschillende muziekinstrumenten moeilijk kunt onderscheiden? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

ZIJN ER DELEN IN MUZIEKSTUKKEN OF LIEDEREN DIE U MIST, TERWIJL U ANDERE DELEN IN DATZELFDE MUZIEKSTUK WEL KUNT HOREN?

30a. Nu en zonder hoortoestel: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie ken ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

30b. Vroeger toen u misschien goed of beter hoorde: ◇ bijna nooit ◇ soms ◇ vaak ◇ bijna altijd

○ Deze situatie kende ik alleen mét hoortoestel, dus bovenstaand antwoord geeft mijn situatie mét hoortoestel weer

Vraag 30c hoeft u alleen te beantwoorden als u bij vraag 30a vaak of bijna altijd invulde!

30c. Vindt u het hinderlijk dat u vaak of bijna altijd bepaalde delen in een muziekstuk niet hoort, terwijl u andere delen in datzelfde muziekstuk wel kunt horen? ◇ nee ◇ een beetje ◇ erg hinderlijk ◇ heel erg hinderlijk

▷ Heeft u last van oorsuizen: ○ nee ○ ja

▷ Veel mensen hebben vaak last van harde geluiden. Heeft u het gevoel dat u meer dan andere mensen last hebt van harde geluiden? ○ nee ○ ja

▷ Hoe is op dit moment uw gezondheidstoestand?

○ zeer goed ○ goed ○ redelijk ○ slecht ○ zeer slecht

▷ Bent u op dit moment in behandeling bij een (huis)arts voor een aandoening, anders dan slechthorendheid? ○ nee ○ ja, namelijk ....

....

Het is belangrijk dat u bij het invullen van de lijst geen vragen hebt overgeslagen. Wilt u alstublieft controleren of u alle vragen hebt beantwoord?

Nogmaals wijzen wij u erop dat al uw gegevens strikt vertrouwelijk worden behandeld.

▷ Eventuele opmerkingen:

Wij waarderen het dat u tijd vrij hebt kunnen maken om alle vragen te beantwoorden. Uw medewerking is erg belangrijk voor dit onderzoek. Wilt u de ingevulde vragenlijst in de antwoordenveloppe terugzenden? U hoeft GEEN POSTZEGEL te plakken. Nogmaals onze hartelijke dank.

SUMMARY

Hearing impairment often has a restricting influence on daily-life activities. Consequences of hearing loss are of great diversity, making it difficult to quantify the extent to which hearing-impaired individuals are disabled or handicapped. Still, objective measures of hearing disability and handicap are needed, for example for (financial) compensation purposes in case of injury or unemployability.

This thesis presents a method to assess hearing disability and handicap objectively. According to the classification of the World Health Organization (WHO) the method is based on three concepts that are defined as follows:

impairment: any loss or abnormality of psychological, physiological or anatomical structure or function.

disability: any restriction or lack (resulting from an impairment) of the ability to perform an activity in the manner or within the range considered normally for a human being.

handicap: a disadvantage for a given in individual, resulting from an impairment or a disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex and social and cultural factors) for that individual.

Particularly the last two concepts are important for the assessment of a person's hearing status. First, the domain of disability should be explored to estimate handicap subsequently. To this day, mainly measurements of impairment (pure-tone thresholds) have been used to describe the disabilities resulting from hearing impairment. Pure-tone thresholds reflect the sensitivity of the ear to pure tones. It is evident, however, that the pure-tone audiogram does not give a satisfactory representation of the variety of auditory aspects in daily-life hearing.

In order to investigate which aspects of hearing are the most important in daily-life, we developed the Amsterdam Inventory for Auditory Disability and Handicap, as reported in chapter 2. This inventory consists of thirty questions and deals with a variety of everyday listening situations. Factor analysis on the responses of 274 hearing-impaired persons shows that five dimensions (factors) of hearing disability should be distinguished: *distinction of sounds*, *auditory localization*, *intelligibility in noise*, and *intelligibility in quiet* and *detection of sounds*. This means that the variety of disabilities affecting the individual in daily-life hearing can be reduced to the five above-mentioned dimensions. Therefore, adequate assessment of a person's hearing status requires quantitative assessment of each dimension of disability. In an attempt to quantify each of the self-reported disabilities, a group of 51 hearing-impaired individuals performed on six psychoacoustical tests: pure-tone audiogram, speech-discrimination, speech-reception-threshold in quiet, speech-reception-threshold in steady-state noise and in fluctuating noise, localization of sounds and recognition of voices. Results of the stepwise multiple regression analysis show substantial correlations between the laboratory performance tests and the disability factors. The battery of tests appeared to be adequate in quantifying self-reported hearing difficulties.

Handicap comprises more than only the experienced disabilities in auditory functioning. It is a disadvantageous position that limits or prevents the fulfilment of a role that is normal for that individual. Personal circumstances play an important role and handicap should therefore be determined individually.

In this thesis the domain of handicap has been explored in two ways.

First, the above-mentioned Amsterdam Inventory has been used to assess to what extent individuals see themselves as being handicapped by a hearing disability. The inventory assesses the so-called *primary handicap* that directly results from the experience of disabilities in auditory functioning. Chapter 5 describes the responses of 239 hearing-impaired persons. The results show that, even though the differences are small, the five above-mentioned disabilities are not equally important in daily-life. Handicap resulting from disability in listening to speech in noise is most strongly felt. Also, the respondents reported a substantial handicapping effect resulting from intolerance of noise, as described in chapter 5. Therefore, *intolerance of noise* should not be ignored in the assessment of handicap. The results in this chapter again emphasize the importance of the multidimensional approach in the assessment of hearing disability and handicap.

Another dimension of handicap (the so-called *secondary handicap*) results from constantly trying to compensate for the disabilities. For example: during a

conversation, a hearing-impaired person will pay a constant effort to hear and to respond appropriately in order to communicate optimally. Such an increased effort may result in stress and fatigue and that is just the so often reported complaint of hearing-impaired people. Auditory fatigue results in making it almost impossible for the hearing-impaired person to perform social activities at the end of a working day.
The possibility to quantify secondary handicap has been investigated as described in chapter 6. It is evident from the international literature that dilatation of the pupil is a sensitive measure of the degree of mental effort demanded by a task. The diameter of the pupil increases with the degree of effort required. According to this finding, pupil dilatation was used as an index of mental effort in our study. During the so-called speech-reception-threshold (SRT) task in noise, we measured the pupil diameter of both normal-hearing and hearing-impaired listeners. The SRT test measures the ability to understand speech (everyday sentences) against a background of (fluctuating) noise. The SRT is defined as the speech-to-noise ratio in dB at which 50% of the sentences can be reproduced correctly. The findings of the investigation show that a relatively easier listening situation (a more favourable signal-to-noise ratio) results in a decrease of pupil dilatation. This indicates that an easier listening situation requires less effort. However, a difference between both groups was found. Hearing-impaired listeners appear to benefit less than normals from easier listening situations (individual SRT + 5dB). An important conclusion resulting from this study is that hearing-impaired people profit less from a more easy listening situation than has been assumed until now.

An overview of the subsequent steps of the method to assess one's hearing disabilities and handicap, as proposed in this study, is presented in a diagram on page 84.

SAMENVATTING

Schatting van de validiteit van het gehoor: een multidimensionale benadering

Slechthorendheid heeft veelal een beperkende invloed op het functioneren in het dagelijkse leven. De gevolgen van slechthorendheid vertonen een grote diversiteit en dat maakt het moeilijk om de beperkingen en de gevolgen daarvan (de ervaren handicap) in maat en getal uit te drukken. Toch is een kwantificeerbare grootheid van de mate van invaliditeit van een slechthorende gewenst, bijvoorbeeld in geval van (financiële) compensatie na een ongeval of bij afkeuring.

Dit proefschrift presenteert een methode om de validiteit van het gehoor objectief vast te stellen. Dat wordt gedaan aan de hand van drie begrippen die door de Wereld Gezondheids Organisatie (WHO,1980) zijn onderscheiden en als volgt zijn gedefinieerd:

stoornis: iedere afwijking van een voor de mens normale psychologische, fysiologische of anatomische structuur of functie.

beperking: iedere vermindering of afwezigheid (ten gevolge van een stoornis) van de mogelijkheid tot een voor de mens normale activiteit zowel wat betreft de wijze als de reikwijdte van de uitvoering.

handicap: een nadelige positie van een persoon als gevolg van een stoornis of een beperking, welke de normale rol vervulling van de betrokkene (gezien leeftijd, geslacht en sociaal-culturele achtergrond) begrenst of verhindert. (vertaling: TNO, 1980)

Bij het schatten van de validiteit van het gehoor gaat het met name om de laatste twee begrippen. De beperkingen die de slechthorende dagelijks ervaart moeten in kaart worden gebracht om vervolgens de handicap te kunnen schatten. Tot op heden worden in de meeste landen vrijwel alleen de gegevens van het toonaudiogram gebruikt om uitspraken te doen over de beperkingen ten gevolge van slechthorendheid. Het toonaudiogram meet de gevoeligheid van het oor voor zuivere tonen. Het is inmiddels echter evident dat het wel of niet goed kunnen horen van zuivere tonen de geluidswaarneming in het alledaagse leven onvoldoende representeert. Om te onderzoeken welke aspecten van horen dan een essentiële rol spelen in die geluidswaarneming is in de eerste fase van het onderzoeksproject de 'Amsterdam

Inventory for Auditory Disability and Handicap' ontwikkeld, zoals beschreven in hoofdstuk 2. Deze vragenlijst, waarin allerlei luistersituaties aan de orde komen, bestaat uit 30 vragen. Factor-analyse van de gegevens van 274 personen toont aan dat vijf dimensies (factoren) zijn te onderscheiden. Naast *detectie van geluid* zijn dat: *herkennen en onderscheiden van geluiden*, *lokaliseren van geluid*, *spraakverstaan in lawaai* en *spraakverstaan in stilte*. Dit betekent dat alle beperkingen in het auditief functioneren zich concentreren rondom de bovengenoemde vijf factoren. Een juiste schatting van de validiteit eist dan ook dat het vermogen van het gehoor voor elk van deze dimensies afzonderlijk bepaald wordt.

In een poging het vermogen voor deze factoren objectief te meten, zijn bij 50 slechthorenden zes verschillende psychoacoustische tests afgenomen, namelijk: toonaudiogram, spraakaudiogram, spraakverstaan in stilte (SRT), spraakverstaan in fluctuerende en continue ruis (SRT in ruis) lokaliseren van geluid en stemherkenning. Het resultaat van de multipele regressie analyse (hoofdstuk 3 en 4) geeft aan dat elk van de bovengenoemde factoren aanzienlijk correleert met een combinatie van tests. De testbatterij blijkt geschikt om de *beperkingen* in kwantificeerbare grootheden (test-scores) uit te drukken.

De *handicap* van een slechthorende omvat veel meer dan alleen de beperkingen in het auditief functioneren. Het gaat om een nadelige positie als gevolg van die beperkingen of stoornis die de normale rol vervulling begrenst of verhindert. Persoonlijke omstandigheden spelen daarin een rol en handicap is daarom individueel bepaald.

In dit proefschrift wordt het domein van handicap op twee manieren bestudeerd. Allereerst is de bovengenoemde Amsterdamse vragenlijst gebruikt om voor elke situatie na te gaan in hoeverre een beperking in het auditief functioneren (indien die zich voordoet) hinderlijk wordt bevonden in het dagelijks leven. De vragenlijst geeft een schatting van de zogenaamde *primaire handicap* die direct het gevolg is van een beperking die men ervaart in het auditief functioneren. Hoofdstuk 5 beschrijft een studie naar de gegevens van 239 slechthorenden. Hoewel de verschillen niet heel groot zijn, blijkt uit de resultaten dat voor de gemiddelde slechthorende de vijf bovengenoemde beperkingen niet even zwaar wegen. Het niet kunnen verstaan van spraak in ruis is het hinderlijkst. Ook blijkt uit het onderzoek dat het last hebben van harde geluiden als zeer hinderlijk wordt ervaren. Dat is een belangrijke reden om *onaangename luidheid* als extra dimensie in het validiteitsonderzoek mee te nemen. De resultaten in hoofdstuk 5 benadrukken nog eens het belang van de multidimensionale aanpak voor het schatten van de validiteit van het gehoor.

Een andere vorm van handicap (de zogenaamde secundaire handicap) ontstaat doordat de slechthorende voortdurend moeite doet om de beperkingen te compenseren. Door extra inspanning en concentratie probeert de slechthorende bijvoorbeeld het gesprek toch te volgen. Vermoeidheid is het gevolg en juist daarover wordt veel geklaagd door mensen met een gehoorverlies. Sociale activiteiten kunnen 's avonds, na een werkdag, niet meer worden uitgevoerd, omdat men te vermoeid is.
Hoofdstuk 6 presenteert een onderzoek naar de mogelijkheid om dit belangrijke aspect van handicap te kwantificeren. Het is al langer bekend dat verandering van de pupilgrootte gebruikt kan worden als index voor mentale inspanning. Hoe groter de verwijding van de pupil (dilatatie), hoe groter de concentratie. In hoofdstuk 6 wordt de pupil dilatatie van zowel goed- als slechthorenden tijdens de zogenaamde speech-reception-threshold (SRT) test in ruis bestudeerd. De SRT test meet het vermogen om spraak (alledaagse zinnen) tegen een achtergrond van (fluctuerende) ruis te verstaan. De SRT is gedefinieerd als die spraak-ruis verhouding in dB waarbij nog 50% van de zinnen foutloos gereproduceerd kan worden. De resultaten van het onderzoek tonen aan dat een makkelijker luistersituatie (een gunstiger signaal-ruis verhouding) bij zowel goed- als slechthorenden een kleinere pupil dilatatie (oftewel minder inspanning) bewerkstelligt. Echter, er is een verschil tussen beide groepen. Bij een gunstiger signaal-ruis verhouding (SRT+5dB) blijken slechthorenden, vergeleken bij goedhorenden, nog steeds veel inspanning te moeten leveren. Een belangrijke conclusie van het onderzoek is dat slechthorenden veel minder van een makkelijker luistersituatie profiteren dan tot nu toe werd aangenomen.

Een samenvattend schema op bladzijde 84 geeft een overzicht van de verschillende stappen van de methode om de validiteit van het gehoor te schatten, zoals die in dit proefschrift worden voorgesteld.

DANKWOORD

Dankwoord

De afdeling Audiologie biedt een voedingsbodem waarop onderzoekers erg goed kunnen gedijen. Dat heeft natuurlijk alles te maken met de mensen die op die afdeling werkzaam zijn. Het is mijn behoefte om vanaf deze plaats een aantal van die mensen bijzonder te bedanken.

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De Naam van God zij geprezen, van nu aan tot in eeuwigheid.

List of Publications

Kramer SE, Kapteyn TS, Festen JM, Tobi H: A strategy to investigate hearing disability and handicap (abstract). Proceedings of the European Conference on Audiology, 219-223, 1995.

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Woestenburg JC, Das-Smaal EA, Brand E, Kramer SE: Learning during visual search in children with attentional and learning problems: a trial-to-trial evaluation of RT and ERP measures. J of Psychophysiology 6:204-224, 1992.

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CURRICULUM VITAE

Sophia Kramer werd geboren op 31 december 1966 te Haarlem. Na het behalen van het eindexamen VWO-ß aan het Eerste Christelijk Lyceum te Haarlem in 1985 begon zij met de studie Psychologie aan de Vrije Universiteit te Amsterdam. Zij koos voor de richting Neuropsychologie en werkte tijdens haar stage, onder leiding van prof. dr J.F. Orlebeke, mee aan een EEG-onderzoek bij kinderen. Vervolgens deed zij, onder leiding van prof dr. J.Ph.Hes, gedurende vier maanden onderzoek naar de invloed van muziek op het mentale vermogen van demente patiënten op de afdeling Psychogeriatrie van het Ichilov Hospitaal te Tel Aviv, Israël. Op 31 augustus 1990 studeerde zij af. In de periode daarna bleef zij werken als assistent-onderzoeker op de afdeling Neuropsychologie van de vakgroep Psychonomie (faculteit der Psychologie en Pedagogiek, Vrije Universiteit). Sinds 1993 is zij werkzaam als onderzoeker op de afdeling Audiologie van de vakgroep Keel- Neus- en Oorheelkunde, faculteit der Geneeskunde, Vrije Universiteit.